INDEX

WORLD METEOROLOGICAL ORGANIZATION

GUIDELINES FOR THE EDUCATION AND TRAINING OF PERSONNEL IN METEOROLOGY AND OPERATIONAL HYDROLOGY

Prepared by
The Executive Council Panel of Experts on Education and Training

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Third edition



WMO - No. 258

Secretariat of the World Meteorological Organization - Geneva - Switzerland

INDEX

WMO TECHNICAL PUBLICATIONS

relating to education and training

WMO No.

- International Cloud Atlas. Abridged edition. (English - French)
- International Cloud Album for Observers in Aircraft. (English - French)

8 - Guide to meteorological instrument and observing practices. 4th edition. (English - French)

240 - Compendium of training facilities for meteorology and operational hydrology. 6th edition (revised). (English - French)

258 - Guidelines for the education and training of personnel in meteorology and operational hydrology. (English)

261 - Problems in dynamic meteorology. (English)

266 - Compendium of lecture notes for training Class IV meteorological personnel. Volumes I and II. (English - French - Spanish - Arabic)

278 - Proceedings of the WMO/IAMAP Symposium on Higher Education and Training (Rome, April 1970). (English - French)

291 - Compendium of lecture notes for training Class III meteorological personnel. (French - Spanish)

300 - Proceedings of the Conference on Meteorological Education and Training in Developing Countries in Africa (Algiers, 1970). (English - French)

305 - Guide on the Global Data-processing System. Vol. I - Organization, practices and procedures of the Global Data-processing System. (English). Vol. II - Preparation of synoptic weather charts and diagrams. (English - French)

306 - Manual on codes (1981 edition). (English - French - Russian - Spanish)

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382 - Compendium of lecture notes for training personnel in the applications of meteorology to economic and social development. (English - French - Spanish)

432 - Proceedings of the WMO/IAMAP Symposium on Education and Training in Meteorology and Meteorological Aspects of Environmental Problems (Caracas, February 1975). (English)

434 - Compendium of lecture notes in marine meteorology for Class III and Class IV personnel. (English - Spanish)

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493 - Proceedings of the Meeting on Education and Training in Meteorological Aspects of Atmospheric Pollution and related Environmental Problems. (Research Triangle Park, U.S.A., January-February 1977). (English)

495 - Handbook of meteorological forecasting for soaring flight. (English - French)

519 - Manual on stream gauging, Vol. I - Fieldwork; Vol. II - Computation of discharge. (English)

544 - Manual on the Global Observing System. Vol. I - Global aspects. Vol. II - Regional aspects. (English - French - Russian - Spanish)

551 - Lecture notes for training Class II and Class III agricultural meteorological personnel. (English)

593 - Lecture notes for training Class IV agricultural meteorological personnel. (English)

596 - Proceedings of the Technical Conference on Climate - Africa (Arusha, 25-30 January 1982). (English - French)

622 - Compendium of lecture notes on meteorological instruments for Class III and IV meteorological personnel. (English)

INDEX

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NOTE

This document, being of an advisory character, is not intended to have the same status as a Guide defined in the special context of Resolution 18, Second Congress.

WMO - No. 258

Secretariat of the World Meteorological Organization - Geneva - Switzerland
1984

INDEX

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ISBN 92 - 63 - 13258 - 5

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INDEX

C O N T E N T S

Page

Foreword xix
Preface to the Third Edition xxi
From the Preface to the First Edition xxiii

P A R T I

EDUCATION AND TRAINING OF PERSONNEL IN METEOROLOGY

CHAPTER 1 - INTRODUCTION AND BACKGROUND INFORMATION 3

1.1 General 5

1.2 Duties of a national Meteorological Service 5

1.3 Fields of specialization 6

1.4 WMO and meteorological education and training 9

1.5 Major WMO Programmes 10
1.5.1 World Weather Watch 10
1.5.2 World Climate Programme 11
1.5.3 Research and Development Programme 11
1.5.4 Hydrology and Water Resources Programme 12
1.5.5 Education and Training Programme 12

CHAPTER 2 - CLASSIFICATION OF METEOROLOGICAL PERSONNEL AND THEIR DUTIES 13

2.1 General 15

2.2 Class I 15

2.3 Class II 15

2.4 Class III 16

2.5 Class IV 16

2.6 Total period of study for various classes of meteorological personnel 17

2.7 Note on syllabi and WMO classification 17

2.8 Revision of the definitions of the Classes I, II, III and IV categorizations 18

INDEX

		Page
CHAPTER 3 -	CURRICULA FOR TRAINING ALL CLASS I METEOROLOGICAL PERSONNEL IRRESPECTIVE OF THEIR FIELDS OF SPECIALIZATION	19
3.1	General	21
3.2	Education in the basic sciences (Class I)	21
3.2.1	Mathematics	21
3.2.2	Physics	23
3.3	Fundamental meteorological education (Class I)	25
3.3.1	Dynamic meteorology	25
3.3.2	Synoptic meteorology	29
3.3.3	Physical meteorology	31
3.3.4	Statistics and thermodynamics of the atmosphere	32
3.3.5	Climatology	33
3.3.6	General hydrology	36
3.3.7	General oceanography	36
3.3.8	Interaction of the ocean and the atmosphere	37
3.3.9	Meteorological instruments and methods of observation	37
3.3.10	Meteorological data processing	39
3.3.11	Satellite meteorology	40
3.3.12	Air pollution meteorology	40
CHAPTER 4 -	ADVANCED TRAINING FOR CLASS I METEOROLOGICAL PERSONNEL	41
4.1	General	43
4.2	Advanced dynamic meteorology (Class I)	43
4.2.1	Hydrodynamics	44
4.2.2	Formulation of basic equations	44
4.2.3	Energetics of the atmosphere	44
4.2.4	Atmospheric wave motion	45
4.2.5	The circular vortex	45
4.2.6	Barotropic stability	45
4.2.7	Baroclinic stability	45
4.2.8	Mountain waves	45
4.2.9	The theory of turbulence	45
4.2.10	Numerical methods	46
4.2.11	Laboratory work	47
4.3	Advanced physical meteorology (Class I)	47
4.3.1	Basic radiation laws	47
4.3.2	Scattering in the atmosphere	47
4.3.3	Solar radiation and its disposition	48
4.3.4	Long wave or terrestrial radiation	48
4.3.5	Radiative and heat balances	49
4.3.6	Ozone	49
4.3.7	Physics of the upper atmosphere	49
4.3.8	Cloud physics	50

INDEX

		Page
4.3.9	Radar meteorology	50
4.3.10	Atmospheric electricity	51
4.4	Advanced synoptic meteorology (Class I)	51
4.4.1	The kinematics of horizontal motion	51
4.4.2	Relationships between wind, pressure, and temperature fields	52
4.4.3	Fronts and frontogenesis	52
4.4.4	Quasi-geostrophic diagnosis	52
4.4.5	Prediction models for large-scale flow	53
4.4.6	Prediction of subsynoptic and meso-scales, by statistical and probability methods	53
4.4.7	Prediction of surface temperature	53
4.4.8	Prediction of cloudiness and precipitation	54
4.4.9	Analysis and prediction in low latitudes	54
4.4.10	Objective analysis	54
4.4.11	Forecast verification and evaluation	55
4.5	Advanced course on weather modification (Class I)	55
4.5.1	Special synoptic aspects	55
4.5.2	Cloud microphysics	56
4.5.3	Cloud dynamics	56
4.5.4	Weather modification theory	56
4.5.5	Design and evaluation of weather modification experiments and operations	57
4.5.6	Observational systems and techniques	58
4.5.7	Technology of weather modification	58
4.5.8	Other related aspects	59
4.6	Advanced course in numerical weather prediction (Class I)	59
4.6.1	Basic dynamic meteorology	59
4.6.2	Physical processes	59
4.6.3	Numerical methods	60
4.6.4	Objective analysis and initialization (Data assimilation)	60
4.6.5	Forecasting models	61
4.6.6	Laboratory sessions	61
CHAPTER 5 –	CURRICULA FOR TRAINING ALL CLASS II METEOROLOGICAL PERSONNEL IRRESPECTIVE OF THEIR FIELDS OF SPECIALIZATION AND SPECIALIZATION IN SYNOPTIC METEOROLOGY (CLASS II)	63
5.1	General	65
5.2	Education in the basic sciences (Class II)	65
5.2.1	Mathematics	65
5.2.2	Physics	69
5.2.3	Chemistry	71
5.3	Fundamental meteorological education (Class II)	71
5.3.1	Dynamic meteorology	72

INDEX

Page

5.3.2 Physical meteorology 73
5.3.3 Synoptic meteorology 75
5.3.4 Climatology 76
5.3.5 Hydrology 78
5.3.6 Oceanography 79
5.3.7 Meteorological instruments and methods of observation 79
5.3.8 Interaction of the ocean and the atmosphere 80
5.3.9 Elements of air pollution meteorology 80

5.4 Specialization in synoptic meteorology (Class II) 80

CHAPTER 6 - CURRICULA FOR TRAINING ALL CLASS III METEOROLOGICAL PERSONNEL IRRESPECTIVE OF THEIR FIELDS OF SPECIALIZATION 85

6.1 General 87

6.2 Education in the basic sciences (Class III) 87
6.2.1 Mathematics 87
6.2.2 Physics 89

6.3 Fundamental meteorological education (Class III) 90
6.3.1 General meteorology 90
6.3.2 Upper-air measurements (meteorological instruments and methods of observation) 92
6.3.3 Climatology 93

CHAPTER 7 - CURRICULA FOR TRAINING ALL CLASS IV METEOROLOGICAL PERSONNEL IRRESPECTIVE OF THEIR FIELDS OF SPECIALIZATION 97

7.1 Education in the basic sciences (Class IV) 99
7.1.1 Earth science 99

7.2 Meteorological training (Class IV) 100
7.2.1 General meteorology 100
7.2.2 Meteorological instruments and methods of observation 101
7.2.3 Climatology 103

CHAPTER 8 - CURRICULA FOR TRAINING ALL METEOROLOGICAL PERSONNEL IN THEIR FIELDS OF SPECIALIZATION 105

8.1 General 107

8.2 Fields of specialization for Class I and Class II meteorological personnel 107

8.3 Fields of specialization for Class III meteorological personnel 107

INDEX

Page

8.4 Fields of specialization for Class IV meteorological personnel 107

CHAPTER 9 - SPECIALIZATION IN CLIMATOLOGY FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL 109

9.1 Specialization in climatology (Class I) 111
9.1.1 Introduction 111
9.1.2 General climatology; the physical basis of climate 111
9.1.3 Organization of a climatological service 111
9.1.4 Instruments and observing procedures 112
9.1.5 Physical climatology 112
9.1.6 Dynamic climatology 112
9.1.7 Synoptic climatology 113
9.1.8 Upper-air climatology 113
9.1.9 Regional climatology 113
9.1.10 Meso- and micro-climatology 113
9.1.11 Climatic change and variability 114
9.1.12 Climate methods and statistics 114
9.1.13 Data-processing methods 115
9.1.14 Applied climatology 116

9.2 Specialization in climatology (Class II) 120
9.2.1 General climatology: the physical basis of climate 120
9.2.2 Organization of a climatological service 120
9.2.3 Regional climatology 121
9.2.4 Meso- and micro-climatology 121
9.2.5 Applied climatology 121
9.2.6 Climatic change 121
9.2.7 Climatic methods and statistics 121
9.2.8 Data-processing methods 122
9.2.9 Climatic services 122

9.3 Specializaton in climatology (Class III) 122
9.3.1 Climatological data and observations 122
9.3.2 Physical climatology 122
9.3.3 Synoptic climatology 123
9.3.4 Regional climatology 123
9.3.5 Meso- and micro-climatology 123
9.3.6 Climatic change 123
9.3.7 Applied climatology 123
9.3.8 Climatic methods and statistics 124
9.3.9 Data-processing methods 124

9.4 Class IV personnel engaged in climatology 124
9.4.1 General climatology 125
9.4.2 Regional climatology 125
9.4.3 Applied climatology 125
9.4.4 Climatic change 125
9.4.5 Climatic services 125
9.4.6 Climate data handling 125

INDEX

		Page
9.4.7	Methods of climatological analysis	125
9.4.8	Practical exercises	126
CHAPTER 10 –	SPECIALIZATION IN MARINE METEOROLOGY FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL	127
10.1	Introduction	129
10.2	Classification of personnel requiring training in marine meteorology	129
10.3	Specialization in marine meteorology (Class I)	129
10.3.1	General	129
10.3.2	Knowledge and appreciation of marine activities influenced by the environment	131
10.3.3	Environmental information requirement	132
10.3.4	Oceanography	132
10.3.5	General knowledge of agencies and organizations concerned with ocean areas, their functions and facilities	133
10.3.6	Specialized knowledge related to the marine environment	134
10.4	Specialization in marine meteorology (Class II)	135
10.5	Specialization in marine meteorology (Class III)	135
10.5.1	Elements of oceanography	135
10.5.2	Meteorological instruments and methods of observation	136
10.5.3	Marine meteorology	138
10.5.4	Marine meteorological services	138
10.5.5	Marine climatology	139
10.6	Class IV meteorological personnel engaged in marine meteorology	139
10.7	Training of port meteorological officers (PMOs) in marine meteorology	139
10.7.1	Duties	139
10.7.2	Training	140
10.8	Training of seafarers in marine meteorology whilst at sea and in navigation school	140
10.8.1	Duties	140
10.8.2	Training	141
10.9	Syllabus for masters and chief officers in marine meteorology	141
10.9.1	Meteorology	141
10.9.2	Climatology	142
10.9.3	Synoptic meteorology	142
10.9.4	Marine meteorology	143

INDEX

Page

10.10 Syllabus for deck officers and marine observers on board ships 143
10.10.1 Meteorology 143
10.10.2 Marine meteorology 144

CHAPTER 11 - SPECIALIZATION IN AERONAUTICAL METEOROLOGY FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL 145

11.1 Specialization in aeronautical meteorology (Class I) 147
11.1.1 Aeronautical meteorological knowledge 147
11.1.2 Aviation knowledge 149

11.2 Specialization in aeronautical meteorology (Class II) 153
11.2.1 Synoptic meteorology 153
11.2.2 Aeronautical meteorological knowledge 153
11.2.3 Aviation knowledge 153

11.3 Specialization in aeronautical meteorology (Class III) 153
11.3.1 Aeronautical meteorological knowledge 154
11.3.2 Aviation knowledge 155

11.4 Class IV personnel engaged in aeronautical meteorology 157
11.4.1 Aeronautical meteorological knowledge..... 157
11.4.2 Aviation knowledge 158

CHAPTER 12 - SPECIALIZATION IN AGRICULTURAL METEOROLOGY FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL 159

12.1 General 161

12.2 Syllabus I - For meteorological personnel 162
12.2.1 Agricultural and biological sciences 162
12.2.2 Agricultural meteorology 163
12.2.3 Agrometeorological observations, instruments stations, networks and processing of data 164
12.2.4 Micrometeorology, microclimatology and topoclimatology 166
12.2.5 Instrumentation and methods of observation for micrometeorological and microclimatological measurements 167
12.2.6 Soil climate 167
12.2.7 The hydrological cycle in agriculture 168
12.2.8 Biological measurements (phenology) 169
12.2.9 Weather and climate in relation to plants, crops, animal production, insects and plant diseases 169
12.2.10 Agroclimatic classifications 172
12.2.11 Frost and protection against frost 172
12.2.12 Windbreaks and shelterbelts 173

INDEX

			Page
	12.2.13	Information, forecasts and warnings for agriculture and forestry	173
	12.2.14	Artificial climates	174
12.3		Syllabus II - For agricultural scientists (Class I)	174
	12.3.1	Introduction	174
	12.3.2	The atmosphere and pressure variation	175
	12.3.3	Radiation in the atmosphere	175
	12.3.4	Meteorological elements	176
	12.3.5	Climatology	177
	12.3.6	Ecology of crops, animals and insects	177
	12.3.7	Agroclimatic stations	177
	12.3.8	Crop forecasts	177
	12.3.9	Investigations and research	177
	12.3.10	Forest meteorology	177
	12.3.11	Satellite applications in agrometeorology	178
	12.3.12	Special weather forecasts for agriculture	178
	12.3.13	Practical work on meteorological instruments and methods of observation	178
	12.3.14	Practical work based on the theoretical course	179
12.4		Specialization in agricultural meteorology (Class II)	180
	12.4.1	Agricultural and biological sciences (Reference: section 12.2.1)	180
	12.4.2	Agricultural meteorology	180
	12.4.3	Optional courses	182
	12.4.4	Projects and seminars	181
12.5		Specialization in agricultural meteorology for agricultural engineers	184
	12.5.1	Synoptic meteorology	184
	12.5.2	Climatology	184
	12.5.3	Agricultural meteorology	184
12.6		Specialization in agricultural meteorology (Class III)	184
	12.6.1	Agrometeorological observations	184
	12.6.2	Agrometeorological instruments	185
	12.6.3	Processing of agrometeorological data	186
	12.6.4	Microclimatology	186
	12.6.5	Soil temperature	186
	12.6.6	Soil moisture	186
	12.6.7	Weather hazards adversely affecting agricultural output	187
	12.6.8	Practical applications	187
	12.6.9	Agrometeorological research	187
	12.6.10	Practical training	187
12.7		Class IV personnel engaged in agricultural meteorology	187
	12.7.1	General meteorology	187
	12.7.2	Meteorological instruments and methods of observation	187
	12.7.3	Climatology	188

INDEX

Page

12.7.4 Air and soil temperature 188
12.7.5 Water vapour in the atmosphere and soil moisture 188
12.7.6 Biological measurements (phenology) 188
12.7.7 Agrometeorological stations 188

CHAPTER 13 - SPECIALIZATION IN HYDROMETEOROLOGY FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL 189

13.1 Specialization in hydrometeorology (Class I) 191
13.1.1 Analysis of meteorological data for design purposes 191
13.1.2 Analysis of hydrological data for design purposes 191
13.1.3 Meteorological aspects of water management operations 192
13.1.4 Hydrological aspects of water management operations 192

13.2 Specialization in hydrometeorology (Class II) 192

13.3 Specialization in hydrometeorology (Class III) 192
13.3.1 Analysis of meteorological data for design purposes 193
13.3.2 Meteorological aspects of water management operations 193

13.4 Class IV personnel engaged in hydrometeorology 193

CHAPTER 14 - SPECIALIZATION IN ATMOSPHERIC CHEMISTRY AND AIR-POLLUTION METEOROLOGY FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL 195

14.1 General 197

14.2 Specialization in atmospheric chemistry and air-pollution meteorology (Class I) 197
14.2.1 Principles of atmospheric chemistry and air-pollution 197
14.2.2 Principles of air-pollution meteorology 198
14.2.3 Monitoring and instrumentation 200
14.2.4 Effects of air pollution 200

14.3 Specialization in atmospheric chemistry and air- 201
pollution meteorology (Class II)

14.4 Specialization in atmospheric chemistry and air- 201
pollution meteorology (Class III)
14.4.1 Principles of air pollution 201
14.4.2 Monitoring and measurements 202

INDEX

		Page
14.5	Class IV Personnel engaged in atmospheric chemistry and air-pollution meteorology	203
14.5.1	Principles of air pollution	203
14.5.2	Air-pollution monitoring	203
CHAPTER 15 -	SPECIALIZATION IN METEOROLOGICAL INSTRUMENTS FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL	205
15.1	Specialization in meteorological instruments (Class I)	207
15.1.1	Technical practices	207
15.1.2	Electronics	207
15.1.3	Meteorological instruments	208
15.2	Specialization in meteorological instruments (Class II)	209
15.2.1	Technical practices	209
15.2.2	Electronic principles	209
15.2.3	Meteorological instruments	219
15.3	Specialization in meteorological instruments (Class III)	211
15.3.1	Technical practices	211
15.3.2	Meteorological instruments	211
15.4	Class IV personnel engaged in meteorological instruments	212
15.4.1	Electricity and electronics	212
15.4.2	Engineering drawing	213
15.4.3	Workshop technology	214
15.4.4	Meteorological instruments	221
CHAPTER 16 -	SPECIALIZATION IN METEOROLOGICAL TELECOMMUNICATIONS FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL	217
16.1	Specialization in meteorological telecommunications (Class I)	219
16.1.1	Fundamental meteorological education for Class I meteorological telecommunications personnel	219
16.1.2	Electronics	220
16.1.3	Meteorological telecommunications	220
16.1.4	Other related subjects	221
16.1.5	Technical practices	222
16.1.6	Organization and telecommunication procedures for the exchange of meteorological information	222
16.2	Specialization in meteorological telecommunications (Class II)	225
16.2.1	Fundamental meteorological education for Class II meteorological telecommunications personnel	225
16.2.2	Electricity and electronics	226
16.2.3	Telephony and telegraphy	226
16.2.4	Radio techniques	226
16.2.5	Technical practices	226

INDEX

Page

16.2.6 Meteorological telecommunications 227
16.2.7 Organization and telecommunication procedures for the exchange of meteorological information 227
16.2.8 Meteorological telecommunication equipment 227

16.3 Specialization in meteorological telecommunications (Class III, Category A) 227
16.3.1 Fundamental meteorological education for Class III meteorological telecommunications personnel (Category A) 228
16.3.2 Electricity and electronics 228
16.3.3 Telephony and telegraphy 228
16.3.4 Radio technique 229
16.3.5 Technical practices 229
16.3.6 Meteorological telecommunication equipment 230

16.4 Specialization in meteorological telecommunications (Class III, Category B) 231
16.4.1 Fundamental meteorological education for Class III meteorological telecommunications personnel (Category B) 231
16.4.2 Electricity and electronics 232
16.4.3 Telephony and telegraphy 232
16.4.4 Radio technique 232
16.4.5 Organization and telecommunication procedures for the exchange of meteorological information 232

16.5 Class IV personnel engaged in meteorological telecommunications 232
16.5.1 Categories of meteorological telecommunications personnel 232
16.5.2 Meteorological education for Class IV personnel engaged in meteorological telecommunications 233
16.5.3 Category A meteorological telecommunications personnel 233
16.5.4 Category B meteorological telecommunications personnel 237

CHAPTER 17 – SPECIALIZATION IN METEOROLOGICAL DATA PROCESSING FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL 241

17.1 Specialization in meteorological data processing (Class I) 243
17.1.1 Numerical analysis 244
17.1.2 Computers and programming 244
17.1.3 Objective weather analysis 245
17.1.4 Numerical weather prediction 246
17.1.5 Meteorological data handling 247
17.1.6 Organization 247

INDEX

		Page
17.2	Specialization in meteorological data processing (Class II) ...	247
17.2.1	Numerical analysis	248
17.2.2	Computers and programming	248
17.2.3	Numerical weather analysis and prediction	248
17.2.4	Meteorological data handling	248
17.2.5	Laboratory and practical work	248
17.3	Specialization in meteorological data processing (Class III) ..	248
17.3.1	Computers and programming	248
17.3.2	Meteorological data handling	249
17.3.3	Numerical weather analysis and prediction	249
17.3.4	Laboratory and practical work	249
17.4	Class IV personnel engaged in computerized meteorological data processing	249
CHAPTER 18 -	SPECIALIZATION IN SATELLITE APPLICATIONS FOR CLASSES I AND II METEOROLOGICAL PERSONNEL	251
18.1	Specialization in satellite applications (Class I)	253
18.1.1	Introduction (a brief history)	253
18.1.2	Satellite systems	253
18.1.3	Satellite sensors	253
18.1.4	Satellite data formats	253
18.1.5	Extraction of cloud information (e.g. cloud amount, cloud top height, cloud types)	254
18.1.6	Interpretation of satellite imagery - Local phenomena	254
18.1.7	Interpretation of satellite imagery - Extra tropical systems	254
18.1.8	Interpretation of satellite imagery - Tropical systems	254
18.1.9	Determination of wind direction and speed from satellite data	255
18.1.10	Determination of vertical temperature and humidity profiles from satellite data	255
18.1.11	Estimation of precipitation from satellite data	255
18.1.12	Radiation balance parameter from satellites	255
18.1.13	Satellite applications in oceanography	255
18.1.14	Satellite applications in hydrology	256
18.1.15	Satellite applications in air-pollution monitoring	256
18.1.16	Satellite applications in agriculture	256
18.1.17	Satellite applications in climatology	256
18.1.18	Quality control of satellite data	256
18.2	Specialization in satellite applications (Class II)	257
18.2.1	Introduction	257
18.2.2	Satellite sensors	257
18.2.3	Image interpretation	257
18.2.4	Quantitative information from satellites	258

INDEX

Page

18.2.5 Satellite applications to oceanography and hydrology 258
18.2.6 Future satellite systems 258

CHAPTER 19 - SPECIALIZATION IN THE APPLICATION OF METEOROLOGICAL INFORMATION TO ECONOMIC AND SOCIAL DEVELOPMENT FOR CLASS I METEOROLOGICAL PERSONNEL 259

19.1 Specialization in application of meteorological information to economic and social development (Class I) 261
19.1.1 Operations research 261
19.1.2 Economics and econometrics 261
19.1.3 Statistics 261
19.1.4 Management science 261
19.1.5 Communications 261
19.1.6 Computer science 262
19.1.7 Mathematics 262
19.1.8 Dynamic meteorology 262
19.1.9 Climatology 262
19.1.10 Introduction level course work in one or more other weather sensitive disciplines 262
19.1.11 Thesis research 263

PART II

EDUCATION AND TRAINING OF PERSONNEL IN OPERATIONAL HYDROLOGY

CHAPTER 1 - INTRODUCTION 267

1.1 General 269

1.2 Professional hydrologists 269

1.3 Hydrological technicians 269

1.4 Hydrological observers 270

1.5 Curricula 270

CHAPTER 2 - CURRICULA FOR EDUCATION AND TRAINING OF PROFESSIONAL PERSONNEL IN OPERATIONAL HYDROLOGY (Corresponding to full university education) 271

2.1 Education in the basic sciences 273
2.1.1 Mathematics 273
2.1.2 Physics 273

INDEX

		Page
2.2	Education in operational hydrology and related subjects	273
2.2.1	Principles of descriptive geometry and technical drawing	273
2.2.2	Theoretical mechanics and fluid mechanics	273
2.2.3	General chemistry and hydrochemistry	273
2.2.4	Principles of geophysics, geology, geomorphology and soil science	274
2.2.5	Surveying	274
2.2.6	Hydraulics: open-channel flow dynamics and channel processes (river bed formation)	274
2.2.7	General meteorology and climatology	275
2.2.8	Synoptic meteorology	276
2.2.9	Physical meteorology (cloud microphysics)	276
2.2.10	Hydrological instruments and methods of observation	276
2.2.11	Design of networks	277
2.2.12	Collection, processing and publication of data	277
2.2.13	Hydrological analysis	278
2.2.14	Hydrological forecasting	278
2.2.15	Applications to water management	279
2.2.16	Organization of Hydrological Services	280
CHAPTER 3 –	CURRICULA FOR EDUCATION AND TRAINING OF SENIOR TECHNICAL PERSONNEL IN OPERATIONAL HYDROLOGY	281
3.1	Education in the basic sciences	283
3.1.1	Mathematics	283
3.1.2	Physics	283
3.2	Education in operational hydrology and related subjects	283
3.2.1	Descriptive geometry and technical drawing	283
3.2.2	Technical practices	283
3.2.3	General chemistry and hydrochemistry	283
3.2.4	Principles of geophysics, geology, hydrogeology, geomorphology and soil science	284
3.2.5	Surveying	284
3.2.6	Hydraulics: open-channel flow dynamics and channel processes (river-bed formation)	284
3.2.7	General meteorology and climatology	285
3.2.8	Synoptic meteorology	285
3.2.9	Hydrological instruments and methods of observation	285
3.2.10	Design of networks	286
3.2.11	Collection, processing and publication of data	286
3.2.12	Hydrological analysis	287
3.2.13	Hydrological forecasting	287
3.2.14	Applications to water management	287
3.2.15	Organization of Hydrological Services	288

INDEX

Page

CHAPTER 4 - CURRICULA FOR EDUCATION AND TRAINING OF JUNIOR TECHNICAL PERSONNEL IN OPERATIONAL HYDROLOGY 289

4.1 Education in the basic sciences 291

4.2 Education in operational hydrology and related subjects 291
4.2.1 Technical drawing 291
4.2.2 Technical practices 291
4.2.3 Hydrochemistry 291
4.2.4 Principles of geophysics 291
4.2.5 Surveying 292
4.2.6 General meteorology and climatology 292
4.2.7 Synoptic meteorology 292
4.2.8 Hydrological instruments and methods of observation 292
4.2.9 Collection, processing and publication of data 293
4.2.10 Hydrological forecasting 293
4.2.11 Organization of Hydrological Services 293

ANNEX - WMO EDUCATION AND TRAINING PUBLICATIONS 295

General information 295

Classes I and II meteorological personnel 296

Classes II and III meteorological personnel 297

Classes III and IV meteorological personnel 297

Other related WMO education and training publications 298

INDEX

FOREWORD

One of the basic purposes of the Organization, as laid down in Article 2(f) of the WMO Convention, is: to encourage research and training in meteorology and, as appropriate, in related fields and to assist in co-ordinating the international aspects of such research and training. This purpose will maintain its validity throughout the coming decade. Examples of the activities of the Organization in the field of education and training are the promotion of the transfer of knowledge and proven methodology and the assistance to Members to train personnel for operating critical elements of the WWW and achievement of other WMO scientific programmes within their own countries.

The planning and the implementation of the WWW system, using more fully the space and computer technology and new observational platforms, with a view to achieving a more balanced data coverage over the globe, are now required. Co-operation with other international organizations and national centres is also required to organize the data base for the World Climate Programme. Assisting Members in developing their own national Meteorological and Hydrological Services to improve services provided for general and applied purposes such as: agriculture, aviation, marine activities, water management, etc. is continually required. Responding to the growing problems of environmental pollution and the long-range transport of pollutants in the atmosphere, too, is required.

Moreover, all such activities are not simply theoretical exercises for weather affects every aspect of the economic and social development in all nations and communities. Its influence is felt in fields hitherto unsuspected - rural development, city planning, energy production and consumption, building construction, food production and conservation, water supply, drainage, transport, etc. The responsibilities of Meterorological and Hydrological Services have therefore increased proportionally and, as a result, a heavy strain has been placed on available resources of meteorological and hydrological personnel. The demand for qualified personnel to serve the needs of growing numbers of users of meteorological and hydrological information and advice is still growing in all countries and particularly in the developing countries.

The aim of this publication is to assist Members of the World Meteorological Organization in the preparation and implementation of training programmes for their personnel. The information given in this revised edition has been brought up to date, in the light of the new technologies and recent developments in meteorological sciences; special attention has been given to training programmes in some of the more recent fields of meteorological specializations such as climatology, marine meteorology, atmospheric chemistry, air-pollution meteorology, numerical weather prediction, agricultural meteorology, meteorological telecommunications, satellite application, and operational hydrology.

I wish to take this opportunity to convey the gratitude of the Organization to the members of the Executive Council Panel of Experts on Education and Training, and particularly to its chairman Dr. R.L. Kintanar, for the excellent work they have done in amending this publication. I would also like to thank the presidents of the various Technical Commissions of WMO as well as the chairmen, members and rapporteurs of their respective working groups who have contributed their advice and experience to this task.

Finally, I wish to pay special tribute to the Permanent Representatives of Members of WMO who have encouraged the issue of such publications.



(G.O.P. Obasi)
Secretary General

PREFACE TO THIRD EDITION

The new technologies and new scientific achievements are gradually transforming many aspects of the national Meteorological and Hydrological Services of the world and thus increasing their efficiency. Many of the major trends in world development, such as increasing shortages of food, water and energy, increased marine activities and pollution of the environment, will place new demands on meteorology and hydrology.

Meteorological and hydrological personnel, given the necessary knowledge, can cope with these trends and help face the new demands. Thus, in revising this publication, the Panel on Education and Training was very conscious in amending some syllabi to cope with the new trends of the development; and, it is to this end that amended syllabi for training meteorologists in climatology and air-pollution meteorology, agricultural meteorology and satellite applications have been included in this new edition. Likewise, the programmes for the training of hydrological personnel in operational hydrology, which were issued as a separate addendum to this publication, have now been included in the revised edition under a special section. In addition, the syllabi prepared for the categories of personnel in a particular specialized field are grouped together in this revised edition in one chapter. This arrangement will ensure easier reference.

As Professor Van Mieghem indicated in the Preface to the First edition, progress and learning are never static. The material in this book, therefore, can only be, as the title states, guidelines for the education and training of personnel. The need for continuous updating of the various training programmes of syllabi, as new knowledge stabilizes in such fields as: energy problems, cloud physics, desertification, oceanic enterprises, urbanization, and similar topics related to other WMO scientific programmes, remains.

Dr. R.L. Kintanar
Chairman
of the Executive Council
Panel of Experts on Education and Training

Geneva, October 1983.

INDEX

From the

PREFACE TO THE FIRST EDITION

Since its creation, the World Meteorological Organization (WMO) has concerned itself with the problems related to the training of meteorological personnel of all grades. In so doing, it has fulfilled its responsibilities as stated under Article 2(f) of the WMO Convention. As many WMO Members became independent, these problems assumed much greater importance. Consequently, in 1959 the Third Congress of WMO recommended that more attention be paid to these problems than had been the case in the past. On the initiative of the Secretary-General of WMO, the Executive Committee, at its thirteenth session (1961), entrusted a consultant with the task of preparing overall plans for the Organization's future activities in the field of education and training of meteorological personnel. In January 1962, the consultant presented the following reports:

(a) The problem of the professional training of meteorological personnel of all grades in the less-developed countries;

(b) Plan for the development of professional meteorological training in Africa; and

(c) Establishment of a training section in the WMO Secretariat to be in charge of problems arising out of the professional training of meteorological personnel in the less-developed countries.

The following year, the consultant prepared a second plan: Plan for the development of professional training of meteorological personnel in South America.

On the express recommendation of the Fourth Congress of WMO (1963), a Training Section was subsequently created in 1964 within the Secretariat. One of the first tasks of the Head of the new Section was to complete a survey on the training of personnel of the national Meteorological Services in Central America and the Caribbean. At its seventeenth session (1965), the Executive Committee created the Panel of Experts on Meteorological Education and Training.

At its eighteenth session (1966), the Executive Committee requested the Panel to "prepare a Comprehensive Guide containing syllabi for both basic and specialized fields of meteorological training".

Two preliminary remarks should be made:

(a) Although the objectives of education and training are the same throughout the world, it should be borne in mind that this publication has been prepared in response to the explicit requests of national Meteorological Services of developing countries. The latter will find in it, the information which they seek. Nevertheless, the need for highly-qualified staff is just as great in developed as in developing countries. For this reason, no effort should be spared in maintaining the training of meteorological personnel at as high a standard as possible in all regions of the world.

(b) In drawing up syllabi for the different grades of meteorological personnel, the Organizations's purpose is to appraise the academic and educational communities of its Members of the levels of general and specialized training that should be attained by meteorologists of all grades to enable them to carry out their respective tasks. It is therefore hoped that this volume will provide a source of information for those who wish to make use of it.

* *

Before dealing with the problems involved in the training of meteorological personnel of all grades and the requisite basic education, it is essential to be quite clear in one's mind as to the purposes of a national Meteorological Service.

A national Meteorological Service is a scientific institution which discharges, at national and international levels, all public service responsibilities related to meteorology, and carries out research within its sphere of scientific activity. It is essential that the scientific staff of a national Meteorological Service engage in research, not only because it provides a beneficial and necessary source of competition amongst themselves, but also because it is the only effective way of keeping abreast of scientific progress - otherwise, methods of work are apt to deteriorate very rapidly, as also the quality of service to the community. In this connexion, it should be recalled that meteorology has evolved from a natural into a physical science. Empiricism belongs to the past. Over the past twenty years, not only has mathematics been increasingly applied to meteorology, but also the world of instruments has been taken over by advanced electronics, and methods of observations and data processing invaded by automation. Routine manual operations are gradually becoming obsolete, and men are progressively being replaced by machines. Meteorological Services today are making use of all kinds of information techniques (automatic data collection and processing): automatic plotting and analysis of aerological soundings ans synoptic charts are one example. Finally, computers are being increasingly used by more and more Meteorological Services, not only for research but also to carry out public service tasks seven days a week.

When tackling the problems involved in the education and training of meteorological personnel, it is important to take the above facts into account. It follows clearly that the scientific staff of a Meteorological Service should have specialized university training in mathematics or physics (or better still, in both subjects if possible), before beginning their meteorological training. Every Meteorological Service keen to maintain its scientific standing should be ready to put all necessary facilities at the disposal of any of its scientific staff who wish to prepare a thesis for a doctorate. It is impossible to carry out research, to accomplish scientific work of value to the public or to implement certain essential parts of the "WMO's scientific programmes", without highly qualified meteorological personnel. It goes without saying that the scientific personnel of every Meteorological Service should be suppported by assistants.

The purpose of this publication is twofold: (a) to define the various Classes of meteorological personnel required for public service and scientific research; and (b) to draw up detailed syllabi of the basic and professional knowledge required of meteorological personnel of all grades.

Many different systems are used throughout the world to define the various types of meteorological personnel. It is not possible to draw up a uniform system applicable to all countries. The Guidelines propose four Classes, with detailed courses for

each Class, ranging from university graduates called upon to discharge highly scientific duties, down to staff to carry out humble but essential tasks, such as observing the weather.

Meteorological personnel may be classified according to the basic education required or the level of professional training to be attained. Both classifications are equally logical and at first sight equally reasonable. In practice however, curricula - whether at primary school, general or technical secondary school, or university level - are so diverse everywhere that a classification according to basic education does not appear to be feasible. On the other hand, because meteorology must be organized on an international basis, it is essential to aim, as far as possible, at a standard level of professional training for each Class: many of the tasks of national Meteorological Services must be carried out in accordance with regulations agreed upon by all WMO Members. The implementation of the World Weather Watch will in fact require even greater uniformity of professional training at the various levels; and consequently, a classification of meteorological personnel according to level of professional training would be more appropriate.

To direct scientific operations, carry out certain essential scientific functions and to carry through research to a successful conclusion, Class I personnel are essential. Routine professional tasks requiring some degree of initiative and a sense of responsibility can be carried out by Class II personnel. To assist members of Classes I and II, personnel of Class III will be required, while personnel of Class IV will perform the humbler everyday tasks.

It is clear, however, that there exists some correlation between the level of professional training and that of basic knowledge: when the former is high, the latter must also rise in proportion. Thus, Class I meteorological personnel must be university-trained; Class II should have completed one or two preliminary years at university, or hold a diploma of a higher technical school; Class III should have successfully completed their secondary education (general or technical); while Class IV should have passed through primary school and the lower grades of general or technical secondary education (first three years in secondary school).

While practically all WMO Members are in agreement as to the definitions of Classes I, III and IV, a substantial minority have formulated some objections concerning Class II. It should be recalled, in the first place, that Class II is not a temporary substitute for Class I, and secondly, that Class II meteorological personnel do not operate solely in the national Meteorological Services of the developing countries. Members of this Class are also to be found in a growing number of developed countries.

National Meteorological Services throughout the world will require an ever-increasing number of Class II personnel, in particular, forecasters and climatologists, and also specialists in telecommunications and information techniques, and in programming and electronics. In addition, one inevitable consequence of the World Weather Watch will be a substantial reduction in the quantity of "pre-processed data" circulating among meteorological telecommunication circuits, with a corresponding increase in "end products". The implementation of the World Weather Watch will thus result in an increase in Class II personnel. While Class I personnel must be available in order to obtain "end products", it will be sufficient to have Class II personnel, with the assistance of Class III, to utilize them.

In the syllabi, a very sharp distinction is made for each Class between the prior basic knowledge required and meteorological training as such. Similarly, where the latter is concerned, those elements of meteorology which all members of any one Class must know are set out in the syllabi along with a description of the knowledge necessary at the level of that Class in each field of specialization.

It should be noted that the syllabi provide only a qualitative indication of the subjects taught. Their actual scope is more difficult to determine. This is a complex task, and in practice can only be carried out by recommending textbooks or by setting test-questions with detailed model answers. It is also possible to set out the contents of a teaching-course by preparing lecture notes or problem workbooks with keys to selected exercises.

The period required for teaching a subject depends as much on the teacher's ability as on the average level of intelligence of his students. Teaching weak and brilliant pupils in the same class is particularly unrewarding. That is why syllabi do not specify the time needed for the various curricula.

A definition of "satisfactory knowledge" of a subject is not given in the Guidelines since this type of appreciation is subjective in the extreme. Satisfactory knowledge can only be indicated by the candidates' replies and the marks awarded - a highly complex and invidious task.

Finally, recent advances in meteorology have been so swift and working methods have developed with such rapidity, that it is absolutely essential to see to it that the various parts of the Guidelines are continually kept up to date.

Professor J. Van Mieghem
Chairman of the Executive Committee
Panel of Experts on Meteorological
Education and Training (1965-1971)

(July, 1969)

INDEX

PART I

EDUCATION AND TRAINING OF PERSONNEL IN METEOROLOGY

INDEX

INDEX

CHAPTER I

INTRODUCTION AND BACKGROUND INFORMATION

INDEX

INDEX

1.1 GENERAL

This chapter illustrates the wide variety of meteorological personnel required in order to carry out the various duties of a national Meteorological Service. The need for qualified scientists and trained technicians is also emphasized.

In the following pages the duties of a national Meteorological Service and the fields of specialization are considered; then the role of the World Meteorological Organization (WMO) in the field of Education and Training is discussed. Finally, there is an outline of the major WMO programmes:

- World Weather Watch (WWW),
- World Climate Programme (WCP),
- Research and Development,
- Hydrology and Water Resources,
- Education and Training.

All these programmes demand and will demand highly qualified meteorological personnel of all grades.

Subsequent chapters will define the grades of personnel, from the meteorologists to his assistants, and will recommend curricula in the basic sciences, in fundamental meteorological education, advanced training and in various fields of specialization.

1.2 DUTIES OF A NATIONAL METEOROLOGICAL SERVICE

The functions carried out by a national Meteorological Service can be summarized as follows;

(a) The organization, operation and maintenance of networks of surface and upper-air observing stations;

(b) The evaluation, processing and archiving of the observational data;

(c) The establishment, operation and maintenance of an efficient telecommunication system for the collection and distribution of the required observational data and processed information;

(d) The provision of meteorological information and advice including weather forecasts, climatological statistics and information on physics of the atmosphere;

(e) Advancement of meteorology by scientific research;

(f) Application of the science of meteorology;

(g) The promotion of meteorology throughout the world by internal co-operation.

In order to carry out these duties efficiently, the Service must have qualified and trained personnel.

1.3 FIELDS OF SPECIALIZATION

The variety of fields of human endeavour that can benefit from the science of meteorology is so wide that no one meteorologist can be expected to acquire the knowledge which would permit him to give expert advice on all of these topics. Consequently, as in other scientific fields, the science of meteorology has been conveniently subdivided into a number of branches, each of which calls for specialized study. The main fields of specialization including border fields and fields of application, are:

(a) Dynamic meteorology;

(b) Physical meteorology;

(c) Synoptic meteorology;

(d) Weather modification;

(e) Numerical Weather Prediction;

(f) Climatology;

(g) Marine meteorology;

(h) Aeronautical meteorology;

(i) Agricultural meteorology;

(j) Hydrometeorology;

(k) Atmospheric chemistry and air-pollution meteorology;

(l) Meteorological instruments;

(m) Meteorological telecommunications;

(n) Meteorological data processing;

(o) Meteorological satellite applications; and

(p) Applications of meteorology to economic and social development.

In accepting any such subdivisions of the science of meteorology, it must be borne in mind that no single field of specialization is completely independent of others. In some cases a major portion of the knowledge required for specialization in one field may

also be required for specialization in another. In all cases a basic minimum knowledge of meteorology is required. Moreover, not all branches of specialization are covered in the above classification: refinements of the main fields will uncover additional areas such as urban meteorology, biometeorology, micrometeorology, etc. Although the latter fields will not be the subject of detailed syllabi in this publication, some general ideas will be given where possible, on the background and experience required by personnel engaged in them. In the following paragraphs, a brief description of the various fields of specialization is given:

Dynamic meteorology: This is the study of the basic thermohydro dynamic processes which determine the motions of the air and the phenomena they produce. Within dynamic meteorology the study of numerical models for simulating atmospheric processes and for numerical weather prediction has developed since the late forties. Because of the rapid calculations possible on modern computers, the theories of dynamic meteorology are being applied directly to the existing weather situation to calculate its future development. Dynamic meteorology covers motions of all scales including meso- and small-scale systems.

Physical météorology: This field includes thermodynamics, cloud physics, radiation, chemical composition and optical, electrical, acoustical phenomena of the atmosphere. As generally accepted, it does not include mathematical theory of the motions of the atmosphere and the forces responsible for them (which fall in the field of dynamic meteorology). Atmospheric thermodynamics lies so near the borderline of physical and dynamical meteorology that it is treated as often in one as in the other branch. All these subjects have received much attention during recent years. The experts in the field of physical meteorology have the advantage that most of the problems they deal with are amenable to the techniques of experimental physics and most of their experiments can be carried out both in the laboratory and in the free atmosphere.

Synoptic meteorology: This is the branch of meteorology in which the analysis and study of the atmosphere are performed in order to understand its behaviour and to predict its future evolution. The basic sciences for synoptic meteorology are dynamic and physical meteorology, the basic tools being weather charts of synchronous observations describing the three dimensional physical state of the atmosphere.

Weather modification: A sound understanding of cloud processes like the evolution of particle spectra and the motion of air and particles from the basis of interference with natural cloud and precipitation forming processes. Further the success of weather modification can only be established when modification experiments are properly planned and evaluated. A well balanced appreciation of ecological, legal and economical aspects is equally important.

Numerical Weather Prediction: This field is included under other specialization such as Dynamic meteorology and data processing. However it is introduced as a separate advanced course in this field.

Climatology: Climatology is the scientific study of climate (collective state of the atmosphere at a given place or over a given area within a specified period of time). It can be subdivided into distinct fields of specialization such as microclimatology, bioclimatology and applied climatology.

Marine meteorology: This covers the additional knowledge required to adequately understand the relationships between the atmosphere and the oceans, between meteorology and oceanography and the need for the application of meteorology to marine activities.

Aeronautical meteorology: Aeronautical meteorology was developed as in application of the synoptic and dynamic branches of the science to answer the specific meteorological problems of air transport and aicraft design and performance. The results of synoptic analyses and prognostic fields of atmospheric parameters are used to develop flight-route, area and aerodrome terminal weather forecasts for use in flight planning operations and briefing of crew members. Aeronautical meteorology includes also aeronautical climatology.

Agricultural meteorology: This is concerned with the application of the knowledge of the atmosphere to agricultural practice. Its scope is wide and includes the study of the relationships between meteorological factors and such things as the soil, plants, animals and the related diseases and pests. Its ultimate aim is to provide meteorological and agricultural information to the agriculturalist, in a form suitable for use in his day-to-day operations, and at the same time give accurate guidance for his seasonal and long-range planning.

Hydrometeorology: This is the part of meteorology which is concerned with the processes in the atmospheric phase of the hydrological cycle and in the boundary between the atmospheric and land phase of the hydrological cycle.

Atmospheric chemistry and air-pollution meteorology: This field examines the conditions and establishes the physical and chemical processes and properties which determine the transport, transformation, distribution and removal of man-made and natural substances released into the atmosphere. Particular emphasis is placed on those substances which may affect weather, climate and the well-being of man and ecosystems. The results of such studies lead to a better understanding of the atmosphere and its interaction with other media and are an essential input to air pollution control measures and thereafter make it possible to ascertain the pollution of adjacent media via the atmosphere.

Meteorological instruments: This field is concerned with the instruments used for the detection, location and measurement (qualitative or quantitative) of one or several meteorological elements. It is becoming increasingly important with the appearance of an ever-widening variety of instruments. Meteorological instruments range from the simple ones found at most weather stations, such as barometers, barographs and anemometers, to more complex types including meteorological radars, automatic weather stations and meteorological satellites.

Meteorological telecommunications: This is designed to ensure the rapid exchange of observed and processed data on a global scale in order to satisfy the requirements of the different fields of meteorology. This branch is assuming increasing importance due to the employment of more and more complex means of telecommunication.

Meteorological data processing: This field is a very important part of the WWW plan. Meteorological data processing is increasingly performed by computer systems. This field of specialization should therefore include computer methods for the treatment of meteorological reports, numerical methods for the analysis and forecasting of meteorological fields and their application to local and area forecasts, as well as forms and methods for storage, retrieval and presentation of data.

Satellite applications: This is a field in which the information obtained from satellites is processed and used in meteorological operations and research. The satellites provide images both in the visible and infrared spectral intervals and provide complete global coverage both day and night. These data are useful to locate the weather systems and keep track of their movements over data sparse areas. Satellites also provide information on the vertical distribution of temperature and moisture.

Applications of meteorology to economic and social development: This is concerned with the study of the way man responds to the atmosphere through the management of economically important weather sensitive activities. It includes analysis of the degree of weather-sensitivity of particular economic enterprises; analysis of weather-sensitive management alternatives; development of well documented sources of economic data comparable to meteorological data and development of affective communications between the Weather Services and economically important decision-making groups.

1.4 WMO AND METEOROLOGICAL EDUCATION AND TRAINING

The Convention of the World Meteorological Organization requires the Organization, Basic Documents (WMO-No.15), Article 2 (F), to ensure research and training in meteorology and as appropriate in related fields and to assist in co-ordinating the international aspects of such research and training. Weather knows no national boundaries. Its effects are international. Consequently, the degree of efficiency of any one country's Meteorological Service will obviously affect that of all other national Meteorological Services, especially those of neighbouring countries. No country can, for example, dispense with the meteorological observations carried out by a neighbour. Thus, any defects in a national Meteorological Service have immediate and troublesome international repercussions.

The education and training activities of WMO can be summarized as follows:

(a) Maintaining high standards in the technical and scientific training of personnel throughout the world in all the fields of activity of the Organization;

(b) Assisting in national, regional and inter-regional training programmes, with particular emphasis on strengthening the existing centres and establishing, as necessary, new regional and national training centres. Assistance would include syllabi, training publications, the provision of fellowships, correspondence courses, roving experts and visiting scientists, and appropriate equipment and materials for training, including post-graduate training;

(c) Undertaking on request studies and surveys and the preparation of reports on the requirements of national Meteorological, Hydrometeorological and Hydrological Services in the field of education and training;

(d) Providing on request advice and information to Members on various aspects of education and training, including correspondence courses and other recent progress in educational methods;

(e) Organizing regional, inter-regional and international seminars (including roving seminars, workshops, courses) and conferences covering various aspects of education and training;

(f) Collaborating with the United Nations, the United Nations specialized agencies and other international organizations in their respective activities, which have a bearing directly or indirectly on education and training in meteorology, operational hydrology, and related activities;

(g) Fostering exchanges of opinions and ideas on education and training between Meteorological, Hydrometeorological and Hydrological Services and members of the academic community.

1.5 MAJOR WMO PROGRAMMES

In view of the important role played by meteorological education and training in the various other WMO programmes, it is appropriate to include in this publication a brief summary of the major WMO programmes.

1.5.1 World Weather Watch

The World Weather Watch (WWW) is a world-wide, co-ordinated developing system of meteorological services provided by WMO Members. Its main thrust is the maintenance and further development of three closely linked operational elements:

(a) The Global Observing System (GOS), consisting of facilities and technical procedures for making observations on land and at sea and from aircraft, meteorological satellites and other platforms;

(b) The Global Telecommunications System (GTS), consisting of telecommunications facilities and arrangements necessary for the rapid and reliable collection and distribution of the required observational data and processed information;

(c) The Global Data-processing System (GDPS), consisting of meteorological centres with facilities for the processing of observational data for real-time (*) use and for storage and retrieval of data for use in non-real time (*).

The main objectives of the programme are:

(a) To achieve an optimum global observing system design on the basis of Observing System Experiments using the FGGE data sets;

(b) To improve the transmission of observational data to the world, regional and national centres so that data are routinely available in a sufficiently timely manner to meet their requirements;

(c) To make available in a timely fashion to all interested Members the processed information to support their individual needs for meteorological and hydrological forecasting activities;

(d) To implement fully the plan for monitoring the operation of the WWW and the Operational Information Service and secure remedial action on the problems identified.

(*) Real-time applications are operations in which the information must be received and used or processed within, at most, a few hours after it is generated. Non-real time applications are those operations which can be carried out over a more extended time period.

1.5.2 World Climate Programme

The World Climate Programme of WMO grew out of the recognition that climate information could be used effectively to help solve some of the major problems of mankind.

The dependence of national economies upon climatic fluctuations is now generally realized and in some planning for economic and industrial development climatic factors are taken into account. Particular attention is being paid to the effects of climate variations on food production. Furthermore, it has been suggested that man's industrial and other activities might reach a level that could contribute significantly to climate variations, such as have occurred in recent years. For this question to be resolved the present knowledge of the natural variations in climate should be much increased.

This programme has four component parts:

- World Climate Applications Programme (WCAP);
- World Climate Data Programme (WCDP);
- World Climate Impact Studies Programme (WCIP);
- World Climate Research Programme (WCRP).

Because the study of the global climate and its impacts is an extremely complex subject, a number of international bodies, governmental and non-governmental, collaborate in appropriate sectors of the programme. WMO is responsible for the coordination of the entire WCP and for the implementation of both the WCDP and WCAP.

1.5.3 Research and Development Programme

Although the Organization is not directly participating in research activities, it plays an active part in assisting Members to implement research projects which are of concern to a large number of countries. Moreover, the Organization disseminates relevant scientific information and draws the attention of Members on outstanding research problems of major importance. It also encourages and, as necessary, helps Members to incorporate the results of research into operational forecasting or other appropriate techniques, particularly when such changes of procedure require international co-ordination and agreement. These are the main functions of WMO's Research and Development Programme. It follows, therefore, that this major programme is directed towards practical problems which are of interest for many of its Members.

The Research and Development Programme of WMO is practical and gives priority to efforts that offer good prospects of meeting the principal requirements of Members. The main objectives of the programme are:

(a) To strengthen research in short-range and medium-range weather forecasting, including local forecasting techniques, with particular emphasis on exploiting the results of the various GARP experiments, in order to improve the forecasting services of Members;

(b) To improve methods of long-range (monthly and seasonal) weather forecasting using the results of GARP experiments and of the predictability studies carried out within the World Climate Research Programme;

(c) To strengthen research in tropical meteorology in order to provide knowledge in atmospheric sciences (including knowledge of climate) in the specific areas of interest in tropical regions, and to facilitate the development of improved techniques for carrying out the required operational services in those regions;

INDEX

(d) To further develop studies of the chemical constituents of the atmosphere and of the long-range transport, chemical transformation and radiative properties of atmospheric pollutants.

1.5.4 Hydrology and Water Resources Programme

The Hydrology and Water Resources Programme (HWRP) has always been and will continue to be viewed from a long-term perspective because in many countries there is a great deal to be done in the development of hydrological services, notably with regard to the strengthening of observing networks, the establishment of forecasting systems and the provision of hydrological information for the efficient management of water resources. The overall objective of the programme is based on the long-term targets set by the UN Water Conference (Mar del Plata, 1977). This Conference adopted a Plan of Action covering the years up to 2000 for the accelerated development and orderly administration of water resources throughout the world. More recently, a number of intergovernmental conferences have defined the time scales for implementation of projects in various sectors.

The overall objective of the HWRP for the coming decade will be:

- To ensure quantitative and qualitative assessment of surface water resources and forecasts of their future occurrence, both as gross and economically usable quantities, for different sectoral uses.

1.5.5 Education and Training Programme

The Education and Training Programme is vital to the successful participation, by developing countries, in all scientific and technical activities of the Organization and therefore a high priority is given to it.

In fact, the education and training activities form an integral part of all WMO programmes. They serve to ensure that the national Meteorological and Hydrological Services of developing countries have the required well-trained personnel to carry out their functions and be able to adapt to new scientific achievements and new technologies. Hence, these activities play a decisive role in transferring knowledge and proven methodology between Members.

Accordingly, the Education and Training Programme has two main goals:

(a) To overcome the shortages of trained staff which restrain countries from fully meeting their responsibilities for providing meteorological and hydrological information and services;

(b) To transfer knowledge and proven methodologies to enable countries to implement, and benefit from, the other major WMO programmes taking into account local conditions.

In the training of personnel in meteorology and operational hydrology, the United Nations Development Programme (UNDP) and the Voluntary Co-operation Programme of WMO (VCP) play important roles.

INDEX

CHAPTER 2

CLASSIFICATION OF METEOROLOGICAL PERSONNEL AND THEIR DUTIES

INDEX

2.1 GENERAL

Establishing a uniform classification of meteorological personnel which will satisfy the requirements of the various branches of meteorology and the various national Meteorological Services is a difficult task. The wide variety of functions carried out by a national Meteorological Service and the equally wide range of personnel required have already been discussed in the previous chapter. Moreover, the diversity of personnel grading systems among the various countries has been clearly demonstrated in the "Compendium of Meteorological Training Facilities" (WMO-No.240) and in the training curricula prepared by certain national meteorological training schools. As a prerequisite, however, to establish syllabi for guidance in the training of meteorological personnel, we must first have a clear idea of the grades of personnel involved, and so far as possible the duties carried out by each grade.

There is no doubt that meteorological personnel can be graded in a number of ways, each with its own particular merit and convenience. It is equally certain however, that no one system will adequately define all types of personnel required. It is therefore necessary to accept a compromise classification, all the while recognizing its deficiencies and limitations. With this in mind, one can develop a system of classification which can be usefully employed as a basis for establishing syllabi for the education and training of meteorological personnel.

The following classification of meteorological personnel has been adopted in this publication on the basis of the qualifications required and duties to be undertaken.

2.2 CLASS I

These are University trained personnel with adequate education in mathematics and physics and who have successfully completed a course in meteorology to the standard specified by the syllabi. In this group there can be various levels, or degrees of qualifications.

All Meteorological Services should have personnel of this Class. Their duties should include, inter alia operational day-to-day work such as weather forecasting as well as consulting, directing and decision-making and management. Clearly also they will be responsible for research and development. This may require additional training either through systematic academic courses or as a result of personal study.

2.3 CLASS II

Such personnel will have undergone a complete secondary or equivalent school education and introductory training in mathematics and physics to the standard specified by the syllabi as well as successfully completing a meteorological course. Such training should be given at a university or other appropriate institution having Class I instructors.

The function of Class II meteorological personnel is to carry out duties relative to the analysis and interpretation of observational data.

More specifically, their duties will include, under guidance by Class I personnel, the analysis of synoptic charts, weather forecasting, study of data relating to physical meteorology (radiation, ozone, etc.), observational instruments and methods, telecommunications, inspections of meteorological networks, etc.

The distinction between Class I and Class II personnel lies not in the skills acquired, since Class II may have a very high degree of skill in some fields, but in the fund of knowledge as organized into a consistent body of theory which supports those skills.

They should also be capable of ensuring functions extending from that of technical adviser, to that of chief of the meteorological telecommunications branch in the Services in which Class I telecommunication personnel are not considered necessary.

2.4 CLASS III

They will have received complete secondary or equivalent school education and adequate training in meteorology.

Class III personnel should be suitably qualified to carry out a wide variety of tasks. They are responsible for the decoding and checking of incoming messages, plotting of meteorological charts, aerological diagrams and cross-sections. They should assist personnel of higher Classes in the analysis and interpretation of observational data, supplying meteorological information under supervision, checking monthly weather summaries of the network stations, and calculating statistical parameters on the basis of such summaries. In accordance with their qualifications, Class III personnel would also be responsible for the calibration of meteorological instruments used in the surface observation network, calibration of aerological sondes, operation of aerological and radiation stations, and other related duties.

2.5 CLASS IV

They should have a basic education equivalent to nine years primary and secondary school or equivalent education followed by appropriate training in basic meteorology to enable them to observe meteorological phenomena accurately and objectively and to understand the underlying significance of their routine tasks. The duties of Class IV meteorological personnel will include all routine surface observations such as atmospheric pressure, temperature, humidity, evaporation, rainfall, speed and direction of wind, sunshine, total radiation, grass minimum temperature, ground temperature, cloud, visibility and present weather. They will also maintain instruments such as barometers and barographs, thermometers and thermographs, maximum and minimum thermometers, psychrometers and hygro graphs, and all other instruments used in surface observations. In addition, their duties may include office work such as the reduction of observation data, transmission of synoptic messages, maintenance of the observation log and preparation of monthly summaries, processing of recording diagrams and the calculation of hourly totals, means and extreme values. They may also be required to plot meteorological charts and diagrams.

2.6 TOTAL PERIOD OF STUDY FOR VARIOUS CLASSES OF METEOROLOGICAL PERSONNEL

In view of the fact that the periods of primary and secondary school and also the school entry age vary from country to country, an indication of the total period of study is highly necessary. For this purpose the following scheme is presented on the assumption that the age at school entry is 6 years:

Class IV - The background education should correspond to at least 9 years of schooling. This should be supplemented by a minimum of 4 months formal training in meteorology and an extensive period of on-tthe-job training.

Class III - A minimum of 12 years of schooling is required before the candidates embark on meteorological study. This corresponds to GCE "A" level in the United Kingdom. The period of the meteorological course should be 8-10 months supplemented by adequate practical and on-the-job training.

Class II - The same general background education as Class III. This should be supplemented by courses in mathematics, physics and other pre-requisite subjects together with meteorological training over a period of 2 years. A minimum of 9 months on-the-job training will be required to complete the training.

Class I - The same general background education as for Classes III and II plus university training in pre-requisite subjects and meteorology for a period of at least 4 years. This should be supplemented by on-tthe-job training of at least 6 months in a Meteorological Service.

2.7 NOTE ON SYLLABI AND WMO CLASSIFICATION

In this publication syllabi for training personnel in each of the above four Classes are presented. Attention is given to variations or additions to these syllabi for personnel engaged in the various fields of specialization of meteorology.

It should be understood, however, that in establishing these syllabi, it is not the intention to lay down standard curricula. To do so would be inadvisable. Training programmes throughout the world must take into account local circumstances and, consequently, variations in the syllabi adopted in the various countries are inevitable. It is hoped, however, that the syllabi presented here will serve as guidance material for meteorological training required for the various Classes of personnel.

It is emphasized once more that the above classification is not expected to be adopted universally since some countries do have other systems which are more suitable to their requirements. It is however the most readily acceptable compromise as demonstrated by many Members of WMO.

2.8 REVISION OF THE DEFINITIONS OF THE CLASSES I, II, III AND IV CATEGORIZATION

In its thirty-fourth session (Geneva, June 1982), the WMO Executive Committee felt that, in view of the various changes and developments which have taken place during the last fifteen years, there was now a need to review the definitions of the Class I, II, III and IV categorizations of meteorological personnel.

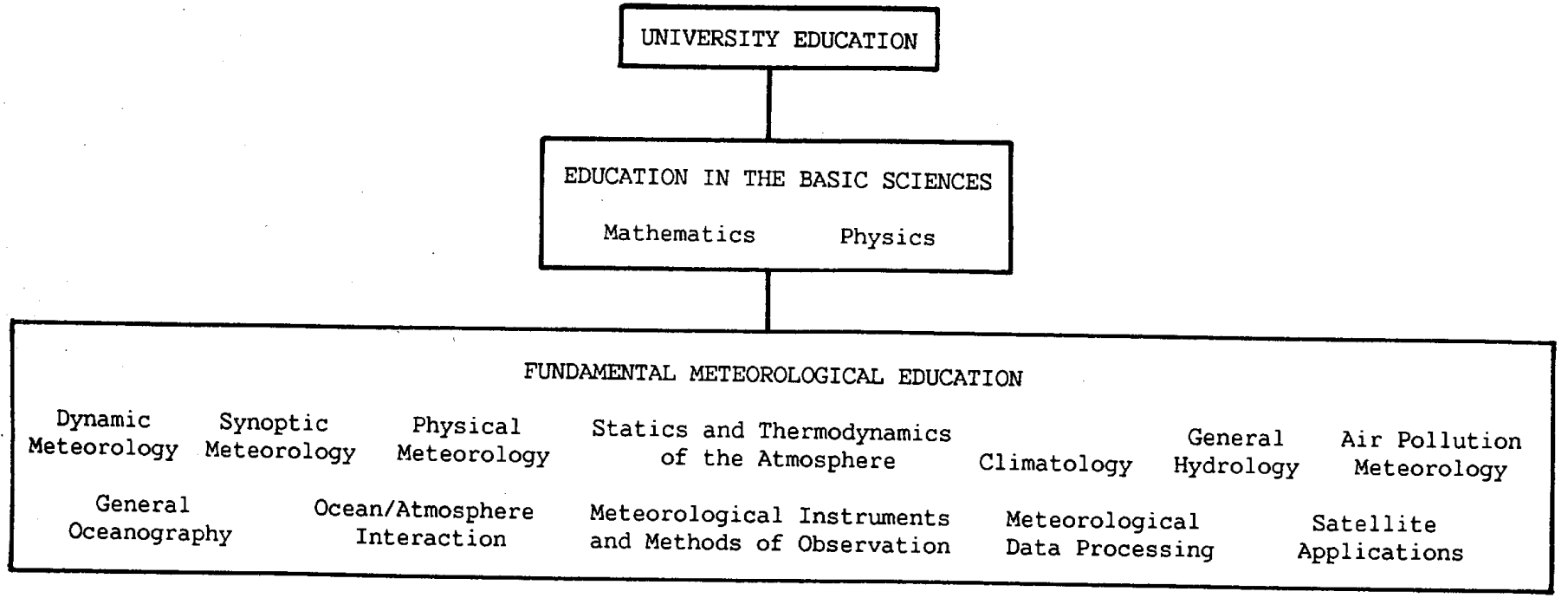
The subject of these revisions is being planned to be fulfilled in the future and therefore, the definitions of the categorizations will be amended accordingly.

CHAPTER 3

CURRICULA FOR TRAINING ALL CLASS I METEOROLOGICAL PERSONNEL IRRESPECTIVE OF THEIR FIELDS OF SPECIALIZATION

CURRICULA FOR TRAINING CLASS I METEOROLOGICAL PERSONNEL

(Schematic representation of contents)



3.1 GENERAL

Although in some cases the syllabi for Class I are given in less detail than for Class II, it is, of course, expected that the general training for the Class I courses will cover the whole of Class II.

Since courses in mathematics and physics for Class I personnel are taught by mathematicians and physicists, it is unnecessary for WMO to elaborate detailed syllabi in these subjects. There is sufficent uniformity of nomenclature to permit the scope of the material to be indicated briefly. Furthermore, although university education may vary from country to country the level of knowledge required in these subjects is implied by the syllabi in meteorology.

The syllabi given below therefore list, without going into detail, the main topics to be covered. However in hydrodynamics and thermodynamics, which are of prime importance in meteorology and oceanography, a certain amount of detail has been maintained.

3.2 EDUCATION IN THE BASIC SCIENCES (CLASS I)

3.2.1 Mathematics

3.2.1.1 Algebra

- Classic linear and non-linear algebra with special emphasis on vectors and tensors; elements of modern algebra: fields, rings, groups, lattices.

3.2.1.2 Differential and integral calculus and advanced calculus

- The classical course in differential and integral calculus including the theorems of Green, Ostrogradsky, Stokes and Gauss; methods of evaluating the asymptotic value of integrals;
- Functions of a complex variable;
- Classical course in series, including Fourier series and orthogonal functions; Fourier integrals;
- Ordinary differential equations including linear and higher order and degree equations; solutions in series and the theory of special functions;
- Classical course in differential and integral vector and tensor calculus;
- Calculus of variation; optimal control theory.

3.2.1.3 Partial differential and integral equations

- Boundary value problems in heat conduction;

- Special functions;
- Eigen functions and Eigen values.

3.2.1.4 Probability theory and statistics

- Foundations of probability theory;
- The statistical method and its scope;
- Contingency and correlation;
- Time series; random series; trends in time series; harmonic analysis; spectrum analysis (power spectra);
- Method of least squares.

3.2.1.5 Numerical and graphical calculation

- Numerical calculation of an expression involving only arithmetical operations;
- Numerical differentiation and integration;
- Numerical calculation of series;
- Solution of ordinary differential equations; numerical approximation and graphical method;
- Simultaneous linear equations;
- Partial differential equations; relaxation methods;
- Non-linear algebraic equations; numerical solution of cubic equations; graphical methods;
- Approximation functions;
- Solution of the standard transcendental equations; graphical methods;
- Standard integral equations.

3.2.1.6 Machine computation

- The use of computers in meteorology: computers, working principles; coding; general construction, central unit, in- and output devices CRT displays, plotters); information carriers (paper tape, magnetic disc, microfilm for machine reading); memories; principles; lineprinters; tapes and cards, tape and punch-card machines; sorting and selection stages; programming principles; flow diagrams; programming languages (ALGOL, FORTRAN); compilers; statistical, accounting and information handling machines; application of machine methods in meteorological services; analogue computers; processing of continuous variables; applications.

3.2.2 Physics

3.2.2.1 Particle dynamics

- Kinematics of a particle;
- Dynamics of a particle.

3.2.2.2 Rigid body dynamics

- Kinematics of a rigid body;
- Dynamics of a rigid body.

3.2.2.3 Elastic media

- Equilibrium of elastic bodies;
- Elastic waves.

3.2.2.4 Hydrodynamics

Kinematics

- Eulerian and Lagrangian variables; decomposition of a field of motion in the vicinity of one of its points into a field of translation; a field of rotation and a field of deformation and divergence; physical significance of vorticity and divergence; application to plane motion.

Statics

- Pressure; force due to the pressure gradient; equations of state and of change of state of a fluid; perfect gas equation; surface tension of fluids; capillarity; barotropic and baroclinic fluids; isobarisostere solenoids; Pascal's law; Torricelli's experiment; barometer; Archimedes' principle and buoyancy applications; hydrostatic equation along the vertical; altimetry, application to the atmosphere; Laplace's equation.

Dynamics

- Eulerian and Lagrangian motion; boundary and initial conditions; continuity equation; case of gases and liquids; compressibility and incompressibility;
- Work-energy theorem, balance of mechanical energy (potential and kinetic energy); application to aerodynamics; Bernouilli's theorem;
- Vorticity and divergence; rotational form of the equations of motion; irrotational motion and two or three-dimensional rotational motion; irrotational motion in three dimensions due to sources, sinks, doublets and line sources; images; flow around an obstacle;

- Circulation and vorticity: absolute and relative circulation and vorticity; case of the barotropic fluid: the Lagrange-Helmholtz theorem; case of the baroclinic fluid: V. Bjerknes's theorem and its interpretations;

- Small disturbances and their propagation in a fluid in equilibrium; compressibility waves (sound waves); gravity and inertia waves;

- Viscous fluids; coefficient of viscosity; case of gas; case of liquids; Navier-Stokes' tensor; integration of the viscous fluid equations in simple cases; Poiseuille's flow and Couette's flow; resistance of liquids to the motion of immersed bodies; Stokes' formula, limiting velocity, applications;

- Turbulent fluids; one and two-dimensional turbulent flow; boundary layer; eddy lines and eddy motions in the wake of an obstacle; Reynolds' number; Reynolds' tensor; turbulent diffusion of heat and momentum, eddy conductivity and eddy viscosity; application to the atmosphere, turbulent diffusion of water vapour in air.

3.2.2.5 Thermodynamics

- Object of thermodynamics: thermodynamic system; definition; exchanges of energy and matter with the external world; closed and open systems; physical state of a system; variables of state; (p,v) systems; Clapeyron's diagram;

- Definition of temperature: temperature scales (Celsius, Fahrenheit, Kelvin); variables of state and the equation of state of a system; homogeneous and non-homogeneous systems; thermal expansion of solids, liquids and gases; case of gases: the laws of Boyle-Mariotte, Gay-Lussac, Avogadro and Dalton (gas mixtures); equation of state of a gas: perfect gas and Van der Waal's gas;

- Definition of heat: quantity of heat; calories; thermal conductivity; specific heat; case of gases; heat of change of phase; heat of reaction (chemistry); calorimetry;

- First law of thermodynamics: various forms of energy (work, heat, electrical and chemical energy, etc.); principle of the conservation of energy; principle of the equivalency of heat and work (Joule); statement and meaning of the first law in the cases of systems at rest and in motion (atmospheric air); in the cases of closed and open systems (clouds in the case of precipitation); case of systems in motion; consequences of the first law and of the kinetic energy theorem as applied to the system; internal energy; entlhalpy; Gibbs's system; work accomplished by the expansion of an ideal fluid; reversible exchange of work and heat; calorimetric coefficients of a fluid; adiabatic transformations; case of the perfect gas.

3.2.2.6 Electromagnetism

- Electrostatics;

- Direct current;
- Magnetostatics;
- Alternating current;
- Electromagnetism.

3.2.2.7 Electromagnetic radiation

- Geometric optics;
- Wave optics;
- Spectroscopy;
- Theory of electromagnetic radiation.

3.2.2.8 Atomic and molecular physics

- Concepts of the composition of matter;
- Elements of wave and quantum mechanics, and atomic physics.

3.3 FUNDAMENTAL METEOROLOGICAL EDUCATION (CLASS I)

In any Meteorological Service there will be day-to-day operational tasks calling for the exercise of independent judgement based on scientific principles. Work of this kind will necessitate a cadre of well-qualified and skilful personnel. Such personnel must have a thorough grounding in dynamic, synoptic and physical meteorology. Syllabi in these subjects are given in paragraphs 3.3.1, 3.3.2 and 3.3.3 respectively. For convenience the syllabus on the statics and thermodynamics of the atmosphere, an essential aspect of both dynamic and synoptic meteorology and also necessary background for the study of cloud precipitation physics, has been reproduced separately in paragraph 3.3.4 rather than under dynamic or synoptic meteorology as is often the case. Further, Class I personnel should also have basic knowledge of climatology, hydrology, oceanography, interaction of the ocean and the atmosphere, meteorological instruments and methods of observation, meteorological data processing, satellite meteorology and air pollution meteorology. Appropriate syllabi are given in paragraphs 3.3.5 to 3.3.12 respectively.

3.3.1 Dynamic meteorology

3.3.1.1 Formulation of basic equations

- Equations of motion in vector form as derived from Newton's second law; discussion of pressure force and gravitation; transformation from non-rotating to rotating co-ordinate systems; discussion of centripetal acceleration and Coriolis force; the concept of gravity;

- Equations of motion in Cartesian co-ordinates (tangent plane approximation) and in spherical co-ordinates; orders of magnitude of various terms (based on observation) leading to the simplified equations;
- Introduction of the hydrostatic approximation; justification of this approximation;
- Equation of quasi-hydrostatic motion using pressure as vertical co-ordinate;
- The continuity equation; Cartesian co-ordinates: pressure as vertical co-ordinate; homogenous and incompressible fluid;
- The thermodynamic equation and equation of state;
- Principles of dimensional analysis.

3.3.1.2 Circulation, vorticity, divergence and deformation

- Vorticity and circulation; Bjerknes' circulation theorem with interpretations;
- Divergence of the three dimensional and horizontal wind field;
- Vorticity and divergence equations in co-ordinate systems with pressure as independent variable; discussion of the order of magnitude of the various terms;
- Introduction of the stream function and velocity potential - Helmholtz theorem; streamlines and trajectories.

3.3.1.3 Static stability

- Equilibrium stratification of mass in the gravity field; pure gravity oscillation; stable, unstable and neutral stratification.

3.3.1.4 The circular vortex

- The stationary circular vortex; the thermal wind relationship; stable, unstable and neutral conditions; elementary treatment of stability criteria.

3.3.1.5 Dynamics of meso-scale phenomena

- Sea breezes;
- Mountain-valley winds;
- Thunderstorms and tornadoes;
- Urban winds.

3.3.1.6 Atmospheric turbulence and diffusion

- The nature of turbulent flow; the turbulent diffusion equation; flow near a boundary; the mixing-length hypothesis; velocity profile near a boundary (smooth surface, rough surface); vertical plumes in the surface boundary layer; power-law profiles; the vorticity transport hypothesis; statistical theories of turbulence; Lagrangian-Eulerian relations;

- Eddy transport of momentum, heat, water vapour and pollutants in the planetary atmospheric boundary layer; the Taylor-Ekman theory of the vertical variation of the wind in the boundary layer;

- The heat flux equation and the problem of convection; Richardson criterion; forced and free convection; plumes and bubbles;

- Spectrum of atmospheric turbulence;

- Diffusion: K-Theory approach, Taylor's theorem, Richardson's law, application to air pollution meteorology.

3.3.1.7 Atmospheric waves

- The elements of linear perturbation theory; compressibility waves; gravity waves; internal and external gravity waves; the importance of the boundary conditions; rigid and free surfaces;

- Inertia waves; inertia stability; calculation of the inertia circle; combined gravity-inertia waves;

- Barotropic waves (Rossby waves);

- Elementary treatment of baroclinic waves.

3.3.1.8 The general circulation of the atmosphere

Observational studies

- A description of the mean state of the atmosphere and its variation with the seasons; distributions of the zonal wind and the zonal temperature field as a function of latitude and pressure; the latitudinal, vertical and seasonal variation of the intensity of atmospheric disturbances; definition of zonal and eddy quantities; algebra of average values and the associated fluctuations; distinction between stationary and transient disturbances.

Momentum heat and water balance

- The time variation of absolute and relative angular momentum; the meridional transport of relative angular momentum by atmospheric disturbances; the convergence of the momentum transport and its importance for changes in the mean zonal wind; the importance of the mean zonal winds;

- The maintenance of the mean zonal temperature field; the meridional transport of sensible and talent heat by atmospheric disturbances; the convergence of the eddy heat transport and its importance for changes in the mean zonal temperature field; the importance of the mean meridional circulation for changes in the mean zonal temperature field; temperature changes caused by the zonal heat sources and sinks;

- Global water circulation; evaporation; precipitation; transport and divergence of the transport.

Energetics of the atmosphere

- Definition of kinetic, potential and internal energy; the proportionality between potential and internal energy in quasi-static flow; the concept of available potential energy; conservation theorems;

- Derivation of the kinetic energy equation for a finite volume, in particular in a zonal ring; transport of kinetic energy in the meridional and vertical direction;

- The maintenance of temperature variance in a finite volume, in particular a zonal ring; the importance of horizontal and vertical heat transports;

- General treatment of atmospheric energetics considering available potential energy and kinetic energy in their zonal and eddy forms and their interaction.

3.3.1.9 Numerical weather prediction

- General principles of objective analysis;

- Models of large-scale atmospheric motion systems: scale analysis of atmospheric motions; the filtering of scales of motions without meteorological significance such as external gravity waves and the short internal gravitational and inertial waves;

- Balance motions: horizontally balanced motions; motion with no tangential acceleration; gradient wind relation; geostrophic wind relation; comparison of geostrophic and gradient winds with actual winds; the divergence and the velocity of the geostrophic wind; the geostrophic thermal wind; deduction of the blance equation from the divergence equation; simplified forms; the balance equation as a generalization of the geostrophic and gradient wind relations;

- The barotropic and equivalent barotropic model;

- Baroclinic model: PE and filtered equations.

3.3.1.10 Laboratory work

- Numerical computation of map factors and of geostrophic winds from height data given in grid points; static stability computations; barotropic and elementary baroclinic forecasts by the relaxation and graphical method, etc.

3.3.2 Synoptic meteorology

In these suggested outlines no syllabus relating to organization and historical development of meteorological services, and technical aspects of communication systems has been given with the thought that this material is appropriate for on-the-job training whithin the various national Meteorological Services.

Where a high speed computer facility is available or analyses and prognoses from such a facility are available, laboratory exercises should include interpretation and use of numerical weather prediction prognoses.

Availability of the products of a Meteorological Service is assumed to broaden the student's experience through contact with a large number of weather situations in real time. It is difficult otherwise to obtain a feel for the processes and problems of forecasting.

3.3.2.1 The synoptic data

- Surface, upper-air and special observations; satellite data; radar; spherics, etc.; representation and analysis of fields of meteorological elements.

3.3.2.2 Pressure and wind field

- Geostrophic wind, gradient wind, cyclostrophic wind, friction wind; change of wind with height (thermal wind); vertical structure of pressure systems as a function of the temperature field; relationships with the temperature advection (hodograph); barotropic and baroclinic stratification; ageostrophic wind components; stream-lines and trajectories; divergence; circulation and vorticity.

3.3.2.3 Air masses, fronts, jet streams

- Air masses (formation, properties, transformation); fronts and frontal zones (equilibrium conditions); model of the polar front; system of jet streams; frontogenesis and frontolysis; vertical motions on fronts; classification of fronts.

3.3.2.4 Synoptic systems

- Life cycle of cyclones; thermal structure of cyclones; cyclone families; cut-off lows; three-dimensional trajectories in moving pressure systems; wave spectrum of the upper wind field; short and long waves; principle of steering; index-cycle; blocking; intensification waves; convective weather systems.

3.3.2.5 Development of cyclones and anticyclones

- Review of earlier development models; application of the pressure tendency equation; divergence field at sinusoidal isohypses

(Bjerknes-Holmboe model); application of the vorticity equation to the development problem; diagnostic relationships in the quasigeostrophic system (use of the omega equation); development theories of Sutcliffe and Petterssen; importance of vorticity advection, temperature advection and diabatic heat transformations; orographic effects; relationship with changes in the long wave pattern; energetics of cyclogenesis; baroclinic instability.

3.3.2.6 Synoptic climatology

- Jet stream and frontal climatology; long waves; blocking;
- Air mass climatology; mean position of cyclones and anticyclones for different seasons; mean tracks of cyclones and anticyclones;
- Grosswetterlage.

3.3.2.7 Tropical meteorology

- Streamline analysis; easterly waves; monsoon circulation; convective systems; tropical disturbances, tropical waves, tropical depressions, tropical storms, tropical cyclones, hurricanes/typhoons.

3.3.2.8 Synoptic weather analysis

- Surface analysis; analysis in constant pressure surfaces and other surfaces; method of construction of the analysis (starting from the surface analysis, through the thickness charts to the thigher standard isobaric surfaces); cross-section analysis.

3.3.2.9 Meso-scale analysis

- Convection systems; local winds and other weather phenomena.

3.3.2.10 Weather prediction

- Short- and medium-range forecasting using numerical weather prediction model output with background knowledge of traditional synoptic and dynamic methods. Emphasis on the interpretation and use of numerical prediction output in forecasting. Long-range forecasting; objective analysis and numerical weather prediction; prediction of individual weather elements using combined statistical dynamic methods. Forecast evaluation.

3.3.2.11 Satellite applications and other modern techniques

- Application of satellite imagery both in the visible and infrared spectral regions for the analysis and interpretation of weather systems. Determination of vertical distribution of temperature and moisture from

satellite measurements. Availability of synoptic data from special observing systems like buoys, constant level balloons, remote weather stations, aircraft, etc.

3.3.2.12 Laboratory exercises

- Practical work in synoptic laboratory is a necessary part of the course of instruction. This should cover a wide range of methods of analysis and prediction. Emphasis should be placed on use and interpretation of numerical prognoses in forecasting.

3.3.3 Physical meteorology

3.3.3.1 Radiation in the atmosphere

- Basic black body laws; definition of terms and units used in radiation; the exponential extinction law; absorption; Rayleigh and Mie scattering; the solar constant; transmission of solar radiation in the atmosphere; effects of clouds; surface albedo; sky radiation; empirical formulae for solar radiation at surface; instruments used for measuring solar radiation; spatial and temporal distribution of solar radiation over the earth including astronomical factors; origin and nature of long-wave radiation in the atmosphere; simple discussion of spectral lines, line shape, bands, effects of pressure and temperature and band models; absorption and emission by water vapour; carbon dioxide and ozone; radiation charts; effects of clouds; nocturnal or net radiation and empirical formulae; diurnal and annual variations of the radiative balance; the heat balance of the earth and atmosphere; principles of radiative sensing of vertical structure of the atmosphere from artificial earth satellites; variation of ozone and its use as an atmospheric tracer; radiative processes in the stratosphere and mesosphere.

3.3.3.2 Meteorological optics

- Refraction of electromagnetic radiation in the atmosphere; microwave ducting, optical mirages as examples; review of the geometric optics of reflection, refraction and diffraction; applications to rainbow, halo, mock sun, sun pillars, glory, corona; transparency of the atmosphere; the visual range; turbidity and its measures.

3.3.3.3 Water substance in the atmosphere

- Solid, liquid and gaseous phases of water; saturation vapour pressures over liquid/solid; specification of water substance in atmosphere; relative, specific, etc., humidity; liquid/solid water content; variation of humidity with height; evaporation; con densation; sublimation at (a) earth's surface, (b) suspended particles; formation of fog, mist and cloud; classification of clouds; precipitation; types and classification; snow cover, properties; melting and evaporation; broad features of water cycle in the atmosphere.

3.3.3.4 Cloud micro-physics

- Nucleation of the liquid phase from the vapour; condensation nuclei, their properties and distribution in time and space; growth of cloud drops and ice crystals by diffusion, snow crystal habit; size, number, fall speed of drops and crystals; limit on diffusional growth and need for precipitation mechanisms; Bergeron-Findeisen process; coalescence of cloud drops; growth of warm rain; formation of graupel and hail, growth of precipitation in convective, stratiform and orographic clouds; icing of aircraft; artificial modification of clouds; critical assessment of techniques for stimulation of rain, prevention ofhail, dissipation of fog and cloud.

3.3.3.5 Atmospheric electricity

- The fair-weather electric field of the atmosphere; ions and ionizing radiations; the conduction current; world-wide aspects of the diurnal variation of electric field and conductivity; observational aspects of thunderstorm electrical properties; theories of thunderstorm electrification; the lightning discharge; thunderstorms as a mechanism for maintaining the fair-weather electric field.

3.3.4 Statistics and thermodynamics of the atmosphere

- Atmospheric pressure and its variation with altitude; geopotential and the geopotential metre; the hydrostatic equation, its importance in meteorology; height of a pressure surface and thickness of a pressure layer; altimetry; barometric pressure and its precision; the standard atmosphere;

- Additional thermodynamics: second law of thermodynamics; general statement and meaning; reversible transformations; statement and implications of the law; one and two-source cycles; Carnot's theorem; thermodynamic temperature scale; entropy; irreversible transformations; statement of the law; Clausius's inequality and non-compensated heat; entropy; evolution of an isolated system; degradation of the energy of a system;

- Consequences of the two laws: thermodynamic potential; Gibbs's equations; chemical potential, application to ideal systems; mixtures of perfect gases (moist air) and dilute solutions; thermodynamic and chemical equilibrium; displacement from equilibrium; change of phase; interphase equilibrium; heat of change of phase; Clapeyron's equation; lag in change of phase; dilute solution; osmotic pressure; Van't Hoff's law: chemical equilibrium between a solution and the solid phase of the solvent; electrolytic solutions; phase rule; Nernst's and Le Chatelier's laws: capillary systems, application to water drops (Kelvin's law) and to ice crystals; steam and internal combustion engines; efficiency; Watt's indicator; refrigeration; jets and nozzles;

- Thermodynamic systems in meteorology: dry air; liquid water; water vapour; ice; non-saturated moist air; aqueous clouds; ice clouds;

clouds formed of water droplets and ice crystals; thermodynamic properties of water in its three phases and the changes of phase; properties of dry air and moist air; virtual temperature;

- Adiabatic transformations of dry and moist air; potential temperature; wet-bulb temperature and the psychrometric formula; equivalent temperature; wet-bulb pseudo- potential temperature and pseudo-potential equivalent temperature; dew-point temperature and its variation with altitude; dry and saturated adiabatic lapse rates; Clausius-Clapeyron equation; mixing of the masses of moist air;

- Aerological diagrams; diagrams equivalent to Clapeyron's diagrams; choice of a diagram; use of diagrams in synoptic meteorology;

- Stability of vertical dry and moist air; stability criteria and instability criteria; conditional instability and latent instability; the parcel and slice methods and a comparison of the two; convective flow in the atmosphere; importance of relief; diurnal variation of stability and convection;

- Precipitable water; quantitative precipitation forecasting; latent heat relationship; the thermodynamics of the hail stage; energy changes on the thermodynamic diagrams; stability changes and large-scale vertical velocity fields; entrainment during convection; the bubble theory of penetrative convection.

3.3.5 Climatology

3.3.5.1 General climatology: The physical basis of climate

- Definition of climate; branches of climatology;

- Components of the climatic system: atmosphere, oceans, cryo spheres, land masses, biomass;

- Astronomical and geographical controls on climate: solar emission; influence of latitude; environmental influences; effects of the distribution of sea and land; effect of water bodies; continentality; man-made effects.

3.3.5.2 Instruments and methods of observation

See Section 3.3.9 "Meteorological instruments and methods of observation".

- Climatic elements: temperature, precipitation, wind, pressure, humidity, sunshine duration, radiation, visibility, cloud amount; instruments and methods of observation for the various climatic elements;

- Remote-sensing data: satellite and radar.

3.3.5.3 Climatological networks

- Classification of stations, planning of stations networks; information relating to stations; establishment and equipment of stations; maintenance of stations.

3.3.5.4 Physical climatology

- Radiation and energy balance: solar constant; radiation laws; factors affecting radiative fluxes in the atmosphere: absorption, reflection, scattering and transmission; global, terrestrial and net radiation; energy and heat balance;
- Hydroclimatology: hydrologic cycle; water balance components - distribution and variability;
- Soil heat transfer.

3.3.5.5 Dynamical climatology

- Climatological aspects of dynamic meteorology: general circulation - definition and controls; global pressure patterns; surface wind fields; major wind systems; monsoons, westerlies, hurricanes, upper winds;
- Climate forecasting.

3.3.5.6 Synoptic climatology

- Climatological aspects of synoptic meteorology: air masses, weather types and fronts; tropical disturbances - geographical distribution and impact.

3.3.5.7 Upper-air climatology

- The atmosphere: its nature, composition and properties; pressure variation with height;
- Extent and structure of the upper levels: troposhere, stratosphere, mesosphere, ionosphere and exosphere.

3.3.5.8 Climatic classification

- Principles of climatic classification;
- Classical schemes; other recent classifications.

3.3.5.9 Regional climatology

- Climatic controls;

- Major global climates: monsoon, marine, continental, arid and semi-arid, arctic and polar, highland.

3.3.5.10 Meso- and microclimatology

- Definition and scope of micro-, meso- and topoclimatology;
- Mesoclimatology: lake/sea and land breezes, mountain and valley breezes, Foehn winds; types of meso-environments; energy and water balance processes;
- Microclimatology: vertical temperature, humidity and wind profiles in the boundary layer; influence of ground surface on the microclimate; flow of heat into the ground; factors affecting soil temperature.

3.3.5.11 Climatic change and variability

- Theories of climatic change and variability; evidence for climatic change; trends and periodic fluctuations; man-made influences;
- Climatic modelling.

3.3.5.12 Climate methods and statistics

- Elements of probability; description of population by means of frequency distributions; stochastic elements of climate; estimation problems; test of hypothesis; relationships problems; use of climatic probabilities in forecasting;
- Climatic maps and diagrams; differences in analyzing synoptic and climatic maps;
- Numerical analysis.

3.3.5.13 Data processing methods

- Climatological data handling: decoding reports; checking and quality control; presentation of data and products; storage and retrieval of climatological data; catalogues of data; inventories of stations including station history; organization of data files;
- Computers and programming: use of computers in climatology; computer operations; programming languages.

3.3.5.14 Applied climatology

See also Section 9.1.14 "Applied climatology".

- Definitions and methodologies for applying climatological data and information to climate-sensitive activities; value of climatological information;

- Selected examples from such fields as: agriculture, building and engineering, energy, fisheries, forestry, human health and comfort, industry and commerce, recreation and tourism, transportation and communications, water resources.

3.3.6 General hydrology

- Introductory material: definitions and relations of hydrology to other sciences; the hydrological cycle; physical characteristics of the watershed; variability and randomness of hydrological phenomena;
- Precipitation: determination of amounts, intensity and duration, spatial and temporal distribution; measurement and accuracy; estimation of missing data;
- Evaporation and evapotranspiration: determination by measurement and by computations; the energy and mass transfer approaches; evaporation from water surfaces, soil, snow and ice; transpiration; total evaporation and total losses; evaporation control;
- Infiltration: soil moisture; laws governing infiltration; measurement; empirical formulae;
- Groundwater: origins and occurrence of groundwater; types of aquifer; interrelation between groundwater and surface water; depletion; water-table fluctuations; movement of groundwater;
- Surface run-off: elementary hydrograph; types of run-off; depression storage, overland flow, surface detention; unit hydrograph;
- Water balance: calculation of yield; short-term and long-term variations; water balance of lakes, swamps, watersheds and regions;
- Hydrometry: various methods of measuring water-levels, velocities and, solid and liquid discharges; storage and processing of data.

3.3.7 General oceanography

- Description of the marine environment; sea water, physical and chemical properties;
- General circulation of the ocean; the currents;
- Climatology of energetic exchanges between the ocean and the atmosphere;
- Developing equations describing oceanic movement;
- Ocean-atmosphere dynamic interactions; geostrophic hypothesis;
- Theory of the general circulation;
- Periodic movements of the sea: swell and tides.

3.3.8 Interaction of the ocean and the atmosphere

- Energy exchange - anomalies and resultant temperature patterns; sea-air heat exchange; heat budget of the oceans and its components; physical models; effect of wind and cloudiness; diurnal and seasonal variability of meteorological elements; land breeze and sea breeze; feed-back physical model;

- Representativeness, availability and deficiencies in existing air and sea data; water mass boundaries and their influence on air mass and frontal systems; formation of the thermocline;

- Dynamics of the upper ocean layer; upwelling; subsidence; divergence and convergence; seasonal overturning;

- Physical characteristics of sea water and air in relation to air-sea interaction processes (e.g., heat capacity, etc.);

- Wave measurement; analysis and prediction - structure and spectrum of ocean waves; data acquisition; platforms and methods; adequacy of data; sea, swell and total waves; wave trains; relationships between wind and wave - period, height and length; effect of duration of wind, fetch and water depth; wave analyses; wave refraction; breaker depth and height; wave prediction;

- Currents - tidal, wind and inertia; currents due to density differences; mass transport by waves; water levels; influence of atmospheric pressure on water levels; storm surges;

- Ice formation and break-up; satellite observations; general description of controlling factors.

3.3.9 Meteorological instruments and methods of observation

Making use of and interpreting meteorological data constitute the primary objective of all work undertaken by meteorologists Class I. It is thus reasonable that such meteorologists should be familiar with the various meteorological instruments and methods of observation used to obtain these data, and in particular with those which are used to explore the upper-atmosphere. Only in this way can meteorologists be in a position to have a precise idea of the accuracy of the data in question and of the inherent sources of error in the observations. The syllabus which follows is thus given for training all Class I meteorologists.

3.3.9.1 General

- Instrumental and non-instrumental observations; a general knowledge of instruments and methods of observation; basic principles of measurements made in meteorology; concept of scale; synoptic scale and local scale; units and constants; difference between an analogue and digital value, general characteristics of meteorological instruments and the conditions they should satisfy; standardization of instruments and methods of calibration.

3.3.9.2 Surface observations

- General study of the principles of operation; scales; characteristics of construction; conditions of exposure; accuracy of readings; sources of error; instrumental errors; zero error; errors due to inertia (time of response); tolerance; errors of observation; systematic error; error due to digitizing; order of magnitude of the total error in various types of instruments used to measure the following elements: atmospheric pressure, temperature and humidity, surface wind, radiation and insolation, precipitation and evaporation, cloud base, visibility, atmospherics.

3.3.9.3 Upper-air observations - general introduction

- Methods of upper-air soundings; notions concerning the particular technical features of sounding equipment; analysis of a sounding and plotting the results on an aerological diagram; use of the diagram; methods of sounding by pilot balloon and by sounding balloon; general remarks; rate of ascent and performance of balloons; pilot balloons; sounding balloons; tethered balloons; constant level balloons, etc.

3.3.9.4 Measurement of upper-wind

- Basic measurements; principles of the methods which can be used; methods by observing a pilot balloon by theodolite, radio-theodolite; the method of primary radar; radar targets (reflectors); the method of secondary radar; methods using radio-navigation systems; errors in upper-wind measurements: relationships between the vectorial errors of the wind and the random errors of observation; accuracy and correctness respectively of the various methods; constant level balloons.

3.3.9.5 Upper-air measurements by radiosonde

- Basic measurements; minimum performance required; accuracy required; main types of radiosonde; calibrating radiosondes; errors in radiosoundings; errors in the measurements of pressure, temperature and humidity; basic equipment for radiosonde stations; analysis of the measurements; special applications of the techniques of radiosoundings; constant level sounding balloons; dropsondes.

3.3.9.6 Application of the techniques of upper-air sounding to the measurements of physical meteorology

- Measurement of the vertical distribution of ozone; ozone sondes; electrochemical, chemical with luminescence, and optical sondes; measurement of short- and long-wave radiative fluxes in the atmosphere; radiometric sonde; measurement of short- and long-wave radiation on aircraft; total radioactivity of the air; radioactivity sondes; vertical distribution of the parameters associated with atmospheric electricity; soundings of the potential gradient; sondes for measuring conductivity; sondes for measuring the air-ground currents; errors in these sondes.

3.3.9.7 Measurements by meteorological rocket

- General characteristics of sounding rockets; measurement of pressure, density, temperature, the composition of the atmosphere, wind speed, turbulence, and solar radiation.

3.3.9.8 Meteorological satellites

- Use of satellites for observations and meteorological research; observing cloud movements by television; measurement of the radiation balance of the Earth-atmosphere system; measurement of the albedo and of infra-red radiation; thermal sounding of the atmosphere; radio-meteorological research; measurement of the vertical distribution of ozone, errors in satellite data.

3.3.10 Meteorological data processing

Meteorological data processing is an essential component of the world-wide WWW plan. It is the instrument whereby theories of the atmosphere and its motions can be put to practical use for the benefit of society as a whole.

Computer systems are becoming more and more common as an aid to weather services and they are gradually taking over many tasks previously performed by hand. In the future therefore automatic data processing will play a dominating role in weather Service. In this light all Class I meteorological personnel should have an adequate knowledge in meteorological data processing.

Those working with research in meteorology can apply their theoretical knowledge to the real atmosphere and contribute to the development of numerical models of the atmosphere. Class I personnel involved in more practical fields in weather services can apply their knowledge of data processing to special operational problems and thus contribute to a more efficient service.

3.3.10.1 Computers and programming

This item is covered essentially by paragraph 3.2.1.6 but special attention should be paid to the following:

- Computers: storage principles; central processing unit; main storage; secondary storage; input and output devices;

- Programming: computer instructions; stored programme concept; assembler and procedure-oriented languages; compilers;

- The principles of operating systems.

3.3.10.2 Numerical weather analysis and prediction

- General principles of data assimilation.

(The rest of this item is covered by paragraph 3.3.1.9 of "Fundamental meteorological education" in "Dynamic meteorology".)

3.3.10.3 Meteorological data handling

General principles of meteorological data handling by computer methods including:

- Decoding of meteorological reports;
- Checking and quality control of meteorological reports;
- Presentation of meteorological data and products;
- Storage and retrieval of meteorological data.

3.3.10.4 Laboratory work

The specifications in paragraph 3.3.1.10 should be supplemented by, for instance: hydrostatic checks of TEMP reports, interpolation from grid values to curves and verification of numerical forecasts.

3.3.11 Satellite meteorology

This item is covered in paragraph 3.3.2.11.

- Satellite applications and other modern techniques.

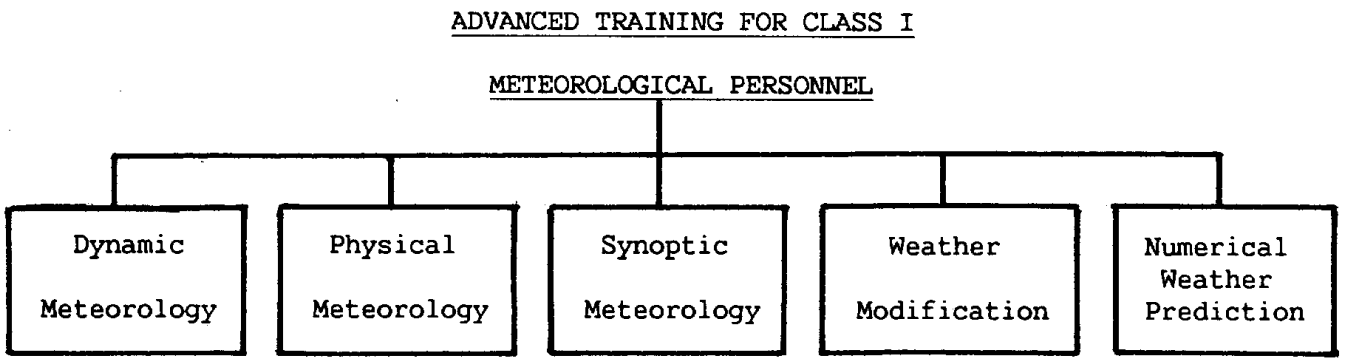
3.3.12 Air pollution meteorology

- Definition of air pollution; history of air pollution problems;
- Sources: natural, anthropogenic; primary and secondary pollutants; emission inventory;
- Transport and turbulent diffusion: scales (micro, meso, synoptic, global); diffusion applications, e.g., ground level concentration fields, etc.;
- Removal processes: atmospheric chemical transformations: dry and wet deposition; WMO global background air pollution monitoring network;
- Effects: air quality criteria (physical, climatological, chemical, biological, aesthetics, etc.;
- Predictions: climatological, statistical and synoptic; air quality simulation techniques.

CHAPTER 4

ADVANCED TRAINING

FOR CLASS I METEOROLOGICAL PERSONNEL


ADVANCED TRAINING FOR CLASS I
METEOROLOGICAL PERSONNEL
Dynamic Meteorology
Physical Meteorology
Synoptic Meteorology
Weather Modification
Numerical Weather Prediction

4.1 GENERAL

Specialization in dynamic, physical and synoptic meteorology will normally occur only at the research level. The syllabi in sections 4.2, 4.3 and 4.4 respectively below indicate the advanced training required in each of these fields to equip personnel for research work. In addition, sections 4.5 and 4.6 indicate the syllabi for advanced courses in weather modification and numerical weather prediction respectively for Class I meteorological personnel.

4.2 ADVANCED DYNAMIC METEOROLOGY (CLASS I)

A characteristic feature of the development of the natural sciences is the steadily increasing use of numerical theoretical investigation methods. In meteorology, in particular, this process has been very rapid, especially as regards the general laws governing atmospheric motion, their theory being part of the study of dynamic meteorology.

The programme has therefore been divided into two parts - the first part deals with the classical studies of the analytic solutions of simple models of the atmosphere, including the structure of baroclinic waves on a model with a constant shear basic current. More realistic and therefore more complex models require the use of numerical methods. These are dealt with in the second part of the programme. Here the method is applied in two directions: as a tool for weather prediction or as a tool for research. In the second case it should be kept in mind that numerical solutions provide numerical results but not physical explanations. The researchers should therefore take the numerical results as the starting point for the physical study of the processes involved.

This method of investigation has been called numerical experimentation. At the present time, numerical experiments are used to study a very wide variety of atmospheric processes, from general atmosphere circulation to small-scale processes of a local nature. Numerical experiments are used to investigate not only atmospheric dynamics but also other atmospheric processes. Recently, the numerical experimental method has also come to be used in the solution of problems in applied meteorology, agriculture, building, aeronautics, and so on.

In particular, several important developments have occurred in the field of dynamic meteorology over the last few years.

(a) Objective analysis: the techniques for objective numerical weather analysis developed since the mid-fifties in several parts of the world have been adopted by weather services to such an extent that the standard synoptic weather map analysis carried out by the professional meteorologist now plays a minor role in many countries. It is, therefore, of the highest importance that meteorologists using such objective weather map analyses should understand the principles underlying the analysis procedures. The standard procedures applied in weather map analysis are therefore included in the syllabus given below.

(b) Numerical weather prediction: numerical weather forecasts of height, temperature and wind fields, including vertical velocity, are now available to many meteorological forecasting offices throughout the world. Clearly, the user of numerical forecasts must know how they

are prepared in order to make use of them in his particular region. It is therefore essential that the graduate student receives a thorough grounding in numerical weather prediction techniques, including the detailed analysis of the possible sources of error inherent in such a forecast.

(c) Simulation models of the atmosphere: during the last decade, great progress has been made in simulating long-term developments in the atmosphere by means of numerical models, which are in fact very similar to the most advanced short-range prediction models. A description of the models, and the results obtained from their use are therefore included in the syllabus for dynamic meteorology.

4.2.1 Hydrodynamics

The syllabus given in section 3.2.2.4 should be expanded as follows:

Dynamics

- Small disturbances and their propagation in fluids with mass and velocity stratification; stability studies of linear models: two and three layer models with density discontinuities (Helmholtz waves); waves on a single layer shear flow (Kelvin waves); two and three layer models with shear discontinuities (Rayleigh waves); combination of shear and density discontinuity effects on the wave motion; models with continuous variations of density and velocity profiles;

- Small disturbances and their propagations in rotating fluids - inertial effects;

4.2.2 Formulation of basic equations

Section 3.3.1.1 should be supplemented as follows:

- Equations of quasi-hydrostatic motion using potential temperature or density as vertical co-ordinate - the equation of motion in co-ordinate systems;

- The continuity equation in co-ordinates other than pressure; homogenous and incompressible fluid.

4.2.3 Energetics of the atmosphere

Section under 3.3.1.8 should be expanded as follows:

- Conversion and transport processes with reference to pressure averages and corresponding fluctuations;

- The selective role of the various scales of atmospheric motions in the energy processes; the generation, conversion and transfer of energy as a function of wave number.

4.2.4 Atmospheric wave motion

- Short wave lengths (ray theory); analysis of the propagation of stable gravity, acoustic and Rossby waves in a variable basic state; fundamental oscillation; Eigen modes of model atmosphere; atmospheric tides.

4.2.5 The circular vortex

- Symetric perturbations of a circular vortex; the stability tensor; application of calculus of variation and other methods to reduce the stability criteria; meridional circulations generated by heat and momentum sources and sinks.

4.2.6 Barotropic stability

- Horizontal motion on a sphere of an inviscid non-divergent fluid; stable and unstable distribution of the vorticity field.

4.2.7 Baroclinic stability

- Baroclinic waves on a basic current which is a linear function of height; stabilizing influence of the static stability on short waves and of the b-effect on long waves; various models.

4.2.8 Mountain waves

- Lee waves; short and long waves.

4.2.9 The theory of turbulence

- Atmospheric and oceanic turbulence; the occurrence of turbu lence; the energy equation for turbulence; the spectrum of turbulence; local similarity theory; the maintenance of Reynolds stresses; turbulence in the surface layer; entrainment; characteristics of two- and three-dimensional turbulence.

4.2.10 Numerical methods

4.2.10.1 Quasi-geostrophic models

- Integration of quasi-geostrophic models: Formulation of the equivalent-barotropic model; the equivalent barotropic model; vertical velocity and divergence in the equivalent-barotropic model; formulation of multi-level models, in particular the two-level model; the modifications of the equations due to the map projections; finite difference approximation in space and time for the quasi-geostrophic equations; the horizontal grid distance; spectral methods, comparison of finite-difference method and spectral method; the time step; truncation errors; method of solution of Laplace; Poison and Helmholtz equations by iterative methods; Liebmann procedure; extrapolated Liebmann procedure; over-relaxation factors: filters designed for special purpose such as eliminating almost all short-wave noise; investigation of the typical errors in quasi-geostrophic forecasts, in particular errors due to the neglect of topographic effects; energy sources and sinks; frictional dissipation and erroneous boundary conditions; consideration of the performance of ultra-long waves in quasi-geostrophic forecasts, in particular the equivalent barotropic in determining the speed of very long waves; the effects of mountains, friction and heat sources and sinks; incorporation of a moisture parameter in a numerical prediction model for precipitation forecasts;

- The stability properties of the two-level quasi-geostrophic models; derivation of explicit formulae for the real and imaginary parts of the phase speed; the neutral or critical stability curve; a calculation of the amplification rate of purely baroclinic disturbances.

4.2.10.2 Integration of the non-geostrophic equation for quasi-static models

- Quasi-static formulation of a non-geostrophic model in adiabatic and frictionless flow; the numerical stability problem (in particular the length of the time in relation to the grid size); finite difference formulations of the non-geostrophic equations on a map projection; a comparison of the baroclinic stability problem for the non-geostrophic equations and the quasi-geostrophic equations.

4.2.10.3 Numerical simulation of the atmospheric circulation

- The formulation of numerical models in simulating the general circulation; integration over very long time periods; descriptions of the performance of the experiments; initial states; time developments of the flow; zonal and eddy flow; the energetics of the numerical methods; comparison between the energetics of the models and the energetics of the real atmosphere; problems of parameterization and limits of predictability;

- Detailed treatment of various general circulation models;

- Numerical methods of long-range forecasting;

- Numerical simulation of meso-scale flow.

4.2.10.4 Objective weather map analysis

- The purpose of objective analysis; procedure used by a numerical prediction unit; analysis by surface fitting over small regions; operational objective analysis; the use of numerical forecasts as a first guess; the use of height and wind data in height analysis in the middle and high latitudes; balance of wind and mass fields; geostrophic adjustment; balance in lower latitudes; weighting functions, empirical and idealized; optimum interpolation; application of normal charts or other climatological information; analysis in data sparse regions; the estimation of upper-air data from surface data over oceans; various methods of objective analysis; comparison of objective and conventional analysis; synoptic and asynoptic data; concept of initialization; four-dimensional data assimilation and analysis.

4.2.10.5 Laboratory models of atmospheric circulation

- Rotating tanks, tornado models, low speed wind tunnels, etc.

4.2.11 Laboratory work

To familiarize the students with the various techniques used in numerical models, a laboratory course should be introduced to solve exercises. In order to perform the problem without excessive hand calculations it is advisable to have access to a medium size electronic computer.

4.3 ADVANCED PHYSICAL METEOROLOGY (CLASS I)

4.3.1 Basic radiation laws

- Rayleigh-Jeans law; review of quantum theory of radiation; Planck distribution law, Wien's displacement law and the Stefan-Boltzmann law; Kirchoff's law and its dependence on thermodynamic equilibrium; the black body and the grey body; the exponential relation of Bouguer; absorption, scattering and extinction coefficients.

4.3.2 Scattering in the atmosphere

- Rayleigh scattering, its angular distribution and polarization; Mie scattering, its angular distribution and polarization; Raleigh scattering and geometric optics as limiting cases of Mie scattering; molecular scattering in the atmosphere; scattering by the typical atmospheric aerosol; scattering by absorbing particles and the effects of absorption in the gaseous medium; scattering by non-spherical particles; multiple scattering.

4.3.3 Solar radiation and its disposition

- Solar physics as related to solar radiation; photosphere, reversing layer and Fraunhofer lines, chronosphere, corona sunspots, flares, faculae; the solar constant and methods for its determination; the solar spectrum outside the atmosphere; the solar wind and corpuscular emissions; critique on the variability of solar emissions; transmissivity of the atmosphere as a function of wavelength and its decomposition into absorption and scattering; astronomical and geometric factors; diffuse or sky radiation as a result of multiple scatter in a Rayleigh atmosphere and modifications due to the aerosol; scattering and absorption by clouds as computed from multiple scattering theory and the observed albedo and transmissivity; empirical formulae for the effect of clouds; the temporal and spacial distribution of global, diffuse and direct beam solar radiation; surface albedos; the planetary albedo on the earth and comparisons with albedos of other planets; the vertical variation of absorption in the atmosphere;

- Atmospheric aerosols: definition of aerosols; stratospheric and tropospheric abundance, horizontal and vertical profiles; typical concentration levels in different scales of background and local pollution; variation with time; physical and chemical nature and composition; distribution by size, number, mass, aerodynamic properties; natural and anthropogenic sources; physical and chemical formation and transformation; resuspension; life cycles, rainout, washout and other removal processes; short term effects of aerosols and their constituents; particular physical and chemical determinations; properties of samples and measure ment equipment; modes and frequency of sampling and their relation to representativity of observations;

- Interpretation of radiation data obtained from meteorological satellites.

4.3.4 Long wave or terrestrial radiation

- Introduction to the theory of spectra; electronic lines; vibrational and rotational modes and their interaction; infrared bands of the triatomic molecules; survey and identification of the principal absorption bands of the atmosphere; spectral line shapes and dependence on temperature and pressure; foreign gas and selfbroadening; limits on applicability of Kirchoff's law and relaxation emissions band models of Landerburg and Reiche, Elsasser, Goody; observations of band absorption and fit of band models; pressure scaling and the Curtis-Godson approximation; derivation of the radioactive transfer equation; numerical and graphic methods for determining radiative fluxes and the vertical flux divergence; methods of treating band overlap; effects of clouds; emissivity of the surface; net radiation at the surface and empirical formulae; instruments for long-wave radiation; the determination of the vertical distribution of temperature and water vapour from observations of long-wave radiation taken by artificial satellites.

4.3.5 Radiative and heat balances

- Diurnal variation of radiative and heat balances at the surface; annual and seasonal radiation balance of the earth atmosphere and in the atmosphere; radiative balance in troposphere and stratosphere and implications relative to tropopause; radiative processes in the mesosphere.

4.3.6 Ozone

4.3.6.1 Stratospheric ozone

- Observational information on geographical and temporal variations of total ozone and on its vertical distribution; absorption and emission bands of ozone; photo-chemical theory of ozone and comparison of theoretical and observational distributions; effects of vertical and horizontal circulations on ozone distribution and correlations between ozone and weather systems; stratospheric ozone depletion mechanisms (halocarbons, N_2O, supersonic transport (SST), nuclear testing, etc.); radiative effects of ozone, the sharp lower limit of the UV solar spectrum at the surface and the radiative contribution to the tropopause; ozone destruction near the surface; ozone as an atmospheric tracer; measurements of ozone by Dobson spectrophotometer, ozone sondes, Umkehr method, from satellites and during solar eclipse.

4.3.6.2 Tropospheric ozone

- Abundance; variations in time and space; background and impact level concentrations; influence of atmospheric circulation systems on concentration; ozone precursors; chemical and photo-chemical formation and mechanisms of depletion; short-term effects of ozone on solar radiation and possible long-term effects of concentration changes; measurement of ozone by chemical and optical, direct and remote procedures (by chemiluminescense, sondes, spectrophotometry).

4.3.7 Physics of the upper atmosphere

- Composition and structure; standard atmosphere;
- Solar radiation; absorption in the upper atmosphere; absorption spectra of N_2, O_2, O_3, etc.;
- Energy exchange by collisions;
- Transport processes: (mean) circulation; eddy transport;
- Model atmospheres; photochemical equilibrium; the effect of transport processes on a model atmosphere;

- Atmospheric tides;
- The ionosphere; composition and general properties; observa tional methods;
- Aurora and air glow;
- Noctilucent clouds; nacreous clouds.

4.3.8 Cloud physics

- Thermodynamic-kinetic theory of nucleation; homogeneous and heterogeneous nucleation; condensation nuclei and their properties; Kohler curves; observational methods and results on size and concentration of condensation nuclei; maritime and conti nental nuclei spectra; sources of condensation nuclei; homoge neous nucleation of ice in water; heterogeneous nucleation of ice and properties of ice nuclei; sublimation nuclei, crystal lattice, epitaxy, bonding forces; strain, steps, dislocations, adsorption; observations of natural ice-forming nuclei and evidence of their nature; ice crystal habit in relation to temperature and supersaturation; equations for diffusional growth of drops and crystals; effects of shape and fall speed; computation of evolution of cloud drops from nuclei; comparison with observed cloud drop spectra and possible explanations; computations of growth of ice crystals and comparison with observations; limits on size of cloud drops and ice crystals attainable by diffusional growth; the two major precipitation processes and computations to show conditions required for each and particle sizes attained; conparison with observed sizes; the coalescence of drops; collection efficiency; effects of electric fields and charges; disruption of rain drops and the Langmuir chain reaction; growth by accretion in the form of ice-graupel and hail; clumping of snow crystals; melting of snow and hail; evaporation of liquid drops; observational data on the characteristics of precipitating clouds; evidence on the occurrence of ice in natural clouds; the release of precipitation from convective clouds, from stratiform clouds, from orographic clouds; artificial modifications of the precipitation process on the basis of the foregoing; the artificial dissipation of fog and low cloud.

4.3.9 Radar meteorology

- Basic principles of microwave radar; wavelengths; antenna factor; peak power; pulse length; pulse repetition rate; scanning modes; polarization; methods of presenting data; calibration techniques; propagation and attenuation of microwaves in the atmosphere; back-scatter of microwaves from hydrometeors on the basis of Rayleigh and Mie theory; convective precipitation as seen by radar and deductions; the radar first echo; radar echoes of hail and tornadoes; stratiform precipitation on radar; the bright band and rain versus snow; cellular structure of stratiform precipitation; the hurricane as seen by radar; the use of Doppler radar for measuring horizontal

and vertical motions; the pulse integrator and the "R" meter; isoecho contouring circuits; automatic data handling systems; the measurement of rain-fall by radar; the Z-R relationships from observed rain-drop spectra; comparison of rainfall observed by radar with that from raingauge networks; millimetre radars for observations of non-precipitating clouds.

4.3.10 Atmospheric electricity

- The fair weather electrical structure of the atmosphere; ionizing radiation and the formation and recombination of small ions; general orientation on the ionosphere (full discussion should be given under upper atmosphere); large or Langevin ions; method of formation, mobilities, variation in time and space; electrical conductivity of the air and its variations; the air-earth current; gross electrical structure of the thunderstorm and methods of observation; the space charge; shielding of cloud charge; observed electrical properties of non-thunderstorm clouds; charge on blowing snow and triboelectric effects; rate of charge separation in thunderstorms from observations; theories of thunderstorm electrification and comparison of their possible charging rates with observations; the lightning discharge; stepped leader, dart leader, main stroke, repetitive strokes; observational evidence of time sequence of events in discharge, quantity of charge in a stroke, peak current and waveform, time between strokes, fraction of total strokes to ground; discussion of the physics of the lightning stroke; thunder; its origin and propagation; the thunderstorm as a mechanism for maintaining the earth-atmosphere charge; vertical electric current above a thunderstorm; estimates of the total number of thunderstorms required and that observed; the diurnal variations of the electric field in universal time and its implications; electric charge on hydrometeors; corona discharges; lightning strikes on aircraft; instruments for the measurement of atmospheric electrical parameters.

4.4 ADVANCED SYNOPTIC METEOROLOGY (CLASS I)

4.4.1 The kinematics of horizontal motion

- Field of horizontal motion represented by zonal and meridional components and by direction and speed; features of the field of flow: troughs; ridges; singular points; axes of confluence and diffluences; relation between streamlines and trajectories in moving features of the field of flow; divergence, relative vorticity, and deformation in cartesian co-ordinates and in natural co-ordinates; stream function and velocity potential.

- Laboratory exercises: analysis of isogons, streamlines and isotachs for a selected synoptic case; sample measurements of divergence, relative vorticity and deformation; discussion of effects of error in the wind measurement; sample construction of trajectories; calculations of stream function and velocity potential for a given wind field.

4.4.2 Relationships between wind, pressure, and temperature fields

- The geostrophic and thermal wind; acceleration and geostrophic departure; gradient and cyclostrophic winds; balance of forces in the surface friction layer; the Ekman spiral; the balance equation; the slope and modification of pressure systems with height; thickness and temperature fields; advection of thickness and temperature by the geostrophic wind;

- Laboratory exercises: analysis of height and thickness fields for various pressure levels for a selected synoptic case; sample calculations of geostrophic and gradient winds and comparison with observed winds; sample calculations of thickness and temperature advections associated with cyclonic and anticyclonic systems; calculation of balance wind for a given pressure field.

4.4.3 Fronts and frontogenesis

- Discontinuities of zero, first and second order; relationships between pressure and temperature fields in the vicinity of frontal discontinuities; kinematics of frontogenesis; the horizontal confluence effect and the effect of vertical motions; characteristics of the frontal structure in surfaces, cyclones and in upper-level troughs; theories of frontogenesis in linear fields of motion and numerical models; dynamics of fronts;

- Laboratory exercises: analyses of cases of frontogenesis in the lower and in the upper troposphere; analyses of frontal structure in vertical cross-sections; sample frontogenetical calculations;

4.4.4 Quasi-geostrophic diagnosis

- The thickness tendency equation; the effects of advection, adiabatic heating and cooling; the quasi-geostrophic vorticity equation; the effects of advection and divergence; the geopotential tendency equation;

- Applications: steering of short waves by large scale flow; deepening and filling of ridges and troughs due to field of temperature advection; steering of shallow cyclones and anti-cyclones by upper-level flow;

- Association of vertical motion with fields of vorticity advection and temperature advection; orographic vertical motion and orographic cyclogenesis; vertical motions generated within the surface friction layer; the so-called Omega equation;

- The effects of adiabatic heating;

- Conditions for surface cyclogenesis;

- Distribution of geopotential tendency and vertical motion for idealized

cyclonic and anticyclonic systems and for jet entrance and exit regions;

- Laboratory exercises: diagnostic calculation of geopotential tendencies and vertical motions for a selected synoptic case; qualitative application of concepts to analysis from operational forecast centre.

4.4.5 Prediction models for large-scale flow

- Equivalent barotropic model based on vorticity equation; limits of applicability; control of ultra long waves;
- Barotropic model using primitive equations; motions defined by filtered and primitive equations; initialization problems (see 4.4.10);
- Primitive equation model for several levels; representation of physics;
- Formulation of models for short-range and medium-range forecasting and for extended predictions related to general circulation;
- Laboratory exercises: critical appraisal of circulation forecasts prepared at operational centres.

4.4.6 Prediction of subsynoptic and meso-scales, by statistical and probability methods

- Techniques of selecting predictors;
- Regression methods; use of numerically predicted flow patterns;
- Formulation of stochastic models based on primitive equations, closure problems;
- Monte Carlo methods;
- Forecast probability statements.

4.4.7 Prediction of surface temperature

- Relation of surface temperature to thickness;
- Effects of heat transfer between atmosphere and surface of earth;
- Effects of wind in the turbulent boundary layer: effects of cloud cover;
- Laboratory exercises: practice forecasting of surface temperature; critical appraisal of objective forecasts prepared at operational forecast centres.

4.4.8 Predictions of cloudiness and precipitation

- Morphology of cloud systems; use of satellite information;
- Statistical relationship of cloudiness and precipitation to large-scale circulation parameters;
- Dynamical models for large-scale humidity prediction: statistical relationship of cloudiness and precipitation to large-scale humidity;
- Cumulus convection; stability indices; relationship to large-scale vertical motion; structure of instability lines and meso-scale circulations; use of radar information;
- Fog: radiation, advection, upslope and frontal types; geographical and temporal distribution;
- Laboratory exercises: analysis of patterns of cloud, precipitation and humidity for a selected synoptic case; graphical prediction of large-scale moisture field; meso-analysis of a selected case of severe convection phenomena; practice forecasting of cloud and precipitation; critical appraisal and use of objective forecasts prepared at operational forecast centre.

4.4.9 Analysis and prediction in low latitudes

- Structure of circulation features; low-level easterlies and high-tropospheric vortices; monsoon circulation; intertropical convergence zone; wind information from satellite data;
- Tropical storms; geographical and temporal distributions; structure and evolution; statistical and dynamical prediction of tracks; numerical models of tropical storm development;
- Laboratory exercises: analysis of a selected synoptic case with tropical storm activity; application of satellite information; sample statistical and dynamical prediction of storm track.

4.4.10 Objective analysis

- Data available for analysis and their accuracy;
- Interpolation methods; surface fitting, scanning and regression methods; weighting factors;
- Analysis at fixed time; introduction of asynchronous data;
- Quasi-continuous analysis; dynamical data assimilation; statistical data assimilation;

- Error structure and control;
- Initialization; static initialization; dynamic initialization; initialization by statistical methods;
- Laboratory exercises: critical appraisal of objective analysis by comparison with observations and manual analysis.

4.4.11 Forecast verification and evaluation

- Measures of forecast skill and forecast utility; use of climatology and persistence as control forecasts;
- Statistical analysis of probability forecasting and analysis;
- Present level of forecasts skill for various elements as a function of time range;
- Limits of predictability;
- Laboratory exercises: verification and evaluation of practice forecasts.

4.5 ADVANCED COURSE ON WEATHER MODIFICATION (CLASS I)

The need to optimise agricultural productivity and overall economic efficiency by preventing meteorological disasters makes it necessary to consider weather modification as one area of importance. Due to the financial implications and the hitherto limited success, all weather modification projects need careful study, preparation and checking by meteorologists with an advanced training in all aspects of weather modification. Parts of such an integrated course already exist in the advanced training programme. However, new aspects need to be considered. The major components of an advanced weather modification course are:

(a) Special synoptic aspects;
(b) Cloud microphysics;
(c) Cloud dynamics;
(d) Weather modification theory;
(e) Design and evaluation of weather modification experiments and operations;
(f) Observational systems and techniques;
(g) Technology of weather modification; and
(h) Other related topics.

4.5.1 Special synoptic aspects

- Identical with section 4.4.8, "Prediction of cloudiness and precipitation".

4.5.2 Cloud microphysics

- Identical with section 4.3.8 "Cloud physics", excluding the part on weather modification.

4.5.3 Cloud dynamics

- The fundamental equations of cloud dynamics: for fluid motion, continuity of dry air, continuity of water substances, the gas law, the first law of thermodynamics for air/water mixtures, the kinetic equation describing the evolution of particle spectra; basic concepts of convection: thermal, puff, jet, plume; 1-dimensional (1-D) models, entrainment; pressure perturbations and limits of 1-D models; Kessler's parameterization concept; 2-D models of clouds, the anelastic assumption, cylindrical and slab symmetry; the modelling of orographic, air mass and squall line storms; the use of sophisticated microphysics involving particle size distributions and supersaturation situations; sensitivity studies; the treatment of turbulence and eddy viscosity; electrical effects; critique of 2-D models; boundary conditions and mesoscale influences; 3-D modelling; general computational aspects of modelling; comparison of models and real clouds; general problems in modelling.

4.5.4 Weather modification theory

4.5.4.1 Principal approaches to weather modification by changes of:

- Particle concentrations (supply of cloud condensation nuclei, ice nuclei, water droplets); particle growth processes (enhancement of nucleation, condensation, sublimation, collision/collection, and breakup); or bulk properties of clouds or air (buoyancy, drag, electrical fields).

4.5.4.2 Fog dispersal

- Physical model of the formation and dispersal of cold fog; methods and means (cooling agents like dry ice and propane, seeding);

- Physics of formation and dispersal of warm fog; methods and means (hygroscopic substances, heat, surfactants);

- Other fog dispersal methods (acoustic, electric, and with lasers).

4.5.4.3 The enhancement of rain and snow

- The inducement of warm rain mechanism by: seeding with giant nuclei; spraying of droplets; increasing the buoyancy (by heating); enhancing the breakup process (by release of surfactants); physical modelling;

- Dynamic seeding of convective clouds with ice nuclei to enhance cloud growth; cloud merger; physical modelling;
- Seeding of frontal clouds;
- Seeding of layer clouds;
- Seeding of orographic clouds; physical modelling; targeting of artificial precipitation;
- Redistribution of precipitation;
- Extra area (down wind and up wind) effects.

4.5.4.4 Hail suppression

- Rationale of hail suppression; competition and glaciation concepts;
- Modelling of possible suppression effects.

4.5.4.5 Moderation of tropical cyclones

- Possibilities of reduction in wind damages;
- Reduction of storm surges;
- Reduction of rainfall;
- Possible effects of cyclone moderation on climate.

4.5.4.6 Other types of weather modification

- Prevention and fighting of forest fires, lightning, flooding; disintegration of clouds, etc.

4.5.5 Design and evaluation of weather modification experiments and operations

- Experiments vs operations; desired effect of weather modification activity; type of operation (filling of reservoirs and irrigation or precipitation when needed);
- Cloud climatology; occurrence of clouds, cloud characteristics including microphysics;
- Natural variability;
- Assessment of success chances;
- Effects on economy and society;

- Planning of the measurement of success or failure of projects (like changes in precipitation and its pattern);
- Statistical designs of experiments: historic, target-control, cross over, randomized single area, floating target;
- Significance tests, t-test, α-test, Wilcoxon signed rank test, Wilcoxon-Mann-Whitney test, squared rank test, covariates;
- Stratification and partitioning of data according to meteorological situations and physical measurement;
- Classical vs. Bayesian statistics;
- Selection of statistical evaluation procedures, implications for measuring network;
- Discussion of actual statistical evaluation of weather modification experiments;
- Weather modification operations not requiring statistical evaluation;
- Discussion of such cases.

4.5.6 Observational systems and techniques

- Radar meteorology (same as in paragraph 4.3.9);
- Mesoscale observational networks;
- Networks to measure precipitation;
- Aircraft platforms for dynamic and microphysical measurements;
- Instruments (nucleus counters, liquid water content measuring devices, droplet and drop size measuring devices, ice particle counters, impactors, temperature and pressure sondes, inertial platforms for divergence measurements; electrical field mills, charge sensors, etc.);
- The use of satellite data.

4.5.7 Technology of weather modification

- Nuclei generators;
- Dry ice crushers;
- Propane nozzles;
- Other equipment. Delivery systems for nucleating or drag creating devices (rockets, shells, flares);

- Large system requirements (aircraft, radar, radiosondes, networks); budgeting of equipment and manpower.

4.5.8 Other related aspects

- Agricultural aspects of weather modification (precipitation requirement of crops, crop compatibility);
- Hydrological and soil problems (water storage and drainage, runoff, etc.);
- Overall economic assessment of weather modification activities;
- Ecological aspects (effects on wild life, pollution, etc.);
- Societal concerns, public relations;
- Legal aspects (liability, insurance, national and international agreements and treaties).

4.6 ADVANCED COURSE IN NUMERICAL WEATHER PREDICTION (CLASS I)

4.6.1 Basic dynamic meteorology

- Equations of motion in rotating spherical co-ordinates, scale analysis, b-plane approximation, geostrophic wind, thermodynamic equation, continuity equation, thermal wind, vorticity and divergence equations. Wave solutions of primitive equations: Rossby waves, gravity waves, sound waves;
- Filtering of vertical sound waves: hydrostatic approximation;
- Filtering of gravity waves: quasi-geostrophic approximation;
- Baroclinic instability in a two-layer model, comparison between quasi-geostrophic and Rossby-mode instability curves.
- Barotropic instability: shear instability and nonlinear wave-wave instability;
- Energy conversions in different types of instabilities, definitions of APE, KE, zonal and eddy parts;
- General nonlinear properties: energy and enstrophy cascades, inherent error growth and limit of predictability.

4.6.2 Physical processes

- Parameterization problem;

- Boundary layer theory: K-theory, Ekman-layer, Monin-Obukhov theory, closure problem, surface processes, sensible heat transfer;
- Convection and clouds: different parameterization schemes (Kuo, Arakawa-Schubert, Sundqvist);
- Radiation: radiative transfer, spectral structure of emission, absorption and scattering, cloud-radiation feedback.

4.6.3 Numerical methods

- Finite difference approximations in space and time;
- Time stepping, CFL instability, truncation, damping and phase errors;
- Boundary value problems, relaxation methods, eigensolutions;
- Vertical co-ordinate systems: pressure and sigma co-ordinates;
- Implicit, semi-implicit and split-explicit methods, staggered grids;
- Spectral representations, finite elements.

4.6.4 Objective analysis and initialization (data assimilation)

- Theory of stochastic processes, probability distributions;
- Statistical structure of meteorological fields; variance and spatial autocorrelation;
- Observational techniques: radiosondes, satellites (temperatures and winds), constant level balloons, buoys; characteristic errors;
- Optimum interpolation method (univariate and multivariate), polynomial fitting, spline interpolation method, empirical orthogonal functions, variational methods;
- Elimination of erroneous observations; spatial interpolation methods, spatial comparison methods, time interpolation methods;
- Balancing mass and wind fields; nonlinear balance equation and its relation to the gradient wind equation, elliptic and hyperbolic regions.
- Linear and nonlinear normal mode initialization, comparisons with quasi-geostrophy and balance equation;
- Four-dimensional data assimilation, continuous and intermittent; observational networks.

4.6.5 Forecasting models

- Examples of general circulation models and global forecasting systems (GFDL model, GLAS model, ECMWF model). Evaluation and verification of model performance. Idealized experiments (removal of topography, doubling of CO_2, etc.). Interpretation of model output by statistic-dynamic methods. Limited area modelling, nested grids. Mesoscale models, models for tropical cyclones, air pollution models.

4.6.6 Laboratory sessions

- Examples and exercises to be solved on a computer are to form an integral part of the course. Examples can be taken from all sub-sections of the course, for instance: baroclinic instability of two-layer model, numerical integration of one-dimensional advection equation, predictability experiments with simple recursion formulae (Lorenz type), relaxation problem, optimum interpolation of three observations with multivariate techniques, linear balance equation with idealized mass fields, diffusion model with point and line sources.

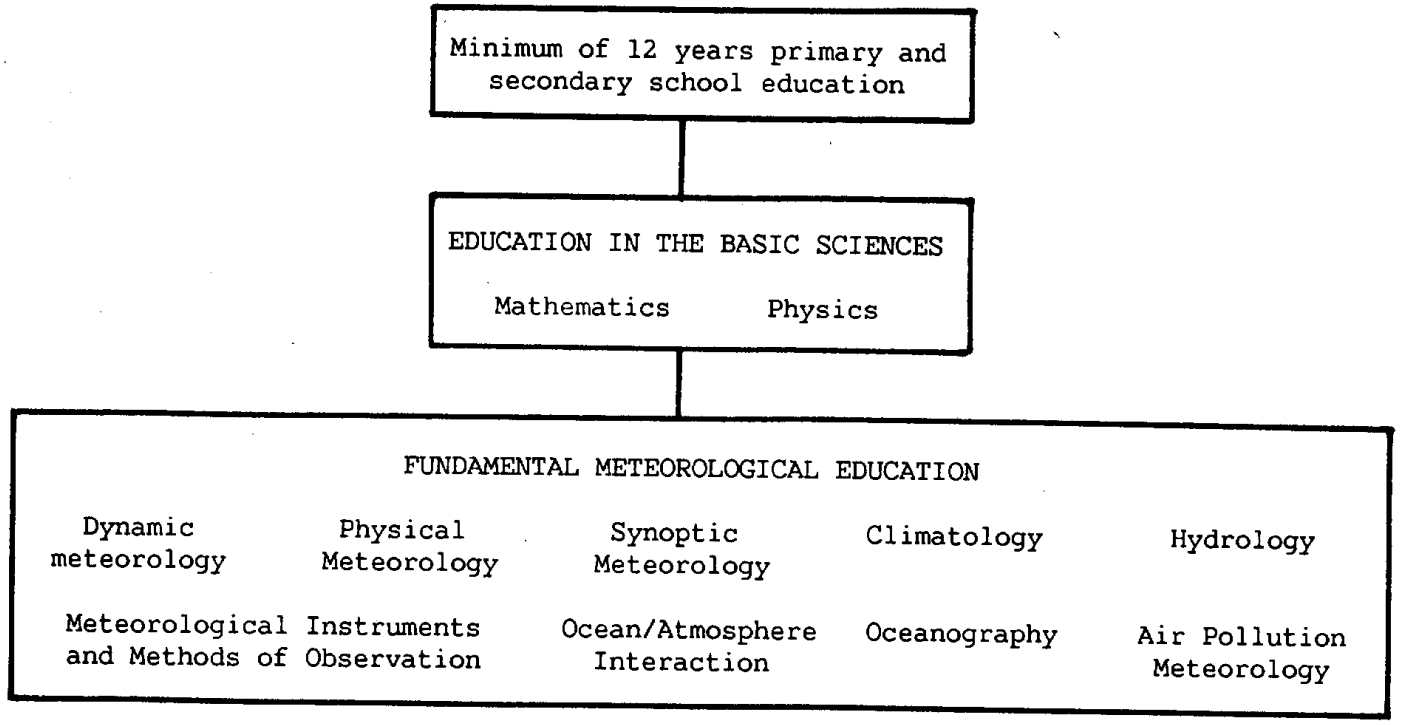
INDEX

CHAPTER 5

CURRICULA FOR TRAINING ALL CLASS II METEOROLOGICAL PERSONNEL IRRESPECTIVE OF THEIR FIELDS OF SPECIALIZATION AND SPECIALIZATION IN SYNOPTIC METEOROLOGY (CLASS II)

CURRICULA FOR TRAINING CLASS II METEOROLOGICAL PERSONNEL

(Schematic representation of contents)



5.1 GENERAL

Class II meteorological personnel must exercise skill and judgement in the interpretation of meteorological data. They must have a thorough understanding of the underlying meteorological principles; their education must be broadly based but, since their work is concerned mainly with application of meteorological knowledge, the emphasis should be on practice. The Class II syllabi, although just as extensive in many respects, will consequently not contain the same amount of theory as that for Class I. This is an important factor which should be borne in mind by instructors in connexion with the syllabi given below.

In the syllabi for the basic sciences, those parts of the general subjects which are considered prerequisites for meteorological training at Class II level, namely mathematics and physics, are emphasized. As a general principle, it is recommended that the instruction in these subjects be confined to those fields which are essential for that level.

As has already been stated elsewhere, in many Meteorological Services Class II personnel are engaged mainly in forecasting. Consequently, to train personnel for fields such as meteorological data processing, climatology or meteorological instruments, it may be necessary to adjust the syllabi given - which are primarily based on forecasting - by placing more emphasis on certain aspects at the expense of others. The extent of such alterations is of course a matter for decision by the training institution.

Class II meteorological training is often carried out at Centres where a well-established mathematics or physics institution does not exist. In such cases the instructors should have at their disposal detailed syllabi and it is for this purpose that in the following paragraphs syllabi for mathematics and physics are given in detail.

5.2 EDUCATION IN THE BASIC SCIENCES (CLASS II)

5.2.1 Mathematics

5.2.1.1 Algebra

- Permutations and combinations; binomial theorem;
- Arithmetic and geometric progressions; calculations of the nth term; sum of the first n terms;
- Infinitely large and infinitely small quantities; limit of a variable; limit of a function; operations on limits;
- Calculation of a limit - examples: elementary knowledge of the continuity of a function; algebraic functions.
- Real numbers; complex or imaginary numbers; conjugate imaginary numbers; graphical representation of complex numbers; modulus; arguments; formula $x + iy = x(\cos\alpha + i \sin\alpha)$;

- Limits; sequences; convergence and divergence of sequences; series; convergence and divergence of series; criteria of convergence of series of positive terms deduced from the study of:

$$U_{n+1}/U_n,\ n/U_n,\ n \propto U_n$$

absolutely convergent series; alternating series; limit of

$$(1 + \tfrac{1}{n})^n \quad \text{and} \quad (1 + \tfrac{x}{n})^n$$

where n is infinite; the number e; Napierian logarithms; series defining the exponential function e^x and the inverse function lgx; the hyperbolic functions; function defined by a complete series in x with real coefficients; interval of convergence; addition and multiplication within this interval; expansion of:

$$l\,(1 \pm x),\ \lg(1 \pm x) \text{ and } \lg\{(1 - x) / (1 + x)\}$$

exponential series e^x and a^x; binomial series; expansion of circular functions; hyperbolic functions and their inverses; the complex variable $z = x + iy$; functions e^z, sin z, cos z; relations

$$e^{x + iy} = e^x\, e^{iy} = e^x\, e^{iy} = e^x\,(\cos y + i \sin y);$$

hyperbolic sines and cosines, their relation to ordinary sines and cosines.

- Determinants and systems of linear equations: solution of 2 or 3 linear equations; definition of a determinant of order n; interchange of rows and columns; interchange of two columns or two rows; expansion, removal of factors; sum of determinants; addition of columns and rows; rank, systems of n linear equations in n unknowns.

5.2.1.2 Solid analytic geometry

- Solid analytic geometry: co-ordinate systems in space; the distance between two points in space; direction numbers or direction components of a line; parametric equations of a line; direction angles; direction cosines; equation of a plane in space; conditions under which two planes are parallel, coincide or are perpendicular; the "normal form" of a plane in space; quadratic surfaces in space as represented by the equation

$$Ax^2 + By^2 + Cz^2 + Dxy + Exz + Fyz + Gx + Jz + K = 0$$

- Cylindrical co-ordinates; spherical co-ordinates.

5.2.1.3 Spherical trigonometry

- Introduction to spherical trigonometry; spherical triangle; pro perties of spherical triangles; formulae relating to right spherical triangles; Napier's rules; solution of right spherical triangles; isosceles and quadrantal spherical triangles; oblique spherical triangles; the law of sines; the law of cosines for sides; the law of cosines for angles; formulae for the tangents of the half angles; formulae for the co-tangents of half the sides; areas of spherical triangle; areas of

a spherical triangle; brief description of the applications of spherical trigonometry.

5.2.1.4 Differential and integral calculus

Much greater emphasis should be given to the practical aspects of the subject and the applications to meteorology.

- Concept of a function of a variable and of a continuous function; concepts of limit, derivative and infinitesimals, principal part, first differential of a function; elements of length, area and volume in various systems of variables; derivatives of the functions of a function; derivatives of the common functions:

$$x^m \ (m \quad 0),\ \sin x,\ \ldots\ \text{arc sin } x,\ \ldots\ e^x,\ a^x,\ \lg_e x/\lg_a x;$$

derivatives of a compound function; application of the concept of derivative; slope of a curve at a point, tangent at that point; study of the variation of a function; extremes of a function; maximum and minimum meaning of the sign of the second derivative; curvature; inflection;

- Function of a variable; Rolle's theorem on finite increments; graphical representation; function of two independent variables; graphical representation using a surface; function of several variables; partial derivatives; formulae for finite increments; application to error calculation; higher order derivatives of a function of several variables;

- Taylor's theorem for functions of one and several variables and its application; convergence of the Taylor series and the remainder of the series; MacLaurin's formula; application of Taylor's theorem to the study of the quotient of two functions of x in the neighbourhood of a given value of x; case where the two functions of x are zero for this value; other forms of indeterminacy; rate of change of e^x and lg x compared to that of x^m; determination of the limit of

$$e^x/x^m \text{ for infinite x and of } x^m \lg x \text{ for } x = 0$$

- Implicit functions; Jacobians; change of independent variables;

- Concept of the primitive functions; Riemann definition of an integral; indefinite integral; integration of rational functions and of some special common functions; integration by parts and by change of variable; definite integrals; theorem of the mean; mean values of a function in an interval; limit of definite integrals when a limit of integration approaches infinity or when the function under the integral sign becomes infinite; rule for differentiation under the integral sign and differentiation of definite integrals; line integral; circulation of a vector; double integrals (flux of a vector across a surface) and multiple integrals;

- Numerical calculation of definite integrals; length of a curve; areas and volumes; calculation of the moment of inertia and of the co-ordinates of the centre of gravity;

- Exercises in differential and integral calculus.

5.2.1.5 Vector algebra and vector calculus

- Introduction; definitions; addition and substraction of vectors; magnitude of a vector; scalar time vector; applications to geometry; scalar product of two vectors; unit vectors; direction cosines; direction numbers; orientation in space; vector product; scalar triple product; vector triple products; vector identities; vector functions of one variable; derivative of a vector function; velocity vector; application of vectors in mechanics; vector fields and scalar fields; the gradient field; divergence of a vector; curl of a vector.

5.2.1.6 Differential equations

This subject should be considered as a course of applied mathematics. All matter relative to partial differential equations should be reduced to a strict minimum. Emphasis will be given primarily to the subject's practical aspects. Numerous examples should be taken from meteorology with particular reference to atmospheric disturbances.

- Ordinary differential equations: equations of the first order and degree; integral curves; equations of higher degree; equations of second and higher order; linear equations; a brief description of how the ordinary differential equations could be solved in series, in particular in the Taylor and Fourier series.

- Partial differential equations: linear partial differential equations of first and second order in two independent variables; the wave equation in one dimension; the vibrating string; normal modes of vibration and heat equation.

5.2.1.7 Probability theory and statistics

- The statistical method and its scope; presentation of data; population and sample; discrete and continuous variables; frequency distributions; histograms; cumulative frequency distributions; ogives; vectorial frequency distributions; wind roses;

- Elementary probability theory; statistical parameters of central tendency, mean, median, mode; quintiles; statistical parameters of variability, range, mean deviation, standard deviation and variance; coefficient of variation; moments, skewness and kurtosis;

- Theoretical frequency distributions; the binomial distribution, the normal distribution, the Poisson distribution; transformations and probability papers;

- Sampling theory; sampling distributions, Central Limit Theorem, standard error; estimation of parameters, confidence intervals and limits; tests of hypothesis and significance;

- Small sampling theory; Student's test; Chi-square test;

- Curve fitting; scatter diagrams; method of least squares; linear regression, scatter about a regression line; the linear correlation

coefficient, covariance, significance of the correlation co-efficient; multiple regression, multiple and partial correlation;

- Analysis of variance; the F test;
- Extreme value distributions; return period;
- Time series, trends, moving averages; harmonic analysis; autocorrelation and spectrum analysis.

5.2.1.8 Numerical and graphical calculations

- Tabulation and differences;
- Interpolation; application of the method of least squares;
- Brief description of numerical differentiation and integration: numerical approximation of the derivatives of a function; graphical calculation; numerical approximation of definite integrals (Simpson's rule); graphical approximation of definite integrals; numerical approximation of double integrals;
- Machine computation: for those Class II personnel who will use numerical techniques in their work, a course on this subject should be organized. In view of the rapid advances which are taking place in construction of computers and the relatively wide variations in their types no suitable syllaby for such training could be included here. This is left to the instructors conducting such courses.

5.2.2 Physics

5.2.2.1 Kinematics

- Kinematics of a point: rectilinear and curvilinear motion; relative motion;
- Rectilinear motion: velocity, acceleration; uniform and accelerated motion, vibratory motion; simple harmonic oscillation and damped harmonic oscillation; superposition of simple harmonic oscillations;
- Motion referred to rectangular, polar, cylindrical and spherical co-ordinates;
- Kinematics of solid bodies: translation; rotation about a fixed axis; helicoidal motion;
- Change of reference systems: absolute and relative motion; entrainment; composition of velocities and accelerations (Coriolis theorem).

5.2.2.2 Electricity and magnetism

- Properties of magnets; static electricity; electric currents; electromagnetism; radio-electricity.

5.2.2.3 Optics

- Geometric optics: laws of reflection and refraction; index of refraction; plane and spherical mirrors; lenses, prisms; regular and diffuse reflexion; diffusion;

- Wave optics; theory of light; period, frequency and velocity of propagation; interference; diffraction; Doppler effect; polarization of light; velocity of light; phase and group velocity.

5.2.2.4 Hydrodynamics

- Fluid mechanics: fluid kinematics expressed briefly in Eulerian and Lagrangian variables; decomposition of a field of motion in the vicinity of one of its points into a field of translation, a field of rotation and a field of deformation; physical significance of vorticity and divergence; application to plane motion; continuity equation; case of gases and liquids, compressibility; ideal fluid, pressure force due to the pressure gradient; equations of state and of change of state of a fluid, perfect gas equation; surface tension of fluids, capillarity; barotropic and baroclinic fluids, isobarisostere solenoids; fluid equilibrium (hydrostatics), Pascal's law, Torricelli's experiment, barometer, Archimedes' principle and buoyancy; applications: hydrostatic equation along the vertical; altimetry, application to the atmosphere; fluid dynamics, Eulerian and Lagrangian motion equations, boundary and initial conditions; work-energy theorem, balance of mechanical energy (potential and kinetic energy); Bernouilli's theorem; vorticity and divergence; rotational form of the equations of motion; irrotational motion and two or three dimensional rotational motion; circulation and vorticity; absolute and relative circulation and vorticity; case of the barotropic fluid; cyclonic and anti-cyclonic circulation.

5.2.2.5 Thermodynamics

Emphasis should be laid on the applications to meteorology.

- Object of thermodynamics; thermodynamic system - definition, exchanges of energy and matter with the external world, closed and open systems; physical state of a system, variables of state, (p.v) systems, Clapeyron's diagram;

- Definition of temperature, temperature scales (Celsius, Fahrenheit, Kelvin); variables of state and the equation of state of a system; homogeneous and non-homogeneous systems; thermal expansion of solids, liquids and gases; case of gases - the laws of Boyle-Mariotte, Gay-Lussac, Avogadro and Dalton (gas mixtures); equation of state of a gas - perfect gas and Van der Waals' gas;

- Definition of heat, quantity of heat, calorie, thermal conductivity, specific heat, case of gases, heat of change of phase, heat of reaction (chemistry); calorimetry;

- First law of thermodynamics: various forms of energy (work, heat, electrical and chemical energy, etc.); principle of the conservation of

energy; principle of the equivalency of heat and work (Joule); statement and meaning of the first law in the cases of systems at rest and in motion (atmospheric air), in the cases of closed and open systems (clouds in the case of precipitation); case of systems in motion; consequences of the first law and of the kinetic energy theorem as applied to the system; internal energy, enthalpy; work accomplished by the expansion of an ideal fluid; reversible exchange of work and heat; calorimetric coefficients of a fluid; adiabatic transformation, case of the perfect gas.

5.2.2.6 Atomic and molecular physics

Recourse to equations and formulae should only be made where they are indispensable to the understanding of the subject matter; only the very simplest of such equations and formulae should be referred to.

- Concepts of the composition of matter; the molecule; the atom; structure of the atom; nucleus and electrons; ions;

- Atomic and molecular theory: atomic and molecular spectra; X-rays to infrared; continuous and discontinuous spectra; width of spectral lines; thermionic electrons; photoelectric effect; nuclear structure and elementary particles; natural radioactivity; X-rays; cosmic rays.

5.2.3 Chemistry

It is desirable that all Class II meteorological personnel possess some knowledge of chemistry. Since however chemistry forms part of the curriculum in practically all secondary school systems, students will normally have acquired sufficient basic knowledge of chemistry during their secondary school studies. A deeper knowledge of chemistry will only be required by those Class II personnel whose work is related to such subjects as atmospheric chemistry, radioactivity or air pollution. A broad outline of the knowledge likely to be required by such personnel is given below. In general, however, it is left to Instructors to decide on whether, and to what extent, chemistry should be a prerequisite to meteorological training.

5.2.3.1 General chemistry

- Introduction; basic laws of chemistry; structure of the atom and Mendeleiev's periodic system of elements; chemical bonds and structure of molecules; speed of chemical reaction; oxidizing-reduction processes; basic principles of electro-chemistry.

5.3 FUNDAMENTAL METEOROLOGICAL EDUCATION (CLASS II)

Class II meteorological training in the fields of dynamic and synoptic meteorology is essentially the same as that for Class I personnel. In principle, therefore, the syllabi for these subjects for both Classes should be the same (see sections 3.3.1 and 3.3.2). For Class II, however, topics should be taught with a view to their practical applications.

5.3.1 Dynamic meteorology

5.3.1.1 Formulations of basic equations

- Equations of motion in vector form as derived from Newton's second law; discussion of pressure force and gravitation; transformation from non-rotating to rotating co-ordinate system; discussion of centripetal acceleration and Coriolis force;
- The concept of gravity;
- Equations of motion in Cartesian co-ordinates (tangent plane approximation) and in spherical co-ordinates; orders of magnitude of various terms (based on observations) leading to the simplified equations;
- Introduction of the hydrostatic appoximation; justification of this approximation;
- Equation of quasi-hydrostatic motion using pressure as vertical co-ordinate;
- The continuity equation; Cartesian co-ordinates; pressure as vertical co-ordinate; homogeneous and incompressible fluid.

5.3.1.2 Circulation, vorticity, divergence and deformation

- Vorticity and circulation; Bjerknes' circulation theorem with interpretations;
- Divergence of the three dimensional and horizontal wind field;
- Vorticity and divergence equations in co-ordinate systems with pressure as independent variable; discussion of the order of magnitude of the various terms;
- Introduction of the stream function and velocity potential - Helmholtz theorem - streamlines and trajectories.

5.3.1.3 Balanced motions

- Horizontally balanced motion; motion with no tangential acceleration; gradient wind relation; geostrophic wind relation; comparison of geostrophic and gradient winds with actual winds; the divergence and the velocity of the geostrophic wind; the geostrophic thermal wind.

5.3.1.4 The circular vortex

- The stationary circular vortex; the thermal wind relationship; stable, unstable and neutral conditions; elementary treatment of stability criteria.

5.3.1.5 Atmospheric disturbances

This section should be reduced to its simplest form.

- Disturbances superposed on a state of hydrostatic equilibrium in the field of gravity - static stability; compressibility and gravity waves in the atmosphere; waves in a surface of discontinuous flow and discontinuous specific mass; disturbances superposed on a rectilinear flow; barotropic waves and cases of two-dimensional disturbances;

- Rossby long waves; brief description of the baroclinic waves and baroclinic instability.

5.3.1.6 General circulation of the atmosphere

- Angular momentum of the atmosphere about the earth's axis; relative and absolute momentum; balance of angular momentum; meridional transport by atmospheric disturbances; relation between this transport and zonal circulation; the balance of the atmosphere's kinetic energy; the role of baroclinicity; the energy cycle of the general circulation; influence of oceans, continents and large-scale orographic features on the general circulation.

5.3.1.7 Atmospheric turbulence

Reference should be limited to equations and formulae which are essential with particular emphasis on those employed in synoptic meteorology.

- The nature of turbulent flow; flow near a boundary; the mixing-length hypothesis; velocity profile near a boundary (smooth surface, rough surface); power-law profiles; the vorticity trans port hypothesis; statistical theories of turbulence;

- Eddy transport or momentum, heat and, water vapour and pollutants in the planetary atmospheric boundary layer; the Taylor-Ekman theory of the vertical variation of the wind in the boundary layer;

- The heat flux equation and the problem of convection; Richardson criterion; forced and free convection.

5.3.2 Physical meteorology

5.3.2.1 Composition of the atmospheric air

- Dry air and its composition: water vapour; carbon dioxide and ozone; properties of these gases, their distribution in space; weather and climate in relation to meteorological phenomena; the aerosols; atmospheric pollutants.

5.3.2.2 Phenomena of radiation in the atmosphere

- Radiant energy: emission and propagation; solar radiation both outside the atmosphere and within it; reflection, diffusion and absorption of solar radiation; direct solar radiation on the surface of the globe as a function of geographic latitude; time of day and season of the year; sky radiation, global radiation and sunshine duration; infra-red radiation of the earth-atmosphere system; temperature of the surface of the globe and temperature of the atmospheric air; long-term radiation equilibrium and thermal equilibrium of the earth-atmosphere system; radiation measurements from meteorological satellites.

5.3.2.3 Electrical and optical phenomena

- Electrical field of the earth; electrical conductivity of the atmosphere; atmospheric ionization; electrical currents in the atmosphere; electrical charges in clouds; electrical discharge in the troposphere;

- Atmospheric transparency; atmospheric turbidity; turbidity coefficient; visibility;

- Mirages, rainbows, halos, coronas and other optical phenomena.

5.3.2.4 Statics and thermodynamics of the atmosphere

- Dry air; liquid water; water vapour; ice; non-saturated moist air; aequeous clouds; ice clouds; clouds formed of water droplets and ice crystals; thermodynamic properties of water in its three phases and the changes of phase; properties of dry air and moist air; virtual temperature;

- Atmospheric pressure and its variation with altitude; geopotential and the geopotential metre; the hydrostatic equation, its importance in meteorology; height of a pressure surface and thickness of a pressure layer; altimetry; barometric pressure, its precision; the standard atmosphere;

- Adiabatic transformations of dry an moist air; potential temperature; wet-bulb temperature and the psychrometric formula; equivalent temperature; wet-bulb pseudo-potential temperature and pseudo-potential equivalent temperature; dewpoint temperature and its variation with altitude; dry saturated adiabatic lapse rates; mixing of the masses of moist air;

- Aerological diagrams; diagrams equivalent to Clapeyron's diagram; choice of a diagram; use of diagrams in synoptic meteorology;

- Stability of vertical dry and moist air; stability criteria and instability criteria; conditional instability and latent instability; the parcel and slice methods and a comparison of the two; convection in the atmosphere; the importance of relief; diurnal variation of stability and convection.

5.3.2.5 Cloud physics

- Cloud microphysics and precipitation microphysics; condensation of water vapour in the atmosphere; condensation nuclei; influence on the saturation pressure of water vapour, surface tension and solubility of nuclei in water; formation of raindrops and of ice crystals; cloud structure, size of drops and crystals; raindrop formation processes;

- Clouds: large-scale and small-scale cooling of moist air by adiabatic and non-adiabatic processes; stratiform clouds (up-draught of air on the synoptic scale); cumuliform clouds (small-scale up-draught); international cloud classification; genera; species and variety; cloud cover; radiation fog and advection fog;

- Frontal clouds; cloud systems and their classification;

- Current techniques on artificial stimulation of precipitation;

- Precipitation chemistry.

5.3.2.6 Snow and ice

- Snow cover and its properties; snow thawing; products of ground condensation and conditions of their formation.

5.3.3 Synoptic meteorology

This syllabus should be followed only by personnel working in fields other than synoptic and aeronautical forecasting. For the latter fields, additional material is given in section 5.4.

- The meaning of weather: the synoptic method;

- World weather network: surface synoptic network; upper-air network; ocean network; automatic weather station network; radar network; rocket network; satellite observations;

- Synoptic weather analysis: the concept of synoptic analysis; preparation of synoptic charts; symbols; drawing of isobars; synoptic representation of the pressure field; isobars on a level surface and contours on an isobaric surface; geostrophic wind; thermal wind; geopotential of isobaric surfaces and thickness of an isobaric layer; geometry and kinematics of surface isobars; contours of constant pressure; surfaces and thickness lines;

- Air masses: source characteristics and classifications; frontal surfaces and frontal zones; cold front, warm front and occluded front; patterns of the pressure field; patterns of the vertical component of the geostrophic vorticity and the flow patterns associated with them; air mass analysis;

- Outline of frontal disturbances: polar front waves; evolution of frontal depressions; occluded depressions; jet streams and their analysis; satellite cloud pictures and data as an aid to synoptic analysis;

- Elements of surface and upper-air analysis in low latitudes; monsoons and tropical disturbances;

- General circulation: the average fields of the atmosphere; the atmosphere as a circular vortex; the meridional profile of temperature; the meridional profile of pressure; the meridional profile of mass; the meridional profile of zonal geostrophic wind; the maintenance of the atmospheric field of temperature; the geographical distribution of net radiation; the principles of the general circulation; the budget of angular momentum in zonal rings;

- The normal fields of temperature and pressure at sea level: normal sea level isotherms and isobars in the Northern and Southern Hemispheres; zonal averages of sea-level temperature with two hemispheres; zonal averages of sea-level pressure in the two hemispheres;

- The normal three-dimensional fields of temperature and pressure in the Northern Hemisphere: the polar vortex; quasi-stationary disturbances superimposed on the polar vortex; the monsoon circulation; the quasi-permanent subtropical highs; the doldrum zone; surface-air and upper-air currents in the equatorial belt;

- Weather forecasting: progress of weather forecasting; scope and essential nature of the forecast problem; types of weather forecast-time, range, content and performance; forecasting techniques or aids - their merits and limitations; extrapolation techniques; kinematic methods; statistical methods; physical tech niques of forecasting the weather; approach to the problem of numerical weather forecasting;

- Laboratory exercises: surface and upper-air synoptic observations; special observations by means of electronic equipments; coding and decoding synoptic information; plotting of data on surface and upper-air synoptic charts; synoptic analysis of scalar functions on a plane; pressure field analysis; synoptic analysis of charts of isobaric surfaces; geopotential temperature and moisture; analysis of relative topographies between isobaric surfaces; isallobaric, isallophysographic and isallothermic charts; computations of geostrophic gradient and thermal wind; analysis of plotted thermodynamic and wind data; application of the various stability criteria (hydrostatic, slice method, convective stability, entrainment, etc.); analysis of surface and upper-air synoptic sequences for typical weather situations.

5.3.4 Climatology

5.3.4.1 General climatology, the physical basis of climate

- Definition of climate; branches of climatology;

- Components of the climatic system;

INDEX

- Astronomical and geographic controls of climate;
- Using climatology in the weather forecast office (supplying information, responding to requests, writing weather synopsis, aids in forecasting).

5.3.4.2 Instruments and observing procedures

- Instruments and methods of observation for the various climatic elements; remotely-sensed data, satellite and radar applications in climatology.

5.3.4.3 Climatological networks

Same as for Class I, section 3.3.5.3

5.3.4.4 Physical climatology

- Radiation, heat and energy balances; radiative fluxes; radiation instruments;
- Water budgets; distribution and variability of water balance components.

5.3.4.5 Dynamical climatology

- General atmospheric circulation; global and local wind systems; climate forecasting; extent and structure of the upper atmosphere.

5.3.4.6 Synoptic climatology

- Grouping of air masses; frequency of weather types; geographical distribution of fronts; frontal zones and air mass frequencies; frequencies of various types of storms and their motions; tropical disturbances, geographical distribution and impact.

5.3.4.7 Regional climatology

- Climatic controls;
- Climatic classification;
- Description of major global climates; climatology of the region or country where the training is given (qualitative description, data and maps).

5.3.4.8 Meso and microclimatology

- General principles; concepts and definitions; examples of micro and mesoclimates, and their controls; elementary introduction to micro-climatic observations and data interpretation;

- Urban environments: energy and water balances; urban-rural climatological differences.

5.3.4.9 Applied climatology

- General background on the application of climatology to various human activities (marine, transportation, food, water and energy); value of climate data and information;

- Selected examples from the region or country where the training is given using the outline suggested in Section 9.1.14, "Applied climatology".

5.3.4.10 Climate change

- Hypothesis of climatic change; evidence for climatic changes; man's effects on climate.

5.3.4.11 Climatic methods and statistics

- Climatic maps and diagrams: preparing maps and figures for analysis; analysing climatic maps;

- Emphasis on using and interpreting basic statistical concepts and tests: probability theory; descriptive statistics; common distributions and their characteristics; relationships between variables (climate and non-climate); time series analysis.

5.3.4.12 Data processing methods

- Machine processing of climatological data; decoding reports; checking and quality control; presentation of data and products; storage and retrieval;

- Computer applications in climatology; programming (principles and simple applications).

5.3.4.13 Climate services

- Use and limitations of normals; climatic anomalies;

- Extracting data from source documents;

- Summarizing and preparing data for publications;

- Communication skills.

5.3.5 Hydrology

Same as for Class I, section 3.3.6, "General hydrology".

5.3.6 Oceanography

Same as for Class I, section 3.3.7, "General oceanography".

5.3.7 Meteorological instruments and methods of observation

- General: general knowledge of instruments and methods of observation; basic principles of measurement in meteorology; the idea of scale; synoptic scale and local scale; choice of site for an instrument enclosure; precision of measurements and readings; procedures for installation, maintenance and checking of instruments; calibrating procedures; the WMO global background air pollution monitoring.

5.3.7.1 Surface observations

- Air temperature: thermometers and thermographs; mercury and alcohol thermometers; maximum and minimum thermometers; bimetallic thermometers and their time constants;
- Ground temperature: soil thermometers and thermographs;
- Atmospheric pressure: mercury barometers; aneroid barometers; hypso- meters; corrections and reductions to be applied to reading;
- Humidity: psychrometric measurements; naturally ventilated psychrometer; aspirated psychrometer; hair hygrometer; dewpoint hygrometer; use of psychrometric tables;
- Precipitation: raingauges and siphon-type recording raingauges; rates of rain-fall recorder; dew measurement; sampling for the determination of the chemical composition of precipitation;
- Evaporation: evaporimeter; evaporation pan;
- Speed and direction of the wind: wind vanes; anemometers and anemographs; definiton of the surface wind for synoptic purposes;
- Duration of sunshine and of global solar radiation; sunshine recorders; actinometers and actinographs;
- Horizontal visibility: estimation from the use of landmarks by day and light at night;
- Turbidity;
- Clouds: genera, species and variety; cloudiness; measurement of the ceiling by estimation, using pilot balloons in the daytime and cloud searchlights at night by the optical echo method; automatic cloud base recorder; the comb nephoscope for measuring cloud speed and direction;
- Hydrometeors: exploration at a distance using radar echoes, radar;
- Thunderstorms: atmospherics direction-finder;

- Distant recording: automatic instruments; automatic stations;
- Meteorological codes for transmitting synoptic surface data; special codes;
- Record keeping.

5.3.7.2 Upper-air observations

- Pilot balloons; radiosondes; radio and radar measurements; analysis of a sounding and presentation of the results of the sounding on an aerological diagram; use of diagrams;
- Information from meteorological rockets (temperature up to approximately 60 km, wind, pressure, density);
- Meteorological satellite observations: clouds, infrared and other radiation measurements;
- Meteorological codes for transmitting synoptic upper-air data; special codes;
- Record keeping.

5.3.8 Interaction of the ocean and the atmosphere

Only a general treatment of the topics given below is required:

- Transfers between atmosphere and ocean: momentum; heat; water vapour; carbon dioxide;
- The atmosphere's action on the ocean: sea-surface winds and currents; waves; swell; bores and tidal waves; storm tides; cold upwelling;
- The ocean's action on the atmosphere: climatic action; modification of air masses due to heating or cooling; sea fogs.

5.3.9 Elements of air pollution meteorology

- Sources; atmospheric concentration; removal processes; effects; measurements techniques;
- The WMO Background Air Pollution Monitoring Network (BAPMoN).

5.4 SPECIALIZATION IN SYNOPTIC METEOROLOGY (CLASS II)

Section 5.3.3 should be supplemented by the following:

- Kinematic analysis, wind and pressure: classification of winds; the

effect of changing pressure distribution; the effect of friction; comparison of gradient wind with observed winds; the geostrophic wind scale; boundary conditions; trajectories; streamlines; relation between trajectories and streamlines; divergence and convergence;

- Kinematic analysis-frontogenesis: definition of frontogenesis; front ogenesis in a conservative field of property; linear fields of motion; frontogenetical and frontolytical sectors;

- General circulation in the troposphere: air masses and the polar front; the subtropical high pressure belt; the subpolar low pressure belt; the cyclonic polar vortex; jet stream: the flow lines and isotachs of a jet stream; tropospheric and stratospheric circulations and the jet stream; the polar front jet stream; frontal jet stream; the multiple jet stream; the subtropical jet stream; stratospheric jet streams; climatography of tropospheric jet streams;

- The characteristic large-scale patterns of standard isobaric surfaces, of their relative topography (temperature field) and of the field of the vertical component of geostrophic vorticity; stable and unstable waves of the zonal westerly current of middle latitudes; formation in the middle and upper troposphere of mobile throughs and wedge lines in the pressure field, of cold cyclones in low latitudes and of warm anticyclones in high latitudes; the phenomenon of blocking; stable and unstable waves of the easterly zonal current in low latitudes; tropical cyclones;

- Common characteristics of atmospheric circulation on the synoptic scale, from 700 to 100 mb; tropospheric and stratospheric disturbances; contour patterns at the 50 mb level and at higher levels; the seasonal changes in the stratospheric circulations; the cyclonic vortex of the polar night and the jet stream associated with it;

- Polar meteorology as applied to weather analyses and forecasting;

- Tropical meteorology: representative value of surface and upper-air measurements of meteorological elements; their diurnal variations; local factors; the orders of magnitude of the terms used in dynamical meteorology (motion, continuity, thermodynamics) in the tropical latitudes; relation between the wind and the isobars in the low latitudes; validity of the geostrophic hypothesis; stream lines and synoptic analysis; computation of the horizontal divergence and the vertical component of vorticity in the tropical latitudes; inter-tropical convergence; the trade winds; the interaction of tropical and mid-latitude weather systems; the general circulation in the low latitudes; mean flow at the surface and in the upper-air; tropical tropopause; seasonal variations of the pressure and wind fields; equatorial low pressures; anticyclones of the subtropical high-pressure belt; trade winds and monsoons; tropical clouds; hydrometeors and meteors of the intertropical zone; air masses in the tropics and their transformations; waves of the easterly current; squall lines; tornadoes; tropical cyclones; their evolution and trajectories; the interaction between the low and middle latitudes; penetration of the polar front in the tropics, its transformations; upper-air front; associated pressure troughs; zonal westerly circulation; shearlines; analysis and evolution of stream lines on synoptic charts;

- Forecasting large-scale patterns of the height and temperature fields by using the vorticity equation; graphical and numerical methods;

- Analysis and forecasting of large-scale patterns of atmospheric distribution of water vapour, cloud cover and precipitation: physical relation between these patterns and those of the forecast horizontal flow and the forecast field of vertical motion; formulation of the physical forecast (temperature, cloudiness, hydrometeors) from the numerical forecast of the field of motion;

- Fine structure associated with the large-scale pattern of the field of motion: convection clouds; use of aerological diagrams; thunderstorms; squall lines; tornadoes; clear-air turbulence; icing; fog; influence of local geographical factors on wind, temperature, clouds and hydrometeors; mountains and hills, coastal and urban area effects;

- Preparation of general and special forecasts; forecasts for shipping, agriculture, etc., (storm warnings, flood forecasting, etc.); air pollution potential (stagnation) forecasts;

- Extended weather forecasting: synoptic extrapolation for two or three days; extended forecasting based on extrapolation of individual upper long waves; extended forecasting based on five-day mean circulation; extended forecasting based on analogous sequences of weather maps; extended forecasting by means of statistical extrapolation; general form of long-range weather forecast; long-range forecasting by means of physical models; numerical long-range forecasting;

- Satellite data in meteorological analysis and forecasting; use of satellite data in weather analysis; large-scale cloud system; synoptic application of satellite-borne infra-red window measurements; local circulations as seen from satellite cloud pictures; satellite cloud pictures and jet stream structure; use of satellite data in mesometeorology; uses of satellite data in severe thunderstorm detection; use of satellite data in the tropics; brief description of the technical aspects of meteorological satellite photography; satellite radiation measurements; radiometric measurements of midstratospheric temperatures; water vapour content from satellite radiation measurements; participation in the workshop on the use of satellite data in meteorological research;

- Meteorological telecommunications: principles of organizing intercommunication between stations; utilization of the various transmission methods, their advantages and disadvantages; elementary notions of telegraphy; description and working of the teleprinter and facsimile; electronic programming devices;

- Collection and diffusion of meteorological data; need for an international organization; international and national telecommunication procedures; continental or world broadcasts; sub-continental broadcasts; transmission of data required for the protection of aircraft; sub-regional and regional broadcasts;

- Systems for transmitting data in flight;

- Meteorological transmission programmes; message writing, exercises;

- Practical exercises on operational regulations concerning telephone, telegraphy and radiotelegraphy and on the functioning of the principal apparatus used (teleprinter, facsimile, radiotelegraphy reception apparatus, telegraph switchboard), installation and day to day maintenance of this equipment; simple repairs; sound reception;

- Laboratory exercises: graphical arithmetical operations and graphical differentiation; graphical constructions of thermodynamic charts or nomographs; plotting of data on thermodynamic and wind sounding charts; isobaric advection of scalar synoptic parameters: computation and analysis; thermal wind analysis; thermal advection as advection of thickness lines; hodographic analysis; isogon and streamline analysis; horizontal and isobaric trajectories; computation of the fields of isobaric divergence, vertical vorticity component and deformation; methods for analysis - at synoptic scale - of vertical velocity fields; evaluation of frontogenetic factor; constant absolute vorticity trajectories computation; Rossby long waves computation; isotach and jet stream analysis; analysis of tropopause; analysis of maximum wind layer; isentropic analysis, isentropic thermal and relative pressure field; surface synoptic analysis: air-mass analysis; allobaric fields; cloud and weather systems analysis; frontal analysis; tropical analysis: streamline and isotach analysis; vertical time-section analysis; isobaric analysis in the low latitudes; plotting of data on synoptic cross-sections and time-sections; space cross-section analysis; local analysis and time-section analysis; cloud weather systems analysis by satellite photos and radar echoes; synoptic weather forecasting and construction of surface and upper-air prognostic charts: displa cement of upper-air troughs and ridges, jet-stream prognosis; displacement of fronts and surface systems; intensity change of weather systems (graphical kinematical extrapolation, graphical application of vorticity equation, interpretation and utilization of numerical weather prediction, etc.); forecasting of weather elements (cloud systems, precipitation, winds, temperature, severe weather conditions); synoptic weather analysis and forecasting on the basis of current synoptic surface and upper-air data, collected in a didactical simulated meteorological office; objective forecasting; local forecasting techniques; verification of forecasts; coding and decoding synoptic analyses and forecasts.

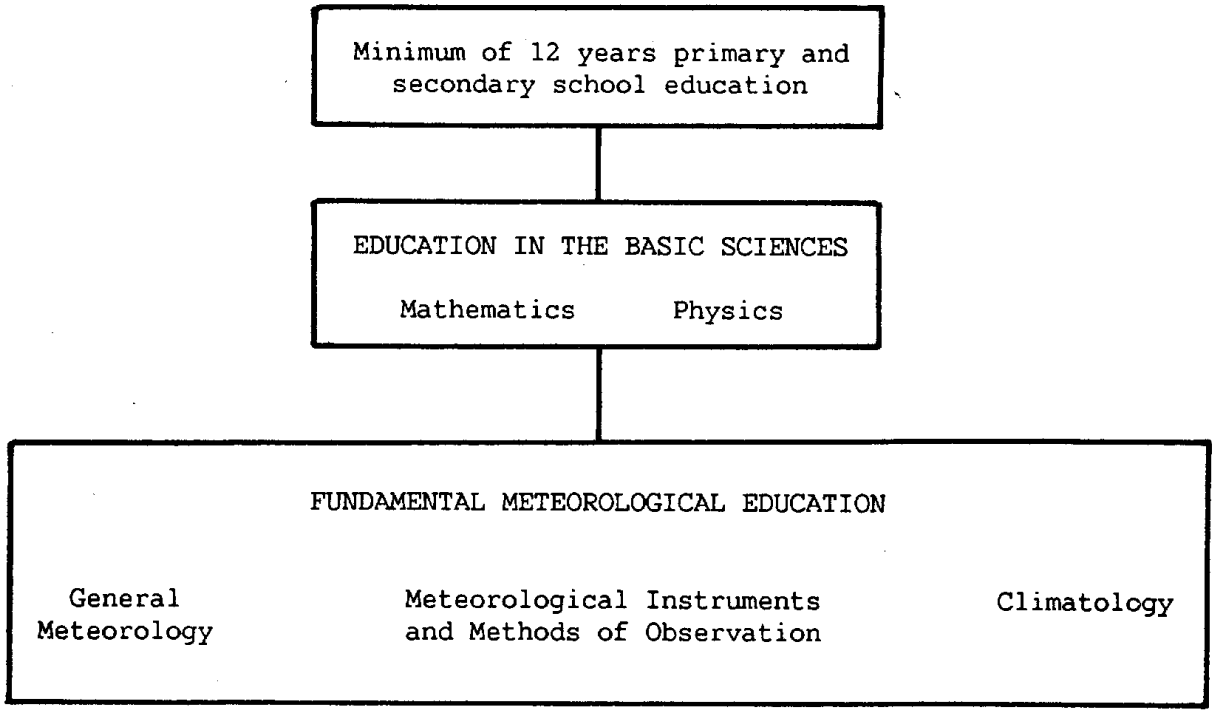
INDEX

CHAPTER 6

CURRICULA FOR TRAINING ALL CLASS III METEOROLOGICAL PERSONNEL IRRESPECTIVE OF THEIR FIELDS OF SPECIALIZATION

CURRICULA FOR TRAINING CLASS III METEOROLOGICAL PERSONNEL

(Schematic representation of contents)



6.1 GENERAL

In their work, Class I and, or Class II meteorological personnel are assisted by Class III, namely, assistant forecasters, assistant climatologists, plotters of synoptic charts and aerological diagrams, radiation and aerological station personnel, surface observing station inspectors within national networks, and so on. When they have acquired sufficient experience, Class III personnel may participate in the interpreting of observational data and, under supervision, provide users with meteorological information or inspect the observation network. In view of the wide spectrum of duties carried out by this Class, it is not easy to draw up training syllabi which will be suitable for all staff, irrespective of their individual functions. In some cases, it may be necessary to employ technologists with knowledge in the field of chemistry, etc.

6.2 EDUCATION IN THE BASIC SCIENCES (CLASS III)

It is essential that all Class III meteorological staff have a thorough understanding of the science of meteorology if they are to carry out their duties efficiently. To acquire this understanding a preliminary grounding in the basic sciences is necessary. The duties of Class III personnel are of the utmost importance and must therefore be carried out in full awareness of their value and the uses to which they are directed.

The purpose of the syllabi in mathematics and physics given in the following paragraphs is to indicate, in broad lines, the knowledge in these subjects which one would normally expect Class III personnel to possess prior to taking up meteorological studies. Except, perhaps, for the section on integral calculus a student with 12 years primary and secondary schooling is already familiar with the material contained in the syllabi. The syllabi will however be of value to instructors conducting refresher courses, or preparing supplementary courses for promotion of Class IV personnel.

6.2.1 Mathematics

6.2.1.1 Algebra

- Natural logarithms;
- Quadratic equations, algebraic and graphical solutions; real and imaginary roots; sign of the quadratic expression; biquadratic equation; transformation of a double radical into the sum of two simple radicals;
- Concept of the function of a variable, its graphical representation; examples, among others,

$$y = ax + b,\ y = (ax + b)/(cx + d) \text{ with } c \neq 0,$$

$$y = ax^2 + bx + c \text{ with } a \neq 0.$$

- Infinitely large and infinitely small quantities; limit of a variable; limit of a function; operations on limits; calculation of a limit - examples: elementary knowledge of the continuity of a function; algebraic functions.

6.2.1.2 Plane and solid geometry

- Geometric loci points equidistant from one or two other points; points equidistant from one or two straight lines; geometric construction of loci;
- Theorem of the external and internal bisectors of an angle of a triangle;
- Polygons: similarity of polygons; regular polygons and their properties; equilateral triangles; square; regular hexagons; polygons inscribed in, and circumscribed about a circle;
- Length of a circumference and of an arc; definition and value of π;
- Surface: unit of surface; equivalent surfaces;
- Angle between a straight line and a plane; trihedrons; polyhedrons; regular polyhedrons; prisms; pyramid; frustum of a pyramid; cylinder; cone; frustum of a cone; their surface areas and volumes; surface and volume of the sphere; surface of spherical zone; the solid angle.

6.2.1.3 Plane analytic geometry

- Cartesian, rectangular and polar co-ordinates; change of cartesian co-ordinates; distance between two points; co-ordinates of the mid-point of a segment; geometric locus, its equation;
- Equation of a straight line: general form; equation of the straight line passing through two points; equation of two parallel and of two perpendicular straight lines; equation of a circle;
- Some standard, simple, plane curves: parabola; ellipse; hyperbola; their equations and construction in the plane.

6.2.1.4 Trigonometry

- Definition of arc and angle; measurement of an angle; units; positive and negative angles; circular functions of an angle; sine, cosine, tangent, cotangent, secant, cosecant and their variation as a function of the angle and their graphical representation; circular functions of the sum or difference of two angles; circular functions of two complementary or supplementary angles, of vertically opposite angles, and of two angles whose sum or difference equals 2; reduction to the first quadrant; noteworthy values of the circular functions; classical elementary formulae; relation between the trigonometric functions of the same angle; conversion of the sum or the difference of two sines or cosines into their product and vice versa; trigonometric tables and their use; solution and discussion of certain classical trigonometric equations; relation between the sides and angles of a triangle; solution of triangles.

6.2.1.5 Differential and integral calculus

- Continuous function of a variable derived from a continuous differential function; derivative of the sum and the difference of two functions and

of the product and the quotient of two functions; derivative of:

$$x^n \quad (n \neq 0), \sin x \text{ and } \cos x.$$

- Applications: (1) tangent to a curve and slope of a curve, at a point; gradient of a scalar; rate of increase or decrease; (2) movement of a point on a straight line: relation between the distance covered and the time taken and between the velocity of the point and the time; maximum and minimum of the function of a variable;

- Simple cases of functions of a function;

- Intuitive notion of the integral of a function; integral of common functions: x^n , sin x, cos x.

- Applications: the area defined by the arc of a curve; the axis of the abscissae and the ordinate of the end points of the arc; lateral area and volume of a body of revolution.

6.2.1.6 Statistics

- Purpose and scope of statistics; frequency distribution;

- Tabulation and graphical representation of statistical data;

- Mean; median; mode; variance; percentile;

- Method of least squares; contingency and correlation; harmonic analysis;

- Measures of dispersion: mean deviation and standard deviation;

- Exercises in statistics.

6.2.2 Physics

- Properties of matter: fundamental physical measurements; linear motion of a particle; Newton's laws of motion, definition of unit force; circular motion and simple harmonic motion; work and energy; equilibrium of systems of co-planar forces; motion of rotation; moment of inertia; compound pendulum; friction; viscosity; impact; hydrostatics; gases; elasticity; surface tension; diffusion; osmosis; occlusion;

- Heat: temperature, thermometry; expansion of solids; expansion of liquids; expansion of gases; gas thermometers; quantity of heat; specific heat; calorimetry, fusion; vaporization; relation between temperature, pressure and volume of any substance; Dalton's law; dew point; hygrometry; modes of transference of heat; nature of heat; mechanical equivalent of heat; adiabatic expansion of a gas; kinetic theory of gases;

- Acoustics: nature of sound; wave motion and sound; determinations of frequency; vibrating systems producing sounds; resonance; composition and resolution of harmonic vibration; Doppler's principles;

INDEX

- Light: reflection and refraction of light; principles of optical measurements; optical instruments; colour; the eye; nature of light; visible and invisible radiation; corpuscular and wave theories; polarization effects; velocity of light;

- Magnetism: magnetic phenomena; law of magnetic force; magnetic potential; magnetic intensity; terrestrial magnetism; permeability; susceptibility; magnetic circuit;

- Static electricity: elementary phenomena; induction of electricity; law of electric force; electric potential; capacity; condensors; energy of charged conducting systems; electrical machines; electrometers;

- Current electricity: elementary phenomena; cells; electric circuits; magnetic action of an electric current; electrical units; Ohm's law; resistance of Kirchhoff's laws; measurement of resistance; electrothermal and thermoelectric effects; chemical action of a current; electrolysis; electromagnetic induction; galvanometers; ammeters; voltmeters; high-frequency oscillations; wireless telegraphy.

6.3 FUNDAMENTAL METEOROLOGICAL EDUCATION (CLASS III)

The syllabi given in general meteorology, upper-air measurements (pilot-balloon, and meteorological codes and transmissions) and climatology are designed for all Class III meteorological personnel. For those responsible for taking radiosonde observation, section 6.3.2.2 should be added. As regards Class III personnel responsible for computer operations, the training in meteorology may be reduced to essentials or even omitted. However, some basic knowledge of meteorological codes and transmissions is necessary.

6.3.1 General meteorology

The syllabus for Class IV personnel (section 7.2.1) should be supplemented as follows:

- Thermodynamics of the atmosphere: adiabatic transformation of non-saturated air and of air saturated with water vapour; the psychrometric formula (Regnault); potential wet-bulb temperature; elementary aerological diagram theory; choice of a diagram; problems that can be solved using this diagram; vertical stability and instability of air; conditional equilibrium and latent instability; thermal convection and convection clouds; moisture indicators: absolute humidity; specific humidity; mole fraction: virtual temperature;

- Clouds, fog and precipitation: basic knowledge of their formation; saturation, condensation nuclei; influence of the surface; tension of raindrops and of the hygroscopicity of nuclei on saturation pressure; the process of raindrop formation; large-scale and small-scale cooling of the air due to adiabatic and non-adiabatic processes; frontal, generally stratiform, clouds (updraught on the synoptic scale); cumuliform clouds (thermal updraught); orographic clouds; turbulence clouds (small-scale updraught); international cloud classification; fog classification; meteors; artificial rain;

- Dynamic meteorology: ideas of scale in meteorology; motion on different scales; synoptic wind; geostrophic approximation (Buys-Ballot's law); ageostrophic local winds; equations of motion on the synoptic scale; geostrophic wind and gradient influence of the temperature field on the wind field; thermal wind; horizontal divergence and convergence and the existence of vertical velocities; consequences of the existence of vertical velocities; detection of horizontal convergence and divergence regions on synoptic charts;

- Synoptic meteorology: air masses; their sources; their physical characteristics on the surface and in the upper air; their circulation; the phenomena of condensation associated with them; their classification; geographical and thermodynamic classifications and their development; fronts; their formation and development; cold, warm and occluded fronts; secondary cold fronts; fronts and temperature; fronts and wind; fronts and clouds; fronts and precipitation; frontal depression of the temperature regions; the incipient depression (wave); the warm sector depression; the occluded depression; the phenomena of condensation (cloud systems) and of precipitation associated with them; families of frontal cyclones; influence of orography on fronts and frontal disturbances; mobile troughs and wedge lines of the pressure field; retrograde depressions; tornadoes; tropical cyclones;

- Atmospheric turbulence: turbulence of mechanical and of thermal origin; turbulent diffusion of heat and of water vapour; effect of the earth's friction on air movement on the synoptic scale; change of wind direction with height in the surface layer (friction layer);

- Local circulation of the air: sea breezes and land breezes; urban winds; dynamic and thermal action of hills and valleys; height and range of influence of a mountain; orographic clouds; modifications of the thermal field caused by topography; Fohn effect; the effects of buildings and trees on the wind field;

- General circulation of the atmosphere; the use of monthly mean isobaric charts at the earth's surface and monthly mean contour charts at 700, 500, 300 and 100 mb levels; average general circulation and instantaneous general circulation, index of zonal circulation, circulation pattern; average general circulation and air masses, introduction of average positions of the polar and Arctic fronts;

- The synoptic observation network; representative value of a meteorological element; synoptic weather charts; fundamental rules and analytical techniques; weather charts and their analysis; synoptic representation of the pressure field; the isobars of a level surface and the contours of an isobaric surface; quasi-static approximation; geopotential (height) of isobaric surfaces and thickness of an isobaric layer; geostrophic approximation; geostrophic wind and thermal wind; pattern and movement of isobars, contours and lines of equal thickness;

- Jet streams: streamlines and isotachs of a jet; the wind field and the temperature field of a jet; tropospheric and stratospheric circulations and jets; the polar front jet; frontal jets; multiple jets; subtropical jets; stratospheric jets; climatography of tropospheric jets;

- Tropical meteorology: representative value of surface and upper air measurements of meteorological parameters; their daily variation;

local factors; general circulation at low latitudes; seasonal variations of the pressure and wind fields; equatorial low pressure areas; intertropical convergence; intertropical front; sub-tropical anticyclones; trade-winds and monsoons; air masses in the tropics and their transformation; penetration of polar air into the tropics; wave-motions of the zonal easterly current; tropical cyclones; squalls; tornadoes; upper front; pressure troughs associated with the zonal westerly circulation; analysis and evolution of stream lines on synoptic charts;

- Elements of atmospheric optics and electricity: refraction, rainbow; halo; corona; blue of the sky; transparency of the atmosphere and visibility; application of notions of static electricity to the electric field of the atmosphere; atmospheric ions and the conductivity of the air; lightning discharge and thunderstorms;

- Elements of air pollution meteorology: sources; atmospheric concentration; removal processes; effects; measurements techniques; the WMO Background Air Pollution Monitoring Network.

6.3.2 Upper-air measurements (meteorological instruments and methods of observation)

The syllabus for Class IV (section 7.2.2) should be supplemented by the following:

6.3.2.1 Pilot-balloon observations

- Lift speed; valve adjustment; inflation; hydrogen generators: principle and use;

- Wind measurement: principles; description and setting up of the theodolite; sighting pilot balloons with the theodolite; recording theodolite; analysis and graphic representation of a sounding; meteorological code;

- Measurements relating to clouds: height of cloud base determined by pilot balloon in the daytime and by a cloud searchlight at night; cloud speed and direction determined by using the comb nephoscope; the theodolite used as a nephoscope;

- Data from radiosondes and rawinsondes;

6.3.2.2 Radiosonde observations

For Class III meteorological personnel responsible for taking radiosonde observations, paragraph 6.3.2.1 should be supplemented by the following:

- Vertical measurement of air pressure, temperature and humidity; principle of radiosonde, telemetering systems in use; radiosonde; types, description, working, adjustment, preparation for a release; basic equipment of a radiosonde station; day to day functioning and maintenance; release; reception; analysis of the sounding; representation of the sounding on an aerological diagram, computation of altitudes;

- Wind measurement: radio-theodolite and radar; description, working principles; preparation for a release, release, reception, analysis of the sounding, day to day maintenance of the equipment.

6.3.2.3 Meteorological codes and transmissions

- Upper-air observation codes; symbolic forms and description of radiosonde and rawinsonde codes;
- Technical messages (special observation codes, forecast codes, etc.);
- Principles of organizing intercommunication between stations; collection and dissemination of meteorological data; meteorological transmission.

6.3.3 Climatology

6.3.3.1 General climatology

- Definitions of weather and climate; basic concepts; using climatology in the weather office (supplying information, responding to requests, writing weather synopsis, aids in forecasting, etc.).

6.3.3.2 Climate observations and data

- Climatic elements; how they are observed, collected, checked, archived and published.

6.3.3.3 Physical climatology

- Radiation: sources of heat for the atmosphere; heat and energy budgets; radiation and sunshine networks;
- Temperature: errors in temperature measurement; lapse rate; soil temperature; air temperature;
- Hydroclimatology: hydrologic cycle; water budget concept.

6.3.3.4 Dynamical climatology

- General atmospheric circulation; semi-permanent pressure patterns;
- Local circulation: local winds; land/sea-lake circulation; topo graphic effects; effects of buildings and trees;
- Upper-air climatology: winds aloft; jet streams; pressure-height relationships;
- Climate forecasting.

6.3.3.5 Synoptic climatology

- Grouping of air masses; mean and frequency of types of weather; geographical distribution of fronts; frequency of frontal passages; frequency of low-level inversions; tracks of highs and lows.

6.3.3.6 Regional climatology and climatic classification

- Climatography of the region (data and maps);
- Major climatic regions of the world; climatic controls;
- Climatic classifications and their characteristics; schemes based on soil and vegetation; single-purpose classification.

6.3.3.7 Micro- and mesoclimatology

- Scales in climatology: micro or local; meso; macro or regional;
- General principles and concepts;
- Various types of microclimates: influence of topography; soil; land use; water body; vegetation;
- Urban climatology: basic physical urban-rural contrasts.

6.3.3.8 Applied climatology

- Methods of and problems in applying climatic data and information;
- Selected applications to agriculture, energy, water resources, human biometeorology, engineering and construction, etc.

6.3.3.9 Climatic change

- Evidence of climatic change; theories of climatic change; man-made climatic change.

6.3.3.10 Climatic methods and statistics

- Analysing and interpreting observational data;
- Basic statistical concepts: central tendency; dispersion; frequency distribution;
- Graphical methods and mapping: constructing tables, graphs and figures; analysing basic climatic maps.

6.3.3.11 Data-processing methods

- Basic principles of flow charting; computer principles and procedures, information storage and retrieval; data communications;
- Computer programming;
- Use of data-processing in climatological services.

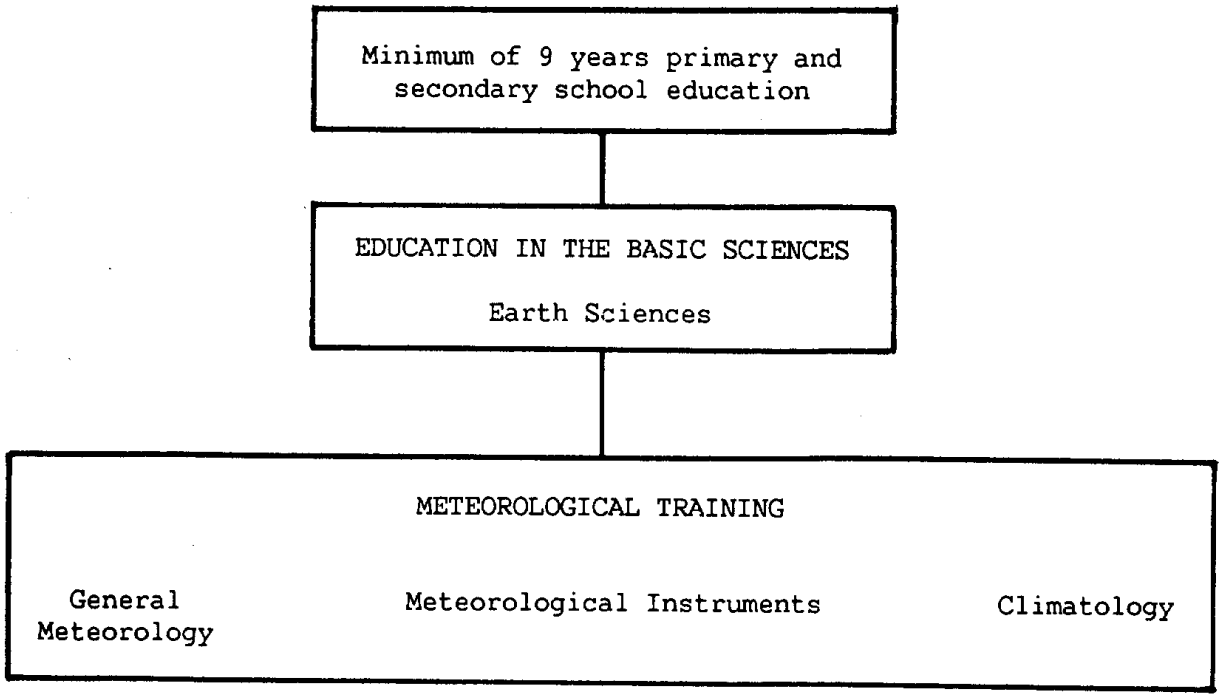
INDEX

CHAPTER 7

CURRICULA FOR TRAINING ALL CLASS IV METEOROLOGICAL PERSONNEL IRRESPECTIVE OF THEIR FIELDS OF SPECIALIZATION

CURRICULA FOR TRAINING CLASS IV METEOROLOGICAL PERSONNEL

(Schematic representation of contents)



7.1 EDUCATION IN THE BASIC SCIENCES (CLASS IV)

The minimum pre-requisite is nine years primary and secondary school education. It is assumed that the student will by then have reached a certain level in mathematics, physics, chemistry and physical geography.

Since the educational programmes of countries vary considerably and, thus also, the depth of treatment of the basic sciences, no attempt is made here to set out detailed syllabi in mathematics, physics, chemistry and physical geography. This is left to national educational authorities.

As against that, it is felt that an indication should be given of the general level of knowledge which a student should have reached prior to entering into the study of meteorology: the syllabus on Earth science given below covers all that a student needs to know before commencing the Class IV course. If a student is weak in some subjects, it is left to the instructor to decide whether he requires supplementary training.

7.1.1 Earth science

- Structure of the earth: lithosphere; hydrosphere; atmosphere; the structure of the earth's crust; composition of the atmosphere and hydrosphere; shape of the earth; various dimensions of the earth; the shape of the earth as a result of external forces; formation of rocks due to processes within the earth;

- Motions of the earth: rotation of the earth around its axis; revolution of the earth around the sun; seasons; the causes of tides;

- The gravitational field of the earth; laws of gravitation; measurements of earth's gravity;

- Earth's interior; the distribution of the mass of the earth; the structure of the earth's interior; the temperature of the earth's interior; the state of the earth's interior;

- Magnetic field of the earth; the direction of the magnetic field; the changes of the earth's magnetic field;

- Energy: definition of energy; flow of energy; change of energy; relation between various kinds of energy; conservation of total energy; the source of the energy of the earth;

- Definition of heat and temperature; the flow of heat from the interior of the earth; the energy output from the sun; conversion of mass into energy in the interior of the sun;

- Solar radiation: the radiant energy from the sun; the effect of the atmosphere on the incoming radiation; the distribution of insolation on the earth;

- The causes of the motion of the atmosphere: the effects of the earth's rotation on the wind; the effects of lands and water in modifying the motion of the air;

- Water in the atmosphere: the definition of water cycle; evaporation; condensation; release of the condensed water from the atmosphere; latent heat;

- Water on the land: the movement of the water into the ground; storage of water in the ground; flow of water over and through the ground; definition of water budget; investigating and interpreting the water budget;

- Sea water: the composition of the sea water; the motion of the sea; waves; transport of energy by waves; winds and water currents; currents caused by differences in density;

- Measurement of time: the definition of time; relative time and measured time; clocks and calendars; geologic clocks; geologic time scales;

- Solar system: planets and their motion; the two distinct groups of planets; difference among planets; asteroids and meteoroids; origin of the solar system; nebular theory;

- Other solar systems: luminosity of the stars; radiation from the stars; movement of the stars in space; stellar temperatures; the origin of the stars; the life history of a star; what is a galaxy; what is the Milky Way; various groups of galaxies.

7.2 METEOROLOGICAL TRAINING (CLASS IV)

The concept of fundamental and specialized training of meteorological personnel as envisaged in other chapters does not strictly apply in the case of Class IV meteorological personnel. On the other hand it is true that not all such personnel carry out the same duties; some are engaged in taking synoptic observations and others man agrometeorological, hydrometeorological or air pollution monitoring stations. As a result the training of these personnel is more need oriented than for other Classes.

For Class IV meteorological personnel who are engaged in taking synoptic observations, the syllabi given in sections 7.2.1, 7.2.2 and 7.2.3 are quite adequate.

An important factor in training Class IV meteorological personnel is on-the-job training. Every effort should therefore be made to strengthen this aspect.

7.2.1 General meteorology

- The composition of the atmosphere: dry air; atmospheric ozone; water vapour; carbon dioxide; thermosphere; interplanetary gas;

- Vertical divisions of the atmosphere: troposphere; stratosphere; mesosphere; thermosphere; ionosphere; exosphere;

- Heat exchange processes in the atmosphere: solar and terrestrial radiation; conduction and convection; advection; mechanical and thermal turbulence (or thermo-convection); energy budget of the

atmosphere; effect of radiation at the earth's surface; temperature differences between land and sea surfaces;

- Air temperature: basic principles of temperature measurements; Celsius, Fahrenheit and Kelvin temperature scales;

- Thermometers: physical processes used in thermometry; types; thermograph; principles of design; measurement of air temperature; exposure; horizontal and vertical variations of air temperature, troposphere, tropopause and stratosphere;

- The effect of gravity on the atmosphere; air density;

- Atmospheric pressure: nature; units; measurement; the hydrostatic equation; the mercury barometer, its principle, setting up and handling; corrections for standard conditions; the aneroid barometer; the barograph; horizontal and vertical variations in pressure; reduction of pressure to sea level; the ICAO standard atmosphere; the barometer used as an altimeter; semi-diurnal variation of pressure; significance of pressure gradient;

- Moist air: the three states of water, solid, liquid and gaseous; density; water vapour pressure; saturation vapour pressure; evaporation; condensation; freezing; sublimation; isobaric and adiabatic processes; latent heat;

- Moisture indicators: relative humidity; mixing ratio and dew point; water vapour pressure;

- Elementary theory of the wet-bulb thermometer; principles of the phychrometer and the hygrometer;

- Rudiments of cloud, fog and precipitation formation; visibility, the influence of water vapour, of water drops and dust (aerosols);

- Expansion or compression of a rising or falling air bubble: variation of the bubble's temperature with height; isobaric expansion and adiabatic expansion; the influence of condensation; basic knowledge of the vertical stability or instability; non-saturated air and saturated air;

- Elementary knowledge of synoptic and dynamic meteorology: air motion; significance of scale; the winds and their causes; rudiments of the general circulation in the tropics and in non-tropical regions; local winds; diurnal wind variation (breezes) and annual wind variations (monsoons); relation between the horizontal pressure gradient and the wind; Buys-Ballot's law and the geostrophic wind; cyclones and anticyclones; air masses and fronts; thunderstorms; synoptic chart analyses; weather associated with synoptic systems.

7.2.2 Meteorological instruments and methods of observation

Surface observations

- Sunshine recorder - Heliograph: location and orientation of the instrument; types of charts used; measurement of sunshine duration;

- Thermometers for measuring the temperature of the air: mercury thermometers and alcohol thermometers: observation hours; correction and coding; meteors; setting; observation hours; bimetallic thermometers; meteorological screens; types and orientation; thermographs; calibrating corrections and analysis;

- Thermometers for measuring water temperature;

- Thermometer for measuring ground temperature at 10, 20 and 50 cm depth; observation hours;

- Mercury barometers: Fortin and Kew; observation hours; reading the barometric height to 0.1 mm; corrections and reduction of the reading to mean sea level; conversion of mm to mb; use of correction tables; coding the corrected and reduced measurement; barograph; barometric tendency and characte ristic; barograms; calibration;

- Psychrometer: principle; maintenance; reading of thermometers; use of psychrometric tables; relative humidity and dew point, computation of dew point; coding; hygrograph; diagrams; calibration; corrections and analysis;

- Evaporimeter (Piche): principle; maintenance; reading; evaporation pans;

- Surface wind measurement: wind speed units; methods of observing wind direction; methods of obtaining wind speed; types of anemometers; analysis of anemographs; gustiness; squalls; coding of wind direction and wind speed;

- Direct-measuring raingauges and snow gauges: observation hours and procedures; coding rainfall measurements; recording raingauge; analysis of rainfall curves; rate of rainfall recorder;

- Visibility: horizontal visibility, measured by estimation or using landmarks in the daytime and light sources at night; coding of observed visibility; oblique and vertical visibility;

- Clouds: international classification of clouds (WMO); general; species and variety of clouds; orographic clouds and special clouds; the meteorological code of clouds; cloud amount; height of cloud base; cloud system and cross-sections of cloud systems;

- Fog: formation; properties; types;

- Hydrometeors: rain; supercooled rain; drizzle; supercooled drizzle, snow grains, snow pellets; diamond dust (ice crystals); hail; small hail; ice pellets; fog; mist; ice fog; drifting snow and blowing snow; spray; deposit of fog droplets; dew; white dew; hoar-frost; rime; glaze (clear ice); spout;

- Lithometeors: haze; dust haze; smoke; drifting and blowing dust or sand; dust storm or sandstorm; dust whirl or sand whirl (dust devil);

- Photometeors: halo phenomena; corona; irisation; glory; mi rage; bishop's ring; rainbow; shimmer; scintillation; green flash; twilight colours;

- Electrometeors: thunderstorms; St. Elmo's fire; polar aurora;
- Principal forms of precipitation and the clouds associated with them; cloud systems; present weather and past weather; meteorological codes of present weather and past weather;
- State of ground and sea.

7.2.3. Climatology

7.2.3.1 General climatology

- Definition of climate; branches of climatology (physical, dynamic, synoptic, bioclimatology, micro- and meso-scales, applied, etc.); climatic elements (temperature, precipitation, humidity, wind speed and direction, visibility, sky cover, sunshine, radiation, etc.).

7.2.3.2 Climatic controls

- Natural influences on climate (latitude, relief, altitude, water, ice and snow, land-use); man's effect on climate.

7.2.3.3 Regional climatology

- Main global climates; climate of the region where training is being conducted (reading climatic maps, graphs and tables); local climates.

7.2.3.4 Applied climatology

- Importance of climate in various human activities; selected examples to demonstrate the use of climate data and information in climate-sensitive activities.

7.2.3.5 Statistical methods

- Computation and use of mean, normals, departures, deviation; summarizing and grouping data; converting units.

7.2.3.6 Exercises in climatology

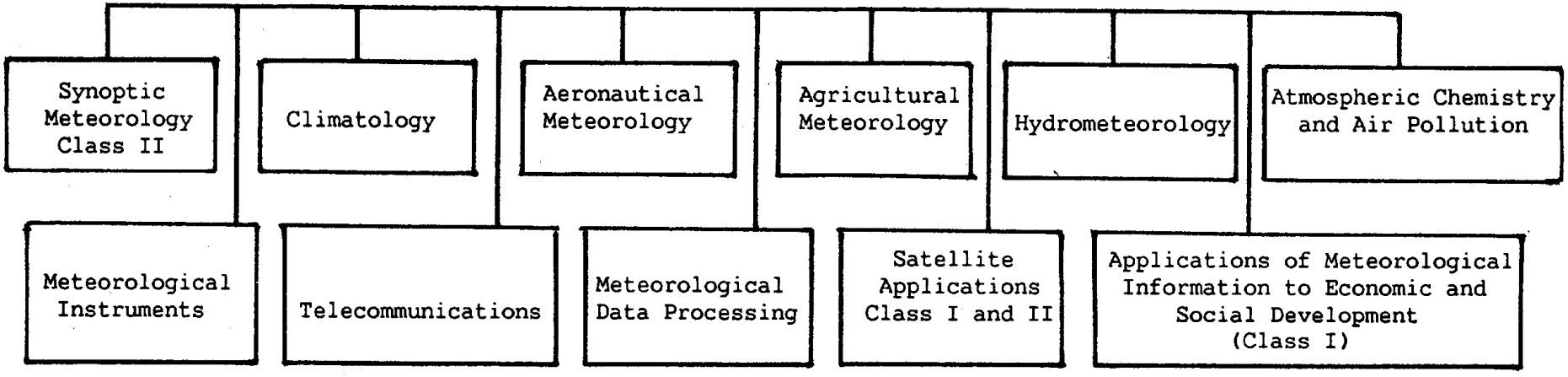
- Preparing monthly summaries; compiling data into tables; constructing graphs; plotting maps.

INDEX

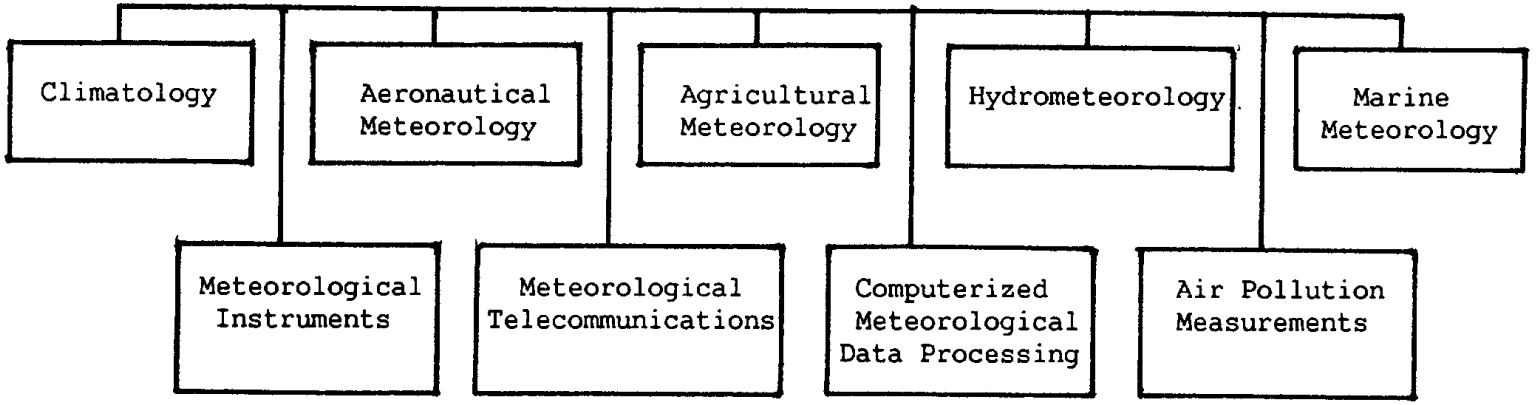
CHAPTER 8

CURRICULA FOR TRAINING ALL METEOROLOGICAL PERSONNEL IN THEIR FIELDS OF SPECIALIZATION

FIELDS OF SPECIALIZATION FOR CLASSES I, II, AND III METEOROLOGICAL PERSONNEL



FIELDS OF ACTIVITIES FOR CLASS IV METEOROLOGICAL PERSONNEL



8.1 GENERAL

Syllabi for training in different fields of specialization for the four classes of meteorological personnel are re-arranged in this revised edition of the "Guidelines", so that the syllabi of the four levels of personnel on a particular specialized field are grouped together in one chapter. The aims of this re-arrangement are to reduce the volume of the publication and to enable a continuity and an easy reference for a particular field of training.

8.2 FIELDS OF SPECIALIZATION FOR CLASS I AND CLASS II METEOROLOGICAL PERSONNEL

The syllabi for specialization in the essentially practical fields of climatology, marine meteorology, aeronautical meteorology, agricultural meteorology, hydrometeorology, atmospheric chemistry and air-pollution meteorology, meteorological instruments, meteorological telecommunication, meteorological data processing, meteorological satellite data and applications of meteorological information to economic and social development for Classes I and II meteorological personnel are given in the following chapters.

8.3 FIELDS OF SPECIALIZATION FOR CLASS III METEOROLOGICAL PERSONNEL

In fields of specialization such as dynamic meteorology, physical meteorology, weather modification, numerical weather prediction, meteorological satellite data, there is no requirement for training Class III personnel. In other fields, such as synoptic meteorology, no further training over and above that given under "Fundamental meteorological education" for Class III is necessary. In certain applied fields, such as aeronautical meteorology, agricultural meteorology, hydrometeorology, marine meteorology, meteorological instruments, meteorological telecommunications, meteorological data processing, or air pollution monitoring, additional training is required. The syllabi for these areas of specialization are given in the following chapters.

8.4 FIELDS OF SPECIALIZATION FOR CLASS IV METEOROLOGICAL PERSONNEL

For Class IV meteorological personnel engaged in climatology, marine meteorology, aeronautical meteorology, agricultural meteorology, hydrometeorology, air pollution measurements, meteorological instruments, meteorological telecommunications or computerised meteorological data processing, these syllabi could be reduced and supplemented by additional material as given in the following chapters.

INDEX

CHAPTER 9

SPECIALIZATION IN CLIMATOLOGY

FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL

INDEX

9.1 SPECIALIZATION IN CLIMATOLOGY (CLASS I)

9.1.1 Introduction

University trained personnel with adequate education in mathematics, statistics and physics should have a basic knowledge of chemistry and radioactivity, elements of astronomy and geodesy, physical geography, and elements of biology and ecology, to give them the background necessary for both the fundamental meteorological education (Class I) and for specialization in climatology. Should more training be needed in these areas, it should become part of the fundamental meteorological education for Class I meteorologists, rather than part of the training necessary to specialize in climatology.

Class I personnel specializing in climatology are responsible for the organization and supervision of various components of a national climatological service. They should be able to perform research and development and act as consultants in various problems of applied climatology. It is in general impossible to expect a single person to become an expert in all fields of climatological study. It is therefore understood that extracts from this syllabi will be used for planning advanced education and training programmes in climatology.

A physical climatologist should be familiar with mathematics, modern data processing methods, the physical basis of climate and certain numerical methods used in climatic modelling. An applied climatologist should also know basic mathematics and be well trained in statistics and computer applications and have in-depth knowledge of general and applied climatology and a number of specialized areas, for example, building and construction, forestry, recreation and tourism.

9.1.2 General climatology; the physical basis of climate

- Definition of climate; historical developments in climatology;
- Components of the climatic system: atmosphere, oceans, cryosphere, land masses, biomasses.
- Astronomical controls: solar, lunar, planetary and cosmic influences; influence of latitude; effects of variation in the earth's axis of inclination and in elements of the earth's orbit; mean temperature of the earth's surface as a function of the solar constant, albedo, emissivity;
- Geographical controls: distribution of sea and land surfaces; degree of continentality; topography and aspect; soil and subsoil; regional and local influences; influences of water bodies (oceans, lakes, rivers); effects related to the nature of the earth's surface (snow, ice, forests, soil, crops); influence of towns, buildings and other human activities; effects of volcanic eruptions on climate.

9.1.3. Organization of a climatological service

- Responsibilities and structure of a national climatological service (services, data management, applications and consultation, research, monitoring and prediction, training);

- Planning and organization of climatological networks;

  General knowledge of WMO programmes, particularly the World Weather Watch, the Research and Development Programme, the World Climate Programme and the Technical Commission for Climatology (CCl).

9.1.4 Instruments and observing procedures

The syllabus given in Sections 3.3.9 and 3.3.5.2 should be supplemented as follows:

- Climatic elements: water and soil temperature; evaporation, evapotranspiration, hydrometeors; lithometeors; photometeors; variability of climatic elements in time (daily, monthly, seasonal, annual, etc.) and space;

- Application of satellite imagery in climatology (agriculture, natural resources and marine applications); use of satellites for observing data: upper-air and surface parameters, radiation budget parameters, ocean temperatures, ice and snow cover.

9.1.5 Physical climatology

Section 3.3.5.4 should be supplemented as follows:

- Energy and heat: energy balance components of the earth/atmosphere system; atmospheric aerosols: physical and chemical nature and composition, natural and antropogenic sources, fall-out, washout and other removal processes; carbon dioxide and ozone; radiation models for deriving observations from sunshine or synoptic data and synthetic data for inclined surfaces;

- Hydroclimatology: geographic distribution and variation of water balance components; extent of snow fields, ice sheets, sea-ice; importance of water balance to agriculture; hemispheric moisture flux; climatonomic relationships;

- Heat transfer in the ground; soil heat capacity.

9.1.6 Dynamic climatology

- Characteristic features of the general circulation: circumpolar vortices, long waves, jet streams, index cycle, blocking action; seasonal pressure patterns;

- Mechanisms of latitudinal heat transfer; advection of heat and water vapour; vertical motion in the atmosphere; atmospheric and oceanic circulation;

- Local wind systems and controls: lake/sea and land breezes, urban winds; topographic effects: slope winds, mountain wind systems, dynamic and thermal actions of hills and valleys, Foehn effects; effects of buildings and trees on wind;

- Climatic prediction: value of climatic prediction; methods; (analogues and persistence, correlation and regression, cosmic or sunspot cycles, feedback and surface influences, numerical modelling); contingency tables; oceanographic-meteorological tele connections; cycles and oscillations; extrapolation, filtering, smoothing and interpolation methods; spectral analysis.

9.1.7 Synoptic climatology

- Climatology of air masses: sources, characteristics and classifi cations on the surface and in the upper air;

- Principal weather regimes; circulation types; anomaly patterns; frequency of high and low pressure centres, tracks of high and low pressure; isallobaric charts; trajectories; Grosswetterlage; stagnating anticyclones, long waves, blocking, jet stream, frontal climatology; tropical disturbances and their climatic impact; index cycles; long-range transport of gases and particulates.

9.1.8 Upper-air climatology

- Upper-air data: standard levels and significant levels; temperature, water vapour (mixing ration of moist air), geopotential, wind; derived data: troposphere, jet stream, temperature inversion (base, top, geopotential temperature, humidity), cloud base, freezing or icing level, isobaric layer thickness;

- Atmospheric pollutants, ozone, aerosols.

9.1.9 Regional climatology

- Regional singularities and spells of weather.

9.1.10 Meso- and micro-climatology

- Mesoclimatology: definition and examples; fog (radiation, advection, upslope and inversion); effects of topography; air drainage; slope winds;

- Topoclimatology: climates of mountains and caves; variations in surface cover and land-use;

- Urban environments: anthropogenic heat sources; heat storage uptake and release; surface roughness; urban energy-heat balance and water budget; urban climate modification of cloud and precipitation;

- Microclimatology: influence of soil type and soil condition, vegetation and topography; sensible heat, latent heat and momentum fluxes; heat exchange and conduction near the soil surface and from water bodies; interaction between atmosphere and vegetation; altering the microclimate: frost prevention, mulches, windbreaks, shelterbelts; atmospheric pollution, effect of stability and wind on pollutant dispersion.

9.1.11 Climatic change and variability

- Orders of climate change: definitions; trends; discontinuities; fluctuations; oscillations; anomalies; geochronology; quaternary; recent as given by meteorological observations locally and globally;

- Evidence of climatic change: geological; proxy information; acquisition, interpretation and use in evaluating extremes of climatic conditions; proxy sources: past meteorological and oceanographic records, archeological information, tree rings, ice cores, seabed cores, sea-levels, fossils, corals, lake sediments, soils; observational records - statistical analysis trends, homogeneity, randomness, normals; the C_{14} method for dating; the O_{18}/O_{16} method for determining temperature;

- Theories of climatic change: terrestrial; astronomical: solar influences including sunspots; ocean/atmosphere interactions; surface albedo variations: atmospheric composition: dust, CO_2, ozone; back-feeding effects of atmosphere and surface conditions;

- Man's effect on climate: urbanization; anthropogenic sources of heat and moisture; contaminants - CO_2, ozone; land-use modifications;

- Impact of climate change on society: societal vulnerabilities; global interdependence; defensive strategies; effect of short-period fluctuations: advantages of climate change; impact of extreme events: range of events, cumulative hazards; sociological, political and economic systems;

- Climatic change information: incorporating knowledge into planning, design, operations; mitigating disasters, protecting resources; transferring climatological information;

- Future climates: monitoring climatic change; modelling; climatic prediction and verification.

9.1.12 Climate methods and statistics

- Descriptive statistics: probability theory: Markov chains; estimation problems: sampling error; data adjustment models;

- Tests of hypothesis: null and alternative testing; difference of means of independent samples; types of error; levels of significance; analysis of variance;

- Relationship problems: correlation and regression; significance testing; multivariate analysis: multiple regression, multiple and partial correlation; discriminant analysis; factor analysis; covariance; non-parametric tests; contingency tables;

- Time series: stochastic processes; spectrum analysis; autoregressive models; Fourier analysis, harmonic analysis; Markov processes; tests for randomness, trends, autocorrelation, persistence;

- Spatial series: spatial coherence; spatial correlation and regression analysis; orthogonal polynomial surfaces; spatial Fourier and spectral analysis; empirical orthogonal functions;

- Econometric statistics: value-added analysis; simulation modelling; cost/loss ratio; non-parametric statistics;

- Climatic diagrams: graphs showing time sequence, spatial distribution, one-dimensional frequency distribution; scatter diagrams; isopleth diagrams; vector quantities; wind roses;

- Climatic maps: consideration of scales, map size, grids, relief, projection, isoline intervals and tints; selection of data; interpolation and spatial averaging; climatic maps for applied purposes;

- Numerical analysis: numerical computations; matrices and matrix inversion; relaxation methods; interpolation methods; spectral analysis; numerical models; Fourier analysis; eigenvectors; Monte Carlo method.

9.1.13 Data-processing methods

- Computer applications in climatology: quality controls, statistical analyses, simulation models, software utilities, computer graphics, direct-user access, multi-data sources, climate services and on-line bibliographic searching;

- Climatic archives: data collection; archiving media; accessing records; file organization; data exchange; quality control;

- Programming applications: use of utility programs and systems programs, scientific statistics packages; summarizing data;

- Computational methods and analysis: smoothing and averaging; extrapolation, interpolation and adjustment; computing indices and risk statistics; computer simulation modelling;

- Climate services: data summaries, presentations and publications; inventories, catalogues and directories; mailing and distribution; servicing data requests; on-line literature searching;

9.1.14 Applied climatology

Applied climatology is the study of how climate data and information can be used in solving social, economic and environmental problems. It includes the preparation of historical and statistical data and the analysis of information for a wide range of planning, design and operational activities.

Training required for personnel engaged in applied climatology must be flexible and broad. Instructors are expected to suggest additional material and use regional case studies and examples to illustrate the applications.

9.1.14.1 General

- Methodologies and analysis: sources of economic, social and environmental data; problem-solving; econometric models; quantifying climate and economic activities; weighted climate indices; cost/loss ratios, benefit-cost analysis; resource appraisal; capital optimization; communicating with users; marketing and promoting.

9.1.14.2 Human biometeorology

- Climatic parameters for use in human biometeorology applications: extremes of temperature; air ionization and sferics; aerosols, air pollution, ozone; solar and infrared radiation and light, sunshine; wind, air turbulence; synoptic weather patterns; changes in atmospheric pressure; electrostatic and electromagnetic fields; acoustic waves (noise);

- Introduction: definitions; distribution on various scales (micro, meso, macro); biosphere; energy budget concepts;

- Environmental human physiology: thermoregulation; special problems of man in hot-dry, hot-moist and cold climates and at high altitudes; man-environment physical models;

- Epidemiology: individual health and disease; etiology of human health, disease and longevity, public health; climate-related diseases; demographic aspects of disease; sources of epidemiological data; nutrition and climate; pathological effects of heat, cold and high altitudes; deseasonalization;

- Comfort: protection, clothing, land use, indoor climates; climatotherapy, resort sites and planning; comfort indices; controlled environments;

- Human behaviour: acclimatization and adaptation; climatic determinism; sociological and psychological effects; survival; climate stress;

- Methods in biometeorology: investigative methods; morbidity and mortality records; sampling properties of climatological and epidemiological data; clinics and climate chambers;

9.1.14.3 Tourism and outdoor recreation

- Climatic parameters for use in tourism and outdoor recreation applications: air temperature; humidity; precipitation types, intensities and quality; cloud cover; visibility; wind speed; water temperature; snow and ice cover conditions; duration of daylight, radiation and sunshine;
- Facility and material design: siting facilities; performance of equipment and clothing;
- Event planning: travelling and touring; marketing and promotion of vacations; scheduling events and projecting attendance; advice for sporting competition;
- Fitness and health: health resorts; therapeutic climates; ultra violet potential for suntanning; activity participation; comfort.

9.1.14.4 Building and construction

- Climatic parameters used in building and construction applications: illumination; precipitation types and intensities; snow (accumulation and drifting); glaze ice; wind speed and direction; air pressure; temperature extremes; humidity; natural hazards (floods, hail, tornadoes, lightning); fog; albedo, solar radiation (altitude and azimuth) and sunshine; snow, wind, ice and hail loads; cloud amount; soil temperature and soil moisture, evaporation;
- General principles; use of reference year; transformation of data from airport-stations to urban areas; developing design values and standards; climatic conditions at the boundary layer and modification of these conditions caused by buildings; building processes; topoclimatology;
- Human settlements: urbanization; town planning for various types of climate; co-location of sites and services; water and energy supplies;
- Architectural and engineering design: structural safety; weather tightness: precipitation penetration, absorption, drainage, air leaks; thermal considerations; ventilations, air movement and wind pressure; natural illumination, daylighting and glare; water-proofing; building orientation; operation and maintenance;
- Construction materials: weathering, corrosion, material degradation; ultraviolet radiation, atmospheric chemistry and other stresses; safety; stockpiling; performance of materials and equipment; soil conditions; thermic variations;
- Climatic aspects of siting: landscaping, orientation and shading; accessibility; environmental impact;
- Energy: passive cooling and heating systems; insulation, degree-days; heat gains or losses on walls, roofs and windows; conservation, efficiency;
- Quality of life indoors; human health and comfort.

9.1.14.5 Agriculture

- Climatological parameters of use in agriculture: temperature; precipitation; degree-days, heat units, soil heat budget; soil moisture; atmospheric humidity; wind; sunshine and radiation; evaporation; soil moisture content and soil moisture tension; state of the ground (dew, snow cover, ice, etc.); climatic indices;
- Land potential: delimitation of natural farming areas (land zonation); soil conservation, desertification, tractionability, introduction of new crops;
- Food production and scheduling: growth units; phenological climatology; yield prediction; animal husbandry; grassland and pastoral production; horticulture; crop-water demands; irrigation; harvesting;
- Distribution: transportation, storage and processing;
- Agroeconomics: supply and demand for agricultural products; climatic variability;
- Combating hazards: weeds, pests, pathogens, pollutants, drought, floods, freeze, exposure, hail, strong winds.

9.1.14.6 Transportation and communication

- Important climatic elements: for marine transport; for air transport; for land transport; for pipelines and for communications;
- Facilities planning and construction: site selection; terminal construction; safety and comfort; vehicle design; loading facilities;
- Route planning and scheduling; navigation; operations efficiency and minimum time routing; artificial dispersal of fog; safety;
- Maintenance: tractionability; extreme weather elements;
- Cargo handling: storage, protection, need for refrigeration or heating; transport and shipping.

9.1.14.7 Energy

- Climatic elements for use in energy applications: sunshine, radiation; wind; high temperature and humidity and low temperature; atmospheric turbidity; ice accretion; soil temperature; water levels; waves; sea ice; surface roughness factor; snow loads; cloudiness and fog frequencies; lightning strikes;
- Exploration and exploitation: renewable energy sources: solar, wind, geothermal, tidal, hydropower, biomass; site selection; engineering design; environmental impact; desalination;
- Production factors: environmental impact; space-heating requirements; worker efficiency; engineering design; offshore drilling; supply interruptions; waste heat;

- Distribution and consumption: transmission design; heat storage; drying; fuel dispatching or load forecasts; conservation–passive measures e.g., vegetation, topography, shading.

9.1.14.8 Fisheries and oceans

- Sea ice; superstructure icing; wind; waves; sea swell; sea surface and bottom temperatures; surface heat budget; water motions; water quality; carbon flux; salinity;

- Fisheries management: yield; disease; predators; fish farming; fish culture; tactical support for fishing fleets; seaweed production; environmental conditions on the migration and spawning of fish;

- Production processes: distribution; productivity; survival; recruitment; biological factors in a marine environment;

- Environmental pollution: waste disposal; heat, oil and waste pollution; spill containment; transport and dispersion; ecological consequences;

- Coastal engineering design and transportation; coastal construction; engineering and maintenance; offshore mining.

9.1.14.9 Water

- Climatic elements for use in water resource applications: precipitation types and intensities; soil moisture surplus, storage and recharge; evaporation and evapotranspiration; groundwater; river and lake ice; water levels; water balance; glacial mass balance; streamflow;

- Planning and design: engineering design, protection, river flow regulation, hydrologic modelling;

- Operations: consumption, conservation, power;

- Water supply: flood forecasts, drainage, irrigation, diversion; rationing, conservation, multiple use conflicts, (irrigation, navigation, hydropower, recreation, consumption), water quality, modification schemes;

- Water-related disasters: flood, drought, landslide, earthquake, erosion.

9.1.14.10 Industry and commerce

- Climatic elements for use in industry and commerce: air temperature extremes; humidity, humidex; weather occurrences; snow and wind loads; ice accretion, ice fog; precipitation; wind chill; snowslides and avalanches; CO_2, aerosols, thermal pollution, fluorocarbons, turbidity, ozone;

- Distribution: storage (warehousing); packaging; spoiling and deterioration; shipping and movement;

- Pollution: control; potential assessment; tolerance; diffusion and dispersion; environmental impact; sources - natural and anthropogenic; emergency actions; containment; waste disposal.

INDEX

9.1.14.11 Forestry

- Climatic elements for use in forestry applications: temperature and degree-days; humidity; precipitation; wetness; wind speed and direction; rainfall interception; soil temperature and soil moisture; evapotranspiration; radiation; CO_2;
- Management: site preparation; regeneration; thinning; reproduction; fertilizing; harvesting; tending; recreation and other uses;
- Productivity: plantation regeneration; phenological climatology; heat units; biomass conversion; plant hardiness;
- Forest fires: prevention and control;
- Hazards: physiogenic - drought, water excess, freeze and ice, blowdown, air pollution, fire; biological - insect, disease.

9.2 SPECIALIZATION IN CLIMATOLOGY (CLASS II)

Class II staff are engaged primarily in the practical applications of climatology. They support professional climatologists in analysing maps and data, preparing data for processing and publication, writing programs or modifying supporting software, interpreting statistics and in answering a myriad of requests for climatological information. Consequently, to train personnel for this specialization, it will be necessary to provide training in techniques such as mapping, statistics, data processing and in applications such as agriculture, energy and water resources is required.

Candidates for Class II training should have had courses in chemistry, astronomy, geography, geology, biology, etc. before beginning specialization training in climatology.

9.2.1 General climatology; the physical basis of climate

- Definition of climate; branches of climatology;
- Components of the climatic system;
- Astronomical and geographic controls of climate;
- Using climatology in the weather forecast office (information, responding to requests, writing weather aids in forecasting).

9.2.2 Organization of a climatological service

- Responsibilities and structure of a national climatological service (services, data management, applications and consultations, research, monitoring and prediction, training);
- Planning and organization of climatological networks;

- Climatological observations and data;
- International climatology: WMO: World Climate Programme, Technical Commission for Climatology (CCl).

9.2.3 Regional climatology

- Climatic classifications - characteristics and limitations; classi cal and recent schemes; single-purpose classification.

9.2.4 Meso- and micro-climatology

- Concepts and principles in microclimatology; vertical profiles of temperature, moisture and wind in the layer near the ground;
- Urban climatology: energy and water processes; heat storage; examples of urban climate effects - temperature, precipitation, radiation, wind, moisture, visibility, etc.

9.2.5 Applied climatology

- Definitions and methods of analysis; sources of data; econoclimatic modelling; compiling indices and risk statistics; communication skills; identifying and serving user needs.

9.2.6 Climatic change

- Proof of climatic change; ice age chronology; pre-instrumental observations; instrumental time series.

9.2.7 Climatic methods and statistics

- Climatic maps and graphs: preparation, analysis and interpretation;
- Probability concepts: probability (prior and joint); return periods; randomness;
- Estimation problems: parametric estimation; confidence intervals and limits; standard error; adjustment of climate series for discontinuities of the station location and missing values;
- Tests of hypothesis: significance testing; tests of normality, homogeneity and goodness of fit;
- Relationships: method of least squares, regression; linear correlation coefficient; simple multi-variate analysis;

- Graphical presentation: normal probability paper; scatter diagrams; trend analysis; resultant wind analysis.

9.2.8 Data-processing methods

- Programming and computer operations; climatic archives; computational methods and analysis;
- Using computers for climatic services: data summaries; presentations and publications; maintaining inventories, catalogues and directories, distribution lists; printing and microfilming from magnetic tape (COM); computer graphics.

9.2.9 Climate services

- Climatic applications: defining user needs; relating climate to user needs; identifying climate factors; calculating and interpreting derived parameters; preparing, analysing and interpreting maps, tables and diagrams; applying problem-solving techniques; interpreting climate data/information to user;
- Information services: organizing technical reference systems; summarizing and preparing data for publication; developing climate reference materials; extracting data from source documents and scientific literature.

9.3 SPECIALIZATION IN CLIMATOLOGY (CLASS III)

Class III specialists in climatology should have a general background in physical geography or earth sciences that includes some knowledge of the earth's structure and landforms, the hydrosphere, global distribution of soil and flora, historical geology, mineralogy and topography.

9.3.1 Climatological data and observations

- Effect of network size and density.

9.3.2 Physical climatology

- Radiation (heat) and energy budget and energy transfer; measurement of radiation and sunshine, geographic variation of global, long-wave and net radiation; greenhouse effect and CO_2;
- Water budget concept and applications (agriculture, hydrology, land-use planning); water balance components (precipitation, evaporation, runoff, soil moisture, groundwater); modifying the water balance.

9.3.3 Synoptic climatology

- Air mass climatology; climatology of synoptic and dynamic features; case studies of common weather types; anomalous patterns.

9.3.4 Regional climatology

- Major climatic regions of the world; singularities and spells of weather.

9.3.5 Meso- and micro-climatology

- Importance of the air layer near the ground for agriculture, hydrology, human settlements, etc.;
- Modification of climate through windbreaks, cloud seeding, reduction of evaporation, frost prevention;
- Diurnal variations of temperature, humidity, wind, precipitation;
- Topoclimatology: effect of slope, valley and mountain; forest climate;
- Urban climatology: urban versus rural differences; urban heat island; air pollution climatology.

9.3.6 Climatic change

- Scales and importance of climatic change;
- Theories of climatic change: astronomical, atmospheric, terrestrial, man-made (inadvertent changes, climatic modification schemes);
- Climatic change and cycles: paleoclimatology; geochronology; climatic records; recent trends; forecasting climates; cycles;
- Impact of extreme events: range of events; cyclones; local storms; cumulative hazards.

9.3.7 Applied climatology

- Methodologies of, and problems in applied climatology;
- Presentation and interpretation of climatological information for selected applications in the fields of agriculture, energy, water, land-use planning, human settlements, building and engineering, human health and well-being, transportation, tourism and recreation.

9.3.8 Climatic methods and statistics

- Simple probability; independent events;
- Measures of dispersion: variance; mean deviation; standard deviation; interpreting standard deviation; coefficient of variation;
- Frequency distribution: percentage frequency; relative cumulative frequency (ogive) and histogram; quantiles; the normal distribution and its characteristics; normal probability paper; normalizing data;
- Relationships: curve fitting; simple regression; contingency tables;
- Time-series analysis: simple smoothing techniques (free-hand, semi-averages, trend analysis); moving means; persistence; periodicity;
- Data analysis: interpolation; data reconstruction and estimation (difference and ratio methods); double mass curve analysis; computing climatic normals;
- Graphical methods and mapping: tabulation and graphical presentation of data; isoline analyses; resultant wind analysis and trajectories; basic mapping principles.

9.3.9 Data-processing methods

- Climatological data handling by computer methods: decoding reports; quality control (error detection and validation); presentation of data and products; storage and retrieval;
- Operating systems: basic principles; use of input and output devices; machine carriers; basic programming; accessing cli mate archives via computers;
- Use of utility programs and system programmes for statistical methods; compiling indices; normals and departures; drawing graphs; plotting maps; publishing data.

9.4 CLASS IV PERSONNEL ENGAGED IN CLIMATOLOGY

Personnel of Class IV perform everyday clerical tasks of compiling tables, filing original climatological data, archiving of files and records, maintaining small libraries, etc. Some are engaged in more technical duties such as the preparation of monthly summaries, evaluation of autographic records, calculation of totals, means, departures from normal, etc.

The basic meteorological training contained in Sections 7.2.1 "General meteorology" and 7.2.2 "Meteorological instruments and methods of observation" has to be supplemented by the syllabus given below.

9.4.1 General climatology

- Definitions; climatic controls; climatic controls; branches of climatology.

9.4.2 Regional climatology

- Variety of climates and controls; classifying climate types; world pattern of average values of basic climatic elements; description of local or regional climates where training is conducted.

9.4.3 Applied climatology

- Uses of climatological records; value of climatological data and information; applications of climatology to food production, energy, water, etc.

9.4.4 Climatic change

- Orders of climatic change; man's effects on climate.

9.4.5 Climatic services

- Completing requests for climatic data and publications; calculating daily, weekly, monthly and annual totals and means.

9.4.6 Climate data handling

- Meteorological instruments and observational procedures; coding and decoding climate messages; reading autographic records and charts; checking and quality control of climate data; maintenance of climatological records; document storage and cataloguing; maintaining inventories of climatological stations and catalogues of data and information; use of computer terminals.

9.4.7 Methods of climatological analysis

- Descriptive statistics: populations versus samples; calculations of central tendency (means, median, mode); calculating averages and selecting extremes from a list of data; running means; degree-day accumulations; computing indices; the range; normals and departures;

- Summarizing data: grouping data; computing frequencies from raw data; frequency intervals; tabulating data;

- Rounding and truncation procedures; estimation of missing observations in a series;

- Graphical methods: uses and characteristics of diagrams (pie, bars, histogram); plotting scattergrams and climograms; wind roses; transposing analysis fron one map to another;

- Use of calculators and computers: tabulations, punch cards; routine computer processing procedures.

9.4.8 Practical exercises

- Summarizing data; constructing tables and diagrams or graphs; plotting maps; letter writing and filling simple requests; using computer terminals; computing indices, degree-days, running means, departures from normal); converting units and rounding off numbers; estimating missing data.

CHAPTER 10

SPECIALIZATION IN MARINE METEOROLOGY

FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL

INDEX

10.1 INTRODUCTION

The oceanic regions of the globe are vast, covering nearly three quarters of the Earth's surface. Marine meteorology, which deals with the atmosphere over these regions and the interaction between ocean and atmosphere, and which must also take the upper ocean into account, is necessarily distinct from studies of the behaviour of the atmosphere over land. It has to be considered as a separate subject with its own requirement for training facilities and programmes for different types of personnel. These range from those who ply the seas and oceans for trade, ficheries sport or offshore developments, to those meteorological personnel at sea or ashore engaged in the issue of weather forecasts, in making observations, or in climatological duties in support of a wide range of marine activities. All seafarers and their advisors upon meteorological affairs need specialist training in marine meteorology and physical oceanography. It is necessary that courses, facilities, sea training and refreshers should be established for the various requirements of these differing personnel.

10.2 CLASSIFICATION OF PERSONNEL REQUIRING TRAINING IN MARINE METEOROLOGY

The types of personnel requiring training in marine meteorology are:

(a) Meteorological personnel who serve marine activities;
(b) Port Meteorological Officers (PMOs);
(c) Seafarers whilst at sea and in navigation schools;
(d) Marine observers on board ships.

Each class of marine meteorological personnel requires training both in formal meteorology and additionally in marine meteorology to the various standards necessary for their particular tasks. The relationship of each type of personnel to the general requirements of the related Class level and the extent of marine meteorological training required may be illustrated broadly by a summary table (Table 1).

10.3 SPECIALIZATION IN MARINE METEOROLOGY (CLASS I)

10.3.1 General

The attention of the national and international meteorological communities has been increasingly focused on the ocean areas. Meteorologists are concerned about the sparse data over ocean areas which inhibit the excellent progress being made in the computerizing of global analyses and prediction. Ocean/atmosphere interaction, and the oceans themselves, are the subject of increasing investigation and research as knowledge is sought of the precise relationships and the influence of the oceans on the atmosphere. It is becoming increasingly clear that longer range prediction requires a precise knowledge of the heat and energy exchange and of the short and long term anomalies of synoptic ocean conditions. Industry is directing greater attention to the mineral and food resources of the oceans and in consequence the exploration and proper exploitation of these resources must receive increased associated meteorological support in the interests of safety, economy and efficiency and the necessary control measures for problems such as marine pollution.

Table 1

Class of Meteorological personnel	Marine meteorological personnel		Training required (2)	
	Shore based	Sea going	General Meteorology	Marine Meteorology
Class I	Chief forecasters	-	4 yrs combined (minimum)	8 months(1) (minimum)
Class II	Forecasters PMOs	Masters Chief	2 yrs combined	11 months on site (minimum)
Class III	Assistants Technical	Deck Officers	8 - 10 months	2 months Extensive on site
Class IV	Observers	Marine observers	4 months	1 month Extensive on site

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Meteorological Services

(2) Includes training periods at sea for deck Officers

The total meteorological community should, therefore, expand its fundamental knowledge of the ocean/atmosphere relationships and of environmental conditions in ocean areas and should train meteorological personnel so that specialized meteorological services can be provided appropriate to the expanding specialized needs of marine interests.

This increasingly vital need is illustrated by the reference to an emphasis on meteorological factors in the UN General Assembly Resolution No. 2172 - Resources of the Sea; in "International Ocean Affairs" a special report arising from this resolution; in "Marine Science and Technology: Survey and Proposals" the detailed report by the Secretary-General of the UN; by the forming of joint panels and working groups of WMO with IOC and FAO to ensure mutual consideration of common areas of interest.

The training required for personnel who will be concerned with specialization in marine meteorology must be of a flexible nature. The need for specialized support will vary with the type of marine activity, with the ocean, the country involved, the industries and services requiring the support, and with advances in technical and scientific capabilities. This syllabus is, therefore, an attempt to indicate the broad nature of the training that may be appropriate in whole or in part to the training institutes concerned. The content as given below is intended, therefore, to be a guideline which should suggest the addition of other material which, to the teaching staff, is relevant to the particular purpose of the training courses being given.

Since the course material must, at this period of international development and rapid change, be flexible, it is presented in two levels only, Class I and Class II which differ in degree more than in nature and can be developed from the same basic outline. Similarly the training for Class III and Class IV can be developed from a single set of course material of a technical nature.

10.3.2 Knowledge and appreciation of marine activities influenced by the environment

- Ocean transportation: surface and sub-surface operations; waves, their influence on safety, economy, comfort; sea ice, its nature, occurrence and influence; ship design; influence of wave characteristics and power spectrum; weather navigation; insu rance rate variations; pitch and roll; ship stability, loadlines; superstructure icing;

- Ocean resources: biological - main food groups; general nature of fishery operations, value, distribution and bi-products; marine algae; seaweed production; mariculture; marine mammals; mineral - explor-ation activities; oil and gas; chemical recovery from sea water, salt, bromine, phosphate; desalination activities;

- Waste disposal and marine pollution: heat, oil and waste pollution;

- Other ocean activities: marine research projects and meteorological components; ocean and coastal engineering - corrosion, hydrostatic pressure, design and construction of rigs, buoys, structures - floating and submerged; marine communication, telephone/telegraph power cables; recreational activities; influence of wind, wave and surf conditions and of storm tides; of sediment and sand flow and pollutants; shipment of perishables, influence of humidity and temperature.

10.3.3 Environmental information requirement

- Need to examine each activity to determine its unique relationships with and sensitivities to the environment and to state definite specifications for the environmental information needed, e.g., pelagic fisheries;

- Evaluation of the related marine environmental factors, e.g., effects of varying environmental conditions on the migration and spawning of fish;

- Examination of the available information and knowledge in relation to the required environmental information, e.g., turbulent and radiative fluxes, effect of medium and synoptic scale motion, ocean convective processes;

- Assessment of data requirements, both present and past and of adequacy of existing data, e.g., temperature at selected levels, and of potential additional sources of needed data. Means of acquisition of meteo-oceanographical data;

- Development of special area studies to provide additional experimental knowledge, to evaluate hypothesis, and for field testing of procedures;

- Establishment of consolidated ocean/atmosphere data files of relevant recent and historical data, and of techniques for rapid retrieval and processing of the data;

- Stating the requirement for additional research covering insufficiently understood elements of the area of specialized service being examined;

- Distribution of forecasts and reports; coastal weather stations; radio-telegraphic and radiotelephonic networks; facsimile; reception of satellite pictures on ships and oceanic platforms.

10.3.4 Oceanography

- Physical properties of sea water: units used in oceanography, ranges, salinity, density, dependence of density on temperature and salinity, heat capacity, diffusion and mixing of properties in the ocean;

- Dynamics of upper ocean: gravity, density and pressure, frictionless ocean currents, geostrophic currents, slope of the sea surface, horizontal currents in a stratified ocean, inertia currents, currents including friction forces, drift current, thermohaline circulation, upwelling, effects of upwelling, mapping of currents;

- Heat balance of the ocean: the heat balance, air-sea interaction, structure of the boundary layer, exchange coefficient and profiles;

- Ocean structure: water masses, ocean fronts and thermoclines: mixed layer depth, halocline, temperature salinity diagram and mixing of water masses, deep and bottom water masses, intermediate watermasses, central watermasses, temperature and salinity range of main water-masses; temperature of air masses over the ocean;

- Platforms and instruments: platforms, instruments, current meters, bathythermographs, reversing thermometer, salinity measurement (Nansen bottle), light in the see (Secchi disc);

- Ocean resources: biological relationships, environmental influence on fish behaviour (a) the effect of sea life on the marine life cycle; (b) effects of current on fish behaviour; (c) effect of light stimulus on fish; (d) miscellaneous influence; scope and limitations of fisheries; forecasting; meteorological aspects of fishery predictions;

- Sea ice: formation of sea ice, breakup of sea ice, physical characteristics of icebergs, ice observation by satellite;

- Sea waves, swells, tsunamis and storm surges: some definitions: group velocity, generation of sea waves, origin and propagation of swell, tsunamis, storm surges positive and negative;

- Under-water acoustics: nature of sound, velocity of sound, propagation modes, refraction of sound waves, factors affecting sound transmission in the ocean: (a) bottom effects; (b) sound velocity profile, propagation diagrams, application of acoustic techniques.

10.3.5 General knowledge of agencies and organizations concerned with ocean areas, their functions and facilities

- The World Meteorological Organization (WMO) and its Commission for Marine Meteorology (CMM);

- The Food and Agriculture Organization (FAO) and its Committee on Fisheries (COFI);

- Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO);

- International Maritime Organization (IMO);

- Scientific Committee on Oceanic Research (SCOR);

- International Council for the Exploration of the Sea (ICES);

- International Commission for the Northwest Atlantic Fisheries (ICNAF);

- An awareness of international developments related to ocean activities, e.g., United National Resolution 2172 on "Resources of the Sea", the International Indian Ocean Expedition (IIOE) project, the Law of the Sea;

- Concepts of publications and committees related to the marine environment, e.g., World Weather Watch (WWW), Advisory Committee on Marine Resources Research (ACMRR) of FAO, the Pardo proposals to United Nations General Assembly, November 1967, the Planning Report Series for WWW, e.g. No. 15 on Services to Shipping, FAO's Paper "Fishermen and the Weather".

10.3.6 Specialized knowledge related to the marine environment

- Air/sea interaction: exchange of energy: turbulent fluxes of sensible heat, turbulent fluxes of latent heat, turbulent fluxes of momentum, radiative fluxes of net incoming radiation, radiative fluxes of outgoing radiation, radiative sea surface heat budget, energy transport by marine currents, exchange of matter: gaseous substances (CO_2, O_2, etc.), liquid and solid substances (sea salt, etc.), electrically charged particles, organic substances;

- Scales of motion: atmospheric, in vertical and horizontal; oceanic, in vertical and horizontal; with time, short, medium and long range;

- Typical processes, e.g. near shore processes; wave action; air mass and water mass modification; diurnal variation of atmosphere and ocean elements;

- Interdependence of ocean and atmosphere; generation and propagation of anomalies of circulation, temperature and composition of atmosphere and ocean; influence and control exercised by one on the other;

- Methods of obtaining ocean observations, their capabilities and weaknesses: bathythermometers and thermographs; infrared ra diometry measures and corrections, satellite radiometry, airborn radiometers; temperature profiles; salinity, current, chemical and opacity measurements; colour as a water mass identification; sound propagation in water; buoy observations;

- Water mass boundaries; major and minor thermoclines; layer depth; halocline and upper zone; upwelling; daily and seasonal ocean characteristics;

- Knowledge of sea ice observing, analysis and prediction procedures and methods;

- Knowledge of wave observation, analysis and prediction procedures and methods, with application of wave information to selected typical problems, e.g., ship routeing, ship design;

- Application of marine environmental information to coastal construction, engineering and maintenance activities, to tsunami warning services and harbour environmental advisory services;

- General knowledge of the organic resources of the oceans; main types of ocean food; harvesting methods;

- Ocean pollution problems; contribution and influence of the environment, including pollution fall-out, wind, currents, air and water turbulence and convective patterns;

- Study in depth of the influence of the environment on a typical marine activity i.e., off-shore drilling and exploiting operations or fishing industry operations (for pelagic, bottom or coastal fish), e.g., fish migration, susceptibility to temperature change, feeding patterns, influence of nutrients and mineral substances, phytoplankton, and

zooplankton concentrations, coastal estuary and island effects on air and water conditions, influence of the thermocline and water density patterns.

10.4 SPECIALIZATION IN MARINE METEOROLOGY (CLASS II)

As for specialization in Marine Meteorology (Class I), section 10.3. The topics should be selected and the material covered to the degree appropriate to the purpose of the Class II training being given.

10.5 SPECIALIZATION IN MARINE METEOROLOGY (CLASS III)

The training in marine meteorology for Class III meteorological personnel should be such as to enable them to provide competent assistance in a marine meteorological office, whether operational, climatological, Port Meteorological or other. Some may take specialized observations, install instruments, work on research projects, train marine officers or take sea ice observations. They need an appreciation of the marine environment and a basic knowledge of conditions at sea, including the adequacy of marine networks and observations and an ability to relate this knowledge to operational and climatological processing in support of marine activities and interests.

10.5.1 Elements of oceanography

10.5.1.1 General geography of the seas

- Formation of the seas; extent of the seas;
- Dynamics of the ocean bottom; morphology of the ocean bottom; the Continental Shelf;
- Classification of oceanic areas: the oceans and the secondary seas.

10.5.1.2 Temperature of the sea and ocean-atmosphere interactions

- Heat balance: evaporation and condensation;
- Time and space variations of temperature; mixing layer; thermocline;
- Survey of forecasting methods for sea surface temperature; charts;
- Some aspects of air-ocean interaction.

10.5.1.3 Marine currents

- Generating forces; draft currents, density currents and slope currents;
- Upwelling;
- Oceanic circulation; major oceanic currents.

10.5.1.4 Waves

- Characteristics: generation, development and propagation;
- Survey of forecasting methods for waves and swells; state of sea charts.

10.5.1.5 Ice

- Sea ice and ice of land origin: fast ice and pack ice, icebergs; Arctic and Antarctic;
- Ice accretion on ships.

10.5.1.6 Tropical disturbances: cyclones and typhoons

- Formation and development stage: areas of formation, season, track and conditions for formation;
- Mature stage: clouds, wind, temperature, pressure and swell; storm surge;
- Decay stage;
- Tracking the movement: ship reports, radar reports, reconnaissance reports and satellite data;
- Counter measures against cyclones.

10.5.2 Meteorological instruments and methods of observation

10.5.2.1 Surface observations at sea

- Observing stations: WMO Voluntary Observing Ships, other sources of observations from sea areas;
- General requirements of observations: Selected, Supplementary and Auxiliary ship stations, equipment required; hours of observations for synoptic purposes and special purposes such as when there is a cyclonic storm, etc., times of transmission of observations;
- Systems: deep depression in temperature zones, tropical storms;
- Wind speed and direction: estimation of wind through sea state, wind measurement with instruments, computation of true wind from instrumental values, reporting winds, pressure systems and winds, estimation of wind from pressure systems, oceanic wind cyclones, special wind phenomena near coasts;
- Atmospheric pressure: units of atmospheric pressure, instruments for measuring atmospheric pressure at sea, variation of atmospheric pressure - diurnal, latitudinal and vertical variation;

- Air temperature and humidity: temperature scales, instruments for measuring temperature and humidity at sea, procedures for measuring temperature and humidity on board, dew point;

- Sea-surface temperature: the temperature to be observed and methods of observation, variation of sea-surface temperature, influence of sea-surface temperature on weather;

- Visibility: meteorological visibility; estimation and reporting of visibility at sea;

- Clouds: classification of clouds, description of clouds, reporting of cloud type, amount and height;

- Precipitation: type of precipitation, estimation of precipitation by visibility, instruments for measurement of precipitation at sea, measurement of precipitation at sea;

- Wave observations: sea and swell, wave observations, wave measuring devices, wave refraction, tsunamis, forecasting of waves;

- Ice observations: formation, movement, decay of sea ice observations, ice nomenclature;

- Ice accretion on ships: causes for ice accretion on ships, effects of ice accretion on ships, reporting of ice accretion at sea, forecasting of ice accretion at sea.

10.5.2.2 Sub-surface oceanographic observations

- Types of observations: physical oceanographic observational requirements and their measurement on board ships;

- Buoy observations at sea: construction and maintenance of buoy systems; types of buoys for measuring meteorological and sub-surface parameters; sources of errors in parameters measured by buoy systems;

- Surface currents: current measurements, ocean current observa tions by ships.

10.5.2.3 Upper-air observations on board ships

- Mobile network of aerological stations at sea, radiosonde, launching radiosonde from a ship;

- Measurement of upper winds by pilot balloon and radar methods.

10.5.2.4 Ship observations

- Recording and reporting: recording of observations on mobile ships, collection and dissemination procedures; transmission problems, future plans for collection of observations; plotting of ships' reports;

- Ship codes: surface and upper-air weather reports from ships; surface and upper-air climatological reports from fixed ocean stations; international analysis code for ships; forecast code for shipping; sub-surface reports from sea stations.

10.5.3 Marine meteorology

- Marine activities: scope and general nature of marine activities and the influence of the environment on them, e.g., transportation and shipping of perishable or non-perishable goods, fishing, ocean exploration and research, ocean pollution, ship design and structural problems, weather navigation and general ship operation;

- Relationships with oceanography, biology, geology, etc.; mutual need for data; use of buoys and other multi-use platforms; scarcity and reliability of overall environmental data; organizations and agencies involved in marine relationships;

- Existing marine support systems: the WMO marine meteorological services system; the companion ocean system IGOSS; problems of data communication; the allocated area of responsibility for routine support (forecasts, warning and advisories) and for marine climatological summaries; an appreciation of adequacies and deficiencies in existing support for marine activities along the lines of the WWW Planning Report No. 15 (The Global Data-processing System and meteorological service to shipping);

- Marine data: difficulties related to voluntary observers, moving platforms, sparse areas, commercial and unscheduled radio relays, as in WWW Planning Report No. 25 (System for the collection of ships' weather reports); potential improvements using, e.g., buoys, satellites and automated equipment;

- Application of marine support: examination of need and definition of precise information required for two typical marine activities, one operational, the other of a planning nature; preparation of plans for associated support based on known and available information; evaluation of adequacy of the support and of additional data; studies and processing required;

- General knowledge of principles and nature of marine forecasting; ice and wave forecasting; distribution of advice by radio, facsimile and other means;

- Marine observing instruments: general knowledge of the nature, operation and characteristics of instruments used only for marine observing; the lack of standards for certain measurements; the need to identify what should be measured, and where and how.

10.5.4 Marine meteorological services

10.5.4.1 General

- International programme; weather and sea bulletins for high seas; form and content of weather and sea bulletins; radio-facsimile charts.

10.5.4.2 Specialized marine meteorological services

- Weather routeing of ships; meteorology in connexion with cargo care; meteorological services to fisheries, offshore mining, coastal activities and to assist operations of marine pollution; other specialized services.

10.5.4.3 Port meteorological services

- Port Meteorological Office, duties of the Port Meteorological Officer.

10.5.4.4 Charting

- Charting of surface chart, upper-air chart, anomaly chart, constant pressure chart and tephigrams.

10.5.5 Marine climatology

- Climatic elements and their observation at sea, meteorological log books, collection and scrutiny of log books, International Maritime Meteorological Punch Cards, historical sea surface temperature data project, marine climatological summaries, averaging of data, marine climatic atlases and charts.

10.6 CLASS IV METEOROLOGICAL PERSONNEL ENGAGED IN MARINE METEOROLOGY

Class IV meteorological personnel should receive sufficient training in the marine area to enable them to have a basic knowledge of the existing marine observing system, the procedures and their adequacy, of the environmental data needed from both atmosphere and ocean and of the interdependence of the ocean and atmosphere.

This knowledge can be gained through courses based on the syllabus covering marine meteorology for Class III meteorological personnel (section 10.5) while limiting the scope and degree of the material covered.

10.7 TRAINING OF PORT METEOROLOGICAL OFFICERS (PMOs) IN MARINE METEOROLOGY

10.7.1 Duties

Port Meteorological Officers are an important link between land based marine meteorological services and meteorological personnel on board ships. They are positioned at ports to facilitate easy visits to ships, to provide necessary meteorological and oceanographic services to ships, and are provided with transport for the purpose. Their location makes it easy for shipboard meteorological personnel to call on them and they have a great role to play for the success of meteorological and oceanographic programmes on board ships.

10.7.2 Training

The training requirements and curricula for Port Meteorological Officers are the same as those given for Class II meteorological personnel occupied in marine meteorological services (section 10.4).

The training should also include sea voyages on board a ship with meteorological and physical oceanographic equipment, to help appreciation of the prevailing conditions over the sea. Trainees also gain first hand knowledge of:

- The ideal conditions for exposure of instruments;
- Taking meteorological and physical oceanographic observations;
- Problems, if any, in the transmission of observations taken on board ship;
- Nature of weather bulletins etc., received by radio;
- Reception of weather data over RTT, weather charts by facsimile and satellite cloud pictures through an Automatic Picture Transmission (APT) ground station on board ship.

10.8 TRAINING OF SEAFARERS IN MARINE METEOROLOGY WHILST AT SEA AND IN NAVIGATION SCHOOL

10.8.1 Duties

Masters and Chief Officers of ships receive meteorological forecasts and other services from land-based centres. Whilst not responsible generally for making forecasts, there may be times, for instance when in the vicinity of a storm field, they may have to use their training in forecasting for survival and safety. They should also be able to assess the measure of reliability that may be placed on a forecast. In times of necessity they should be able to forecast weather from the meteorological charts received by radio facsimile on board ships. If an APT receiver is available, they should be able to interpret the cloud pictures received from weather satellites and make best use of them. They should also organize meteorological and oceanographic observations and arrange their dissemination.

Deck officers of ships make meteorological and oceanographic observations; prepare weather charts from data received in sea area bulletins or through RTT reception: receive by facsimile broadcast surface and upper air weather charts both synoptic and prognostic; maintain meteorological and oceanographic logs. The radio officer records synoptic weather observations; he receives the broadcast sea area meteorological and oceanographic bulletins and transmits meteorological and oceanographic observations to coastal radio stations.

Marine observers on board of WMO Voluntary Observing Ships are responsible for the accurate recording and reporting of weather observations, which is a voluntary addition to their duties. These personnel make surface and, from some ships, upper air observations. They may also make physical oceanographic observations such as bathythermograph readings. They should also arrange the transmission of these

observations. The maintenance of instruments under the direction of Class III personnel is also their responsibility. Plotting of weather charts, maintenance of meteorological logs, reception of weather charts over facsimile and reception of weather data over RTT, are other duties which they may have to perform.

10.8.2 Training

The training requirements and curricula in marine meteorology for seafarers will vary somewhat according to the level of duties required by different authorities and national practices. However, the basic requirements for Class II and Class III marine meteorological personnel, together with adequate seagoing training should be met. As a guide to the content of this marine meteorological training a set of syllabi for Masters and Chief Officers, and Deck Officers and Marine Observers on board ships are suggested in sections 10.9 and 10.10 respectively.

10.9 SYLLABUS FOR MASTERS AND CHIEF OFFICERS IN MARINE METEOROLOGY

10.9.1 Meteorology

10.9.1.1 Dynamic meteorology

- Newton's laws of motion; equation of absolute motion, component equations; equation of continuity, motion in relation to pressure surfaces and isentropic surfaces; equation of motion;
- Balanced motion - geostrophic wind, cyclostrophic wind, inertial wind, cyclonic and anticyclonic flow;
- Kinematics of quasi-horizontal motion; divergence, convergence and vertical motion; barometric tendency equation; vorticity;
- Vertical structure of wind systems, thermal wind equation.

10.9.1.2 Thermodynamics

- Units and dimensions; Gas Laws, ideal gas equation; first and second law of thermodynamics; work and energy; specific heat of gases; adiabatic process; potential temperature;
- Moisture in the atmosphere - Clapeyron's equation, saturated adiabatic lapse rate;
- Thermodynamic diagrams; Normand's theorems, equivalent potential temperature;
- Stability and instability by parcel method and slice method; variation of stability with vertical motion; convection and entrainment;

- Gravity; geopotential; pressure height curves; precipitable water vapour; rate of precipitation.

10.9.2 Climatology

- Earth–Sun relationship; cause of seasons; radiation balance;
- General circulation of the atmosphere over the globe; convective circulation; meridional circulation; waves and vortices in zonal belts
- Distribution of pressure and temperature over the surface of the Earth; climatic zones; diurnal and annual variation of surface temperatures in different latitudes;
- Relation between wind and pressure; effect of land and sea on wind; monsoon circulation; wind and pressure distribution at higher levels;
- Rainfall and its distribution over the globe; the effects of continents and oceans on rainfall; effect of altitude on precipitation; diurnal and annual variation of precipitation, snow, evaporation, cloudiness, fog, etc.;
- Upper-air circulation over the world;
- Climatology of air masses, fronts, cyclones and anticyclones;
- Regional climatology; climatology of different countries, Arctic, Antarctic and other oceanic areas.

10.9.3 Synoptic meteorology

- Air masses: production and transformation of air masses, conservative properties, air masses sources in winter and summer, classification of air masses;
- Fronts: surface of discontinuity; structure of fronts; classification of fronts; kinematic and dynamic boundary conditions; frontogenesis and frontolysis; principal frontal zones;
- Extra-tropical cyclones and anticyclones: cyclone model; life cycle of cyclones; fronts and weather; occlusions; thermal structure of cyclones; cyclone family. Theory of cyclone development; forecasting guides; anticyclones; cut off cyclones and anticyclones; blocking; index cycle;
- Tropical cyclones: life cycle, surface and upper-air structure, pressure, temperature, wind, humidity, and cloud fields; energy aspects; formation of tropical storms; theories of formation; intensification and motion of tropical storms;
- Jet stream: polar front jet stream; subtropical jet stream; polar night jet stream; easterly jet stream; characteristic features of the various jet streams; theories of formation; weather development; cloud and clear air turbulence;

- Synoptic features in the equatorial regions in different seasons of the year;

- Special topics: radar meteorology and satellite meteorology with special reference to cyclone detection.

10.9.4 Marine meteorology

The syllabus is the same as that for marine meteorological Class II personnel outlined in section 10.4.

10.10 SYLLABUS FOR DECK OFFICERS AND MARINE OBSERVERS ON BOARD SHIPS

10.10.1 Meteorology

- General idea of the atmosphere: insolation, terrestrial radiation, temperature zones of the world; diurnal and seasonal variation of atmospheric temperature over land and over sea; dry adiabatic lapse rate, saturated adiabatic lapse rate, variation of temperature with height; troposphere, stratosphere, tropopause;

- Atmospheric pressure: diurnal variation; seasonal variation; barometric tendency; storm prediction by observations of atmospheric pressure; the use of barometric observations and weather signs at a single station to predict the development and movement of a depression or storm;

- Water vapour in the atmosphere: evaporation, condensation, precipitation, relative humidity, saturation and dew point; Foehn wind effect; formation of dew, hoar frost, glazed frost, and rime; the differences between drizzle, rain, shower, snow, hail;

- Visibility: definition; judging and reporting visibility; meaning of mist, fog, haze, spray and their effect on visibility; types of fog: radiation fog, advection fog, smog, Arctic smoke, orographic fog; dust storm; thunderstorm; hail;

- Clouds: formation by turbulence, orographic lifting, convection currents and frontal lifting; classification due to height and appearance of the ten basic types commonly seen and their abbreviations;

- Phenomena: thunderstorm, tornado, water spout, rime, snow, sleet, dew, rainbow, halo and corona;

- Pressure gradient and wind: isobars; pressure gradient; Coriolis force; geostrophic wind scale; angle of indraft; meaning of veering, backing, gust, squall; Buys-Ballot's law and cautions when applying it; the Beaufort wind scale and Beaufort weather notation;

INDEX

- Isobaric patterns: the recognition of and the weather associated with straight isobars, depression or cyclone, anticyclone, ridge, col, and trough (frontal and non-frontal); elementary ideas of air masses, fronts and extra-tropical depressions;

- General pressure and wind distribution: the ideal condition; the seasonal situation; prevailing winds;

- Periodic and local winds: land and sea breezes; monsoon; anabatic and katabatic winds; Norwester, Elephantas, etc.;

- Practical: cloud pictures from weather satellites and their interpretation; precipitation echoes from radar and their interpretation.

10.10.2 Marine meteorology

The syllabús is the same as that for Class III and Class IV marine meteorological personnel outlined in sections 10.5 and 10.6.

CHAPTER 11

SPECIALIZATION IN AERONAUTICAL METEOROLOGY

FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL

INDEX

11.1 SPECIALIZATION IN AERONAUTICAL METEOROLOGY (CLASS I)

The development of a world-wide air transportation system calls for efficient meteorological service in all parts of the world, thus enhancing the need for guidance to administrations in regard to the standard they should aim at in the recruitment and training of personnel for the field of aeronautical meteorology. The quality of the meteorological service provided is a major factor in safe and economic air transportation. Changes in navigational systems enable the new types of aircraft to land under lower minima; meteorological observations and forecasts of even greater accuracy than before will thus be required. This will make it imperative that the personnel engaged in the activities of an aeronautical meteorological service be highly qualified and fully aware of the importance of their responsibilities.

The education and training of Class I personnel engaged in the provision of meteorological forecasts for aeronautical purposes should be programmed in a similar manner to that of Class I personnel engaged in dynamic, physical or synoptic meteorology. This should be supplemented by special courses in aviation knowledge and procedures for meteorological service to international air navigation. Syllabi for these subjects are given below.

11.1.1 Aeronautical meteorological knowledge

11.1.1.1 Aircraft icing

- Theory of formation; processes and dependence upon temperature; drop size; liquid water content; airframe configuration and aircraft speed;
- Types of icing; clear ice; rime ice and hoar frost;
- Ice accretion rates; association with cloud types (stratiform and cumuliform clouds); thunderstorms; freezing precipitation; orographic and frontal lifting effects;
- Methods of forecasting the risk of ice formation and means of avoiding icing areas;
- Formation and effects of in-flight structural icing on different types of aircraft, e.g., on wing and tail surfaces, propellers, rotor blades, Pitot tube, antennas and windshield; formation or deposition of structural icing, including frost, on parked aircraft;
- Formation of in-flight icing in engine systems for piston, turbo-prop and turbo-jet engines.

11.1.1.2 Turbulence

- Turbulence near the ground; mechanical turbulence as a function of wind speed, wind shear and terrain roughness; convective turbulence as related to hydrostatic instability; effects of boundary-layer turbulence on take-offs and landings of aircraft; turbulence related to clouds, fronts and thunderstorms;

- High-level turbulence (CAT); association with horizontal and vertical wind shear, jet stream, stability and tropopause inversion;
- Mountain wave turbulence applied to both boundary layer and high-level;
- Gravity waves;
- Wake turbulence;
- Methods of forecasting the risk of the existence of turbulence; means of avoiding turbulence areas.

11.1.1.3 Other meteorological phenomena hazardous to aviation

- Reduced surface visibility; fog - its manner of formation and dissipation; the relationship of visibility to fog type and duration, to sandstorms and duststorms, to the various hydrometeors such as rain, drizzle, snow, blowing snow and to air pollutants such as smoke;
- Knowledge of the theory and practical techniques for the artificial dissipation of fog and low clouds affecting aerodromes;
- Thunderstorms; association with in-flight turbulence, hail, icing and lightning; surface conditions related to thunderstorms such as strong, gusty winds, wind shifts, poor visibility; frontal and airmass thunderstorms; squall-line thunderstorms;
- Low-level vertical wind shear associated with marked inversions and/or low-level jet streams;
- Specific knowledge in the interpretation of weather radar information towards making short-term forecasts for the terminal area;
- Vertical wind shear in the approach and landing phases of flight.

11.1.1.4 Meteorological aspects of flight planning

- Meteorological basis for pressure-pattern flying; definitions of rhumb line, great circle and composite tracks; wind components;
- Least-time tracks; use of D-value; determination of drift angle;
- Requirements for en-route wind, temperature and weather forecasts and forecasts for terminal areas for preliminary operational planning, preflight planning and in-flight planning;
- Preparation of area forecasts, route forecasts (e.g. cross-sections) and flight forecasts;
- Special emphasis on the importance and techniques of briefing of flight crews and operational personnel.

11.1.2 Aviation knowledge (*)

11.1.2.1 Definitions

Aeronautical meteorologists should be familiar with the ICAO definition of terms which have conventionally limited meaning when used for international aviation purposes. In particular they should be aware of the meaning of, and distinctions between the following terms:

- Air-report (consisting of position information, operational information and meteorological information), meteorological report, briefing, forecast, aerodrome forecast, landing forecast, observation, SIGMET information, visibility, runway visual range;
- Altitude, elevation, height, density altitude, pressure altitude, flight level, cruising level, transition altitude, transition level, transition layer;
- Operator, operator's local representative, pilot-in-command;
- Flight information region, controlled airspace, advisory airspace, controlled area, control zone, ATS route, airway, advisory route, air traffic control service, air traffic advisory service, flight information service, alerting service, area control, approach control;
- Aerodrome, instrument runway, landing area, movement area, approach, final approach, circling approach, initial visual approach and missed approach areas; take-off and climb-out directions;
- "Service:, "provide", "issue", "make available", "supply".

11.1.2.2 Procedures for meteorological services for international air navigation

Aeronautical meteorologists should have a good knowledge of the following, together with the corresponding regional procedures and plans:

- Area forecast systems; area forecast centres and their functions;
- Meteorological offices and their functions; aeronautical meteorological offices (classes and functions), meteorological watch offices;
- Aeronautical meteorological stations and their functions; routine and special observations, selected special reports, reports for take-off or landing;
- Landing forecasts; self-contained and trend-type, period of validity, format;

(*) This section is based on the chapter "Aviation knowledge" of ICAO Doc. 7192 - AN/857 PART 7, Training Manual, Part 7 - Aeronautical Meteorological Forecasters. The manual contains information on relevant ICAO training aids and publications.

- Aerodrome forecasts; area covered, period of validity, amendment criteria, obtaining aerodrome forecasts from other aerodromes;

- Information for operators or operator's local representatives; preliminary, and pre-flight planning; briefing and display of meteorological information required by operators; information required from operators;

- Information for pilots-in-command prior to departure; briefing, documentation, route forecast, flight forecasts, aerodrome forecasts;

- Information for pilots-in-command during flight, scope and responsibility of area meteorological watch; SIGMET information, VOLMET broadcasts;

- Information for and from air traffic services; types of meteorological information required by aerodrome control towers, approach control offices and area control/flight information centres; collection of aircraft meteorological reports;

- Forms of meteorological messages; routine and special reports in code or plain language; reports for take-off and for landing; forecasts and amendments to forecasts; trend-type landing forecasts; ditching reports; flight, route and area forecasts; SIGMET information message; dimensional units;

- Information for search and rescue according to local procedures;

- Aeronautical climatological information;

- Forms used; publication of records;

- Retention of records.

11.1.2.3 Air traffic services

- Visual and Instrument Flight Rules; the meanings of and distinction between VFR, VMC, IFR and IMC; scope of Flight Information Service, including the provision of Automatic Terminal Information Service (ATIS); the objectives of, and the criteria for, the provision of Air Traffic Control Service; rules governing terrain clearance; cruising level system; vertical separation minima and methods of effecting horizontal separation;

- Functions and distinction between Area Control Centre, Approach Control Office, Aerodrome Control Tower and Flight Information Centre;

- Holding and Approach Procedures; Alerting and Search and Rescue Services; methods of aerial search;

- Requirements for aircraft position reporting and meteorological reporting procedures;

- Procedures for co-ordination between ATS units and the meteorological service; meteorological observations performed by ATC personnel in aerodrome control towers;

- Computation and use of transition levels, layers and altitudes and of the lowest usable flight level en-route that will ensure adequate terrain clearance;

- Special requirements relating to Category II and III operations particularly runway visual range and cloud base.

11.1.2.4 Aerodromes

- Design of aerodromes in so far as meteorological factors are concerned; specific knowledge of the physical design of the aerodrome with which they are concerned; purpose and operation of aerodrome lighting, particularly as it relates to operations in lower visibility conditions and its relation to RVR assessment; effect upon aerodrome ground services of changing weather conditions such as the requirement for snow clearing operations and the effect of wet runways on braking action.

- Détermination of aerodrome reference temperatures and methods used by aerodrome services for measuring runway surface conditions related to meteorological aspects such as snow depth and runway braking action; awareness of local climatological conditions and their effects on environmental aspects such as noise and air pollution caused by aircraft landing, taking-off and taxiing.

11.1.2.5 Operation of aircraft

- Significance of aerodrome operating minima, (*) and awareness of the minima applicable to the regular and alternate international aerodromes with which they are concerned;

- Knowledge of approach systems - visual and instrument, categories of operations; altimeter setting procedures; the ICAO Standard Atmosphere;

- Basic flight navigation, the principal aids to navigation and methods of determining winds in flight;

- Effects of air density, humidity, icing, low-level wind shear, turbulence and wind on aircraft performance and the meteorological factors influencing fuel consumptions;

- Special requirements of light, low-level and short-range aircraft (IGA) and aerial work, and of SST aircraft (including sonic boom questions).

11.1.2.6 Aeronautical information services

- Meteorological elements required for publication in the Aeronautical Information Publication (AIP), and of the specifications for AIP;

(*) Aerodrome operating minima are defined in ICAO Annex 6, Part 1, and are the subject of a number of Standards and Recommended Practices in ICAO Annex 6, Part 1, Chapter 4.2.6.

- General specifications for NOTAMs, their origin and distribution;

- ICAO Abbreviations and Codes used in messages on the Aeronautical Fixed Service (AFS); Aeronautical Mobile Service (AMS) and in Aeronautical Information Services documents;

- Information concerning the meteorological service which is required to be depicted on Instrument Approach, Landing and Aerodrome Charts.

11.1.2.7 Aeronautical telecommunications

- Elementary understanding of the general organization of aeronautical telecommunications but they should have a thorough knowledge of the procedures applicable to the preparation of meteorological messages which they or their assistants will normally originate;

- Operation of the Aeronautical Fixed Service, including particularly the Aeronautical Fixed Telecommunication Network (AFTN), Aeronautical Mobile Service; message headings, addressing of messages, priorities of messages; regional aeronautical MET telecommunication procedures (MOTNE, VOLMET broadcasts, etc.).

11.1.2.8 Regulatory documents and related publications

WMO

- Technical Regulations, Volume II - Meteorological Service for International Air Navigation;

- Manual on Codes (WMO-No. 306);

- Manual of Aerodrome Meteorological Practices (WMO-No. 186);

- Guide to Meteorological Instruments and Observing Practices (WMO-No. 8), Chapter 16;

- Weather Reporting (WMO-No. 9), Volume B, Data processing.

ICAO

- Annex 3, PANS-MET (Doc. 7605 MET/526);

- Regional Supplementary Procedures (*) (Doc. 7030);

- ICAO Abbreviations and Codes (Doc. 8400);

(*) All regional supplementary procedures in the MET field except those governing air-reporting have now been included in Part IV of the ANPs.

- Location indicators (Doc. 7910);
- Meteorological tables for international air navigation (Doc. 7155 - MET/522);
- Manual of Aeronautical Meteorological Practice (Doc. 8896 - AN/893);
- Relevant Air Navigation Plans (ANPs) (*).

11.2 SPECIALIZATION IN AERONAUTICAL METEOROLOGY (CLASS II)

Section 5.3.3 should be supplemented by the following.

11.2.1 Synoptic meteorology

As for Specialization in Synoptic Meteorology (Class II), section 5.4.

11.2.2 Aeronautical meteorological knowledge

Same syllabus as that for Class I meteorologist, paragraph 11.1.1.

11.2.3 Aviation knowledge

Same syllabus as that for Class I meteorologist, paragraph 11.1.2.

11.3 SPECIALIZATION IN AERONAUTICAL METEOROLOGY (CLASS III)

Observations for aeronautical purposes are characteristically different from those for synoptic purposes. The synoptic observations are intended to be representative of the weather over a large area and are made at routine times separated by intervals of several hours. Meteorological observations for aeronautical purposes are made to satisfy the aeronautical operational requirements and are intended to be representative of the weather at an aerodrome or of particular meteorological parameters at limited areas on or near the aerodrome. On a routine basis they are made more frequently than synoptic observations as well as being made on a non-routine basis to cover changes in the weather and to satisfy the requirements of pilots and air traffic services.

(*) All regional supplementary procedures in the MET field except those governing air-reporting have now been included in Part IV of the ANPs.

11.3.1 Aeronautical meteorological knowledge

11.3.1.1 Observations required in aviation meteorology

- Surface wind direction and speed, including changes and variations;
- Visibility and runway visual range, including spatial and temporal variations RVR observations, by visual means or by use of automatic instruments such as the transmissometer and the videometer;
- Cloud amount, height and type and spatial and temporal variations; ceiling observations using automatic instruments such as the ceilometer;
- Pressure measurements for the purpose of determining QFE, QNH.

11.3.1.2 Meteorological phenomena hazardous to aviation

- Aircraft icing; elementary knowledge of icing types; formation, accretion rates and association of icing with clouds, freezing precipitation, orographic and frontal lifting;
- Turbulence: elementary knowledge of turbulence near the ground as related to topography, air-mass stability, clouds, fronts and thunderstorms;
- Elementary knowledge of high-level turbulence (CAT) and its association with wind shear and jet streams.

11.3.1.3 Meteorological aspects of flight planning

- Meteorological basis for pressure-pattern flying; meteorological requirements for en-route winds and temperatures; weather and terminal area forecasts;
- Interpretation of area, route and terminal forecasts and preparation of material for briefing of flight crews.

11.3.1.4 Reporting, coding and dissemination of weather information

- Complete knowledge of international meteorological codes related to observations, such as METAR, SPECI, SYNOP, PILOT, TEMP and CODAR, and aeronautical forecasts, such as ARMET, TAF, ARFOR and ROFOR;
- Knowledge of procedures for dissemination of weather information at the aerodrome including the special needs of ATC units;
- Knowledge of the procedures for the preparation of the plain language forms of meteorological messages.

11.3.2 Aviation knowledge (*)

11.3.2.1 Definitions

- Meteorological report, observation;
- Visibility, runway visual range;
- Altitude, elevation, height, aerodrome elevation, flight level, transition level;
- Aerodrome meteorological minima, instrument runway, landing area;
- Landing forecast, aerodrome forecast, forecast, SIGMET (information), briefing, air-report (consisting of position information, operational infor- mation and meteorological information);
- Operator, operator's local representative, pilot-in-command.

11.3.2.2 Procedures for meteorological services for international aviation

Assistants should have a thorough knowledge of the definitions and rules applicable to their particular duties. They should also have an understanding of the procedures relating to the following:

- Organization of the meteorological service and particularly the functions of the various types of meteorological offices;
- Aeronautical meteorological stations and their functions, routine and special observations and reports, selected special reports, reports for take-off and landing;
- Meteorological watch;
- Observations required from aircraft and the procedures related to the ground-to-ground dissemination of these observations;
- Introduction to the responsibilities of ICAO and WMO in aeronautical meteorology.

11.3.2.3 Air traffic services

Assistants should have an understanding of the function of the air traffic service units with particular regard to the corresponding demands for meteorological services, including the types of meteorological information required by the various air traffic services units and the updating of this information by means of duplicate read-out

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(*) This section is based on the chapter "Aviation knowledge" of ICAO Doc. 7192 - AN/857 PART 6, Training Manual, Part 6, Aeronautical Meteorological Assistant. The manual contains information on relevant ICAO training aids and publications.

INDEX

instruments in ATS units or by prompt data transmission originated by the meteorological office or station. Assistants should also be familiar with special requirements relating to Category II and III operations particularly in respect of runway visual range and cloud base information and any other specific local requirements by aeronautical users for meteorological information.

11.3.2.4 Operation of aircraft

- Flight planning;
- Duties of flight operations officers when exercising operational control;
- Navigation and landing aids;
- Effects of air density, icing turbulence, wind and vertical wind shear on aircraft performance;
- Altimeter setting procedures, standard atmosphere;
- Performance characteristics, including fuel consumption of civil aviation aircraft; characteristics of propeller type, turbo-prop and turbo-jet, and, where applicable, supersonic aircraft;
- Effects of various weather phenomena on aeronautical operations and on aerodrome ground services.

11.3.2.5 Aeronautical telecommunications

Assistants require only an elementary understanding of the general organization of aeronautical telecommunications, but they should have a good working knowledge of the operation of the aeronautical fixed service (particularly AFTN), the aeronautical mobile service and any special broadcasts and/or regional telecommunications networks applicable to the region concerned, e.g., MOTNE. Such knowledge should include: message headings, addressing of messages, priorities of messages and any appropriate regional procedures (e.g., relating to MOTNE, VOLMET, etc.).

Assistants should be acquainted with the ICAO abbreviations used in messages on the aeronautical fixed services (AFS) and aeronautical mobile services (AMS). The more frequently used abbreviations should be known by heart.

11.3.2.6 Regulatory documents and related publications

WMO

- Technical Regulations, Volume II - Meteorological Service for International Air Navigation;
- Manual on Codes (WMO-No. 306);
- Guide to Meteorological Instruments and Observing Practices (WMO-No. 8), Chapter 16;
- Weather Reporting (WMO-No. 9), Volume B, Data processing.

- Annex 3 PANS-MET (Doc. 7605-MET 526);
- Regional Supplementary Procedures (*) (Doc. 7030);
- ICAO Abbreviations and Codes (Doc. 8400);
- Location indicators (Doc. 7910);
- Manual of Aeronautical Meteorological Practice (Doc. 8896-AN/893).
- Relevant Air Navigation Plan Publications (ANPs) (*)

11.4 CLASS IV PERSONNEL ENGAGED IN AERONAUTICAL METEOROLOGY

Observations for aeronautical purposes are characteristically different from those for synoptic purposes. The synoptic observations are intended to be representative of the weather over a large area and are made at routine times separated by intervals of several hours. Meteorological observations for aeronautical purposes are made to satisfy the aeronautical operational requirements and are intended to be representative of the weather at an aerodrome or of particular meteorological parameters at limited areas on or near the aerodrome. On a routine basis they are made more frequently than synoptic observations as well as being made on a non-routine basis to cover changes in the weather and to satisfy the requirements of pilots and air traffic services. The basic curriculum for Class IV personnel referred to in sections 7.1 "Education in the basic sciences" and 7.2 "Meteorological training" has to be supplemented by the syllabi given in 11.4.1 and 11.4.2.

11.4.1 Aeronautical meteorological knowledge

11.4.1.1 Observations required in aviation meteorology

- Surface wind direction and speed, including changes and variations;
- Visibility and runway visual range, including spatial and temporal variations; RVR observations by visual means or by use of automatic instruments such as transmissometer and videometer;
- Cloud amount, height and type and spatial and temporal variations using automatic instruments such as ceilometer;
- Presure measurements for the purpose of determining QFE, QNH.

(*) All regional supplementary procedures in the MET field except those governing air reporting have now been included in PART IV of the ANPs.

11.4.1.2 Reporting, coding and dissemination of weather information

- International meteorological codes related to observations such as METAR, SPECI, SYNOP, PILOT, TEMP and CODAR, and aeronautical forecasts, such as ARMET, TAF, ARFOR AND ROFOR.

- Procedures for dissemination of weather information at the aerodrome including the special needs of ATC units;

- Procedures for the preparation of the plain language forms of meteorological messages.

11.4.2 Aviation knowledge

Same syllabus as that for Class III, Section 11.3.2.

CHAPTER 12

SPECIALIZATION IN AGRICULTURAL METEOROLOGY

FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL

INDEX

INDEX

12.1 GENERAL

The personnel employed in agricultural meteorology can be grouped in two main categories:

- Personnel with a basic training in meteorology;
- Personnel with a basic training in agricultural sciences.

In each of these two categories, a further distinction should be made between graduates and non-graduates.

In preparing syllabi for the various classes of personnel, distinction is made between the following groups:

(a) Professional meteorological personnel (graduates with basic training in meteorology);

(b) Agricultural scientists (graduates with basic training in agricultural sciences);

(c) Technical assistants in Agrometeorological Services (non-graduates with training in mathematics and physics at secondary school level).

Duties and training of the various groups of agrometeorological personnel

The graduate personnel (professional meteorological personnel and agricultural scientists) are responsible for the organization and supervision of agrometeorological services and for research in agricultural meteorology.

Technical assistants would carry out the following duties: agrometeorological observations (instrumental, visual, phenological); installation, maintenance, checking and calibration of instruments, with the exception of very delicate instruments, the adjustment of which should be entrusted to professional officers (a) and (b) above; elementary processing of agrometeorological data; routine computations of averages, normals, frequencies, etc; preparation of punched cards; statistical analysis of agrometeorological data under guidance of the professional officers; assisting in research projects.

The qualifications and training programmes proposed for these classes of personnel are shown in the form of syllabi indicating the standard of knowledge required and the extent to which the subject should be covered. The syllabi are prepared for the three classes of personnel mentioned above, and an additional syllabus is given for the purpose of teaching agricultural meteorology in secondary level schools of agriculture, horticulture and forestry. Further, in the case of professional meteorological personnel (Syllabus I) the candidates must have attained the required standard in physics, mathematics, meteorology and climatology, and have a sufficient background in the biological and agricultural sciences (if he has not already taken a degree in agriculture).

This syllabus can be covered:

(a) As part of a four-year B.Sc. Agric. course in agrometeorology;

(b) During postgraduate work in agricultural meteorology after a degree in pure science;

(c) During postgraduate work in agricultural meteorology after a degree in agricultural science.

While instruction in biometry, botany (including plant physiology), crop science and soil science is considered essential for this course in agricultural meteorology, a knowledge of animal science, entomology and plant pathology will, under certain circumstances, also be desirable.

Syllabus I must be considered as the minimum requirement for the training of Class I agrometeorological personnel. Personnel engaged in advisory tasks in agrometeorology, should receive training in the appropriate parts of this syllabus.

A one-year course in agricultural meteorology (Syllabus II) is proposed for candidates holding degrees in agricultural sciences. The purpose of this course is to make the agricultural scientist more conscious of weather and climate and to train him to measure meteorological and climatic influences whenever he should engage in research. The standard of mathematics and physics required will be that of the first year at university. If the postgraduate work of the agricultural graduate leans towards agricultural meteorology in animal, crop and soil studies, he may receive training in appropriate parts of Syllabus I for professional meteorological personnel.

The syllabus for agrometeorological personnel (Class II) is given in section 12.4 and for agricultural engineers in section 12.5.

The syllabus for technical assistants (Class III) in agrometeorological services is given in section 12.6. The standard of mathematics and physics required will be that of secondary or high school.

The syllabus for teaching agricultural meteorology (Class IV) at secondary level schools of agriculture, horticulture and forestry (the word "secondary" in this context implies advanced education below university level) is given in section 12.7 and consists of a number of lectures and practical exercises. The purpose of including these lectures and exercises is twofold:

(a) To avoid elementary meteorology being taught at Universities, the time thus saved can be devoted to agricultural meteorology; and

(b) To prepare a certain number of observers for agrometeorological stations.

12.2 SYLLABUS I - FOR METEOROLOGICAL PERSONNEL

12.2.1 Agricultural and biological sciences

- Soil science: composition and formation of soils; weathering of rocks and minerals; the soil profile; simple classification of soils; plant nutrition and soil fertility; organic matter in soils; micro-organisms; the physical and chemical properties of soil; soil and plant relationships; soil erosion - types, causes; principles of soil conservation;

- Botany: the morphology, anatomy and histology of flowering plants; systematic classification of plants; life-histories and reproduction of the more important plants; economic botany;

- Plant physiology: the plant cell; solutions and membranes; the roots of plants; the intake of water and solutes by plants; the loss of water by plants; the processes of photosynthesis, including CO_2 requirements; respiration and growth in plants; the translocation of water and materials in plants; frost and drought hardiness; photoperiodicity;

- Ecology: plant association, successions and climaxes;

- Field crops: physiographic, climatic, edaphic and biotic factors in relation to plant growth; crop production in relation to the agro-ecological conditions of the country concerned; agronomic practices; crop and fodder production; land utilization and industrial crops;

- Horticultural crops: classification of horticultural plants; climatic and soil requirements; elementary morphology and physiology; propagation; pruning; orchard layout and culture;

- Pastures: the origin, development and stabilization of vegetation in relation to the environment; vegetation types, their management and application in veld management; the establishment and management of cultivated pastures;

- Plant pathology: importance of plant diseases; causes and classification; diseases caused by parasitic bacteria and fungi, viruses and non-parasites; influence of environmental factors on diseases of economic plants; principles of plant disease control;

- Zoology: the elements of anatomy, histology and physiology; distinguishing characteristics of the major groups of the animal kingdom; a knowledge of the morphology, physiology and reproduction of representative types; elementary cytology, embriology and genetics;

- Animal anatomy and physiology: the form, structure and functions of the locomotry, nervous, circulatory, respiratory, digestive, excretory, endocrine and reproductive systems of farm animals;

- Animal husbandry and disease of livestock: the principles of animal production; the nutrition of farm animals; physiological reaction to environmental changes in relation to food utilization; ecology of livestock; factors influencing growth and development, important animal diseases;

- Entomology: embryology, histology, physiology, ecology and the chemical, biological or other methods of control of the more important insect pests injurious to vegetables, fruit trees, field crops and pastures, stored grain and grain products, forests.

12.2.2 Agricultural meteorology

- Agricultural meteorology: definition, aims and scope; difference between meteorology and agricultural meteorology; a short history of

agricultural meteorology in relation to the needs of agriculture and the development of meteorological instruments;

- The importance of weather and climate for agricultural production: the adaptation of plants, crops and animals to the climate; the necessity of adjusting farming systems to the natural environment; critical growth periods in relation to temperature and soil moisture; the importance of weather and climatic data in determining the irrigation requirements of crops; climate in relation to insect pests and plant diseases; production and cultivation practices in relation to climate; climatic hazards affecting agricultural output, e.g., drought, hail, frost, strong wind, etc.; effects of climatic and weather upon storage and transportation;

- National Meteorological Services and the World Meteorological Organization (WMO); national agrometeorological organizations and the Commission for Agricultural Meteorology (CAgM).

12.2.3 Agrometeorological observations, instruments, stations, networks and processing of data

- Meteorological observations: units; accuracy required; sources of errors; exposure of instruments; general rules and procedures for the observation and recording of pressure, air temperature, atmospheric humidity, wind, sunshine and radiation, precipitation, soil temperature, soil moisture contents and soil moisture tension, evaporation, evapotranspiration; interpretation and analysis of autographic charts; cloud classification; cloud cover; estimation of cloud base; horizontal visibility; existing weather conditions; state of the ground;

- Biological observations: observations on native plants, cultivated crops and trees, farm animals, diseases, insect pests and general activities on the land;

- Instruments and methods of observation: the choice of a site for an instrument enclosure; a detailed study of the procedures for installation, maintenance, checking and calibration of the instruments used in agricultural meteorology;

- Pressure: the mercury barometer: method of observation, exposure, transportation and installation; correction of barometer readings to standard conditions; index error, gravity correction, temperature correction; the barograph; the aneroid barometer; the hypsometer;

- Surface wind: the pressure plate anemometer; cup and fan anemometers; the hand anemometer; the totalizing anemometer; contact and generator types of anemometer and anemograph; the pressure tube anemograph; the hot-wire anemometer;

- Duration of sunshine: sunshine recorders; exposure, maintenance and evaluation of records;

- Radiation: pyrheliometers; solarimeters; pyranometers; pyrradiometers; net radiometers; illuminometers and devices for measuring

the spectral distribution of solar radiation; instruments designed for use within crop canopies; estimates of radiation using sunshine, cloudiness and haze data;

- Temperature: liquid-in-glass thermometers - ordinary thermometers, maximum thermometers, minimum thermometers, soil thermometers; reading a thermometer; electrical thermometers - resistance thermometers, thermocouples, thermistors; auxiliary electrical equipment; thermographs - bimetallic type, Bourdon-tube type, mercury-in-steel type; thermometer and thermograph exposure - general requirements in order to obtain representative air temperature; thermometer screens; artificial ventilation; exposure of grass minimum thermometers; the importance of calibration certificates; possible sources of defects in thermometers and the various procedures to rectify them;

- Atmospheric humidity: psychrometers - simple psychrometer without artificial ventilation, the sling psychrometer, the Assmann-type psychrometer; exposure and observational procedure; care of the wet bulb; operation of wet bulb below freezing; sources of error in psychrometry; the psychrometric formula; tables and slide rules; hair hygrographs - general requirements, exposure, management and transportation, accuracy and sources of errors, washing the hairs; dew-point and frost-point hygrometers; electrical absorption-type hygrometers;

- Precipitation: the ordinary and totalizing raingauges; rainfall recorders - natural siphon type, float type, tilting-bucket type, weighing type; rainfall intensity recorders; snow measurements - snow depth and density; the measurement of rainfall and hail by radar;

- Dew: artificial grass mats and asbestos plates; Parchinger's absorption method; the Leick porcelain plate; the paper-strip dew indicator; the Hiltner dew recorder; the Kessler dew recorder; the dew balance of Monteith; leaf-wetness recorders;

- Soil moisture: soil moisture content; electrical resistance units; electrical capacitance; thermal conductivity; neutron scattering; mechanical and chemical resistance; gamma-ray absorption; nuclear magnetic resonance; soil moisture tension; tensiometers; suction plate, pressure plate and pressure membranes; absorption by porous material; vapour pressure and freezing point;

- Soil temperature, heat flow and soil properties: different kinds of soil thermometers and thermographs; methods of measurement of heat flux; heat flux plates; methods of measuring heat capacity, conductivity and diffusivity;

- Evaporation and evapotranspiration: evaporation - small and large evaporation pans, porous porcelain bodies, porous wick devices, lysimeters; exposure, maintenance, scale; observations and entries; calculations; advantages and disadvantages of different types of pan let into the ground and exposed above the surface; factors influencing evaporation from a pan - depth of evaporating surface, rim effect, colour and size of pan, netwire cover, microclimate; comparison of different types of pan; evaporation from a free water surface (pan) in relation to evaporation from other types of evaporimeter; estimating evaporation from empirical formulae based on Dalton's law; aerodynamic

and energy balance approaches; eddy correlation and water balance techniques; evapotranspiration - lysimeters, types and application; various types of atmometer and evaporation pan; micrometeorological methods - aerodynamic energy-balance, eddy correlation; approaches of Thornthwaite, Penman, Blaney-Criddle, Haude, Turc, Prescott, Hedke, Lowry and Johnson, Hoffmann and others; the relation between actual and potential evaporation;

- Agrometeorological stations and networks: classification of stations - principal, ordinary and auxiliary; design of networks;

- Processing of agrometeorological data: meaning of an observation; errors of observation; observations as samples of a population; the use of statistical methods for the quality control and processing of observations; the collection, treatment, representation and storage of climatic data; the tabulation and cataloguing of climatic observations; the publication of climatic data; nomenclature of different maps used in climatology, climograms and phytoclimograms; correlation between agrómeteorological and biological data; preparation of plans for statistical studies; systematic and accidental errors; machine methods; the need for simultaneous biological and meteorological measurements of comparable accuracy and validity of sample.

12.2.4 Micrometeorology, microclimatology and topoclimatology

- Definition and scope of micrometeorology, micro- and topoclimatology:

- Heat budget at the earth's surface: incoming and outgoing radiation types; net radiation; heat flux in the soil; soil temperature; heat transfer in the lower air layers; free convection; turbulence; latent heat flux;

- Temperature, humidity and wind relations near the ground surface: variations in air temperature; temperature profiles (day and night); humidity fluctuations; wet and dry type moisture distribution profiles; wind structure near the ground; laminar and turbulent flow; wind profiles; effect of wind on microclimate, air pollution and dispersal of spores and seeds;

- The influence of the ground surface on the microclimate: type, colour and structure of the soil; microclimatic soil cover and cultural practices; the influence of soil moisture and soil freezing on the air layer near the ground; the microclimate above water surfaces: pools, lakes rivers, sea; the influence of snow cover and ice on soil and microclimate; the microclimate in the boundary zone between different types of soil surface;

- The influence of plant cover (crops) on micrometeorology and microclimatology: the heat budget of plants; radiation penetration and exchange within a low plant cover (crop) and within a tall plant cover (forest); air temperature and humidity within a plant cover; evapotranspiration within a plant cover; the leaf area index; dew; rainfall interception; leaf-wetness within agricultural crops and forests; the influence of forests on the climate of the surrounding area;

- The influence of topography on the microclimate: the radiation budget of different slopes; the influence of topography on day- and night-time temperature profiles, on temperature distribution, cold air drainage, frost hollows, etc; the influence of topography on air humidity, on wind speed and wind direction; local winds: down- and up-slope winds, down- and up-valley winds; the influence of topography on soil temperature, soil moisture and on rainfall.

12.2.5 Instrumentation and methods of observation for micrometeorological and microclimatological measurements

- Methods of evaluating and presenting micro- and topoclimatological data: the use of statistics in microclimatology; methods for estimating long-range macroclimatological possiblities from short-term microclimatological results: diagrams, large-scale maps, etc.;

- Importance for agriculture of the air layer near the ground: influence of the variation in and the distribution of radiation, temperature, humidity, and wind profiles on plants, animals, insects and plant diseases; influence of the microclimate on soil management practices, plant disease control (spraying, dusting), irrigation, combined-harvesting, etc.;

- Modification of the microclimatological environment: the modification of the climate within plant covers (crops) by planting, manuring, cultivation, etc; the influence of shading, mulching, glass screens, walls, changing the colour of the soil or screens, and irrigation on the heat and water budget of plant covers and on the whole microclimate.

12.2.6 Soil climate

- Soil temperature: heat exchange at the soil surface; the soil heat flux as part of the energy budget; factors affecting the soil heat flux; sharing of heat between air and soil;

- Heat conduction in the soil: the classical theory of heat conduction in solids; transfer of heat by movement of water and water vapour within a soil;

- Thermal properties of soils, their variation and measurement: heat capacity; conductivity; diffusity;

- Soil temperature variations: diurnal and annual cycles at the surface and other depths; theory of periodic temperature variations; equations for calculation of temperature at any depth and time given certain boundary conditions; Fourier analysis of soil temperatures; non-periodic variations of soil temperature; application of Laplace transforms to soil temperature studies; sinusoidal temperature variations in natural layered soils;

- Factors influencing soil temperature: source and amount of heat; the energy balance; latitude, slope of land, distribution of land and water soil colour; albedo in different parts of the spectrum; thermal

properties of soil; soil moisture, evaporation and condensation; vegetative cover, snow cover; frost penetration;

- Modification of soil temperature by cultural practices: shading; mulching; changing colour of surface; irrigation and drainage; tillage; glass and plastic covers;

- Influence of soil temperature on agricultural production: influence of soil temperature on plant growth; germination and seedling emergence, sprouting of bulbs and tubers, growth of roots and shoots, effect on nutrient uptake; interactions between soil and air temperatures on plant growth, crop quality; extreme soil temperatures and plant injury, plant diseases, extent, thickness and duration of snow cover, alternate freezing and thawing, soil heaving, moisture movement; influence of soil temperature on activity of micro-organisms: distribution, growth and number; decomposition of organic matter; ammonification and nitrification; soil aggregation; influence of soil temperature on insect life;

- Soil moisture: soil moisture content - percentage by volume, bulk density; hygroscopic water, capillary water, gravitational water; soil moisture-energy relations; total potential in the soil system, the capillary potential, free energy, soil moisture potential pF and log-tension, relation between soil moisture content and soil moisture tension for different types of soil; the movement of water in the soil; movement of liquid water in saturated and unsaturated soils; movement of water vapour; movement in relation to plant-root extraction; the influence of soil moisture content and potential on plant growth; field capacity; wilting point; available soil moisture in relation to germination, transpiration and vegetative growth, maturation and yield of crops; critical growth periods; farming systems in relation to available soil moisture; the importance of water conservation for agricultural purposes;

- Evaporation and evapotranspiration: evaporation; the theory of evaporation; factors influencing the evaporation from a free water surface: radiation, temperature of the water surface, wind movement, air pressure, quality of water; evaporation losses and the future of evaporation pans in agricultural research; evapotranspiration; the individual and combined influence of soil, plant and climatic factors on evapotranspiration; irrigation scheduling; effect of soil, crops and climatic factors on irrigation needs; application of estimating evapotranspiration on the scheduling of irrigation.

12.2.7 The hydrological cycle in agriculture

- The hydrological cycle: rainfall and its interception by plants, crops and forests; runoff; infiltration; moisture retention of the soil; percolation; evaporation; evapotranspiration, its importance in agriculture; effects of agricultural practices on component parts of the cycle; soil moisture budgets; use of models appropriate to alternative husbandry practices, fallow periods, irrigation, etc.;

- Droughts (long-period): definition; possible causes; frequency; principal drought-afflicted areas and countries; long-term planning against drought; the possibility of cloud stimulation;

- Excess of precipitation: runoff, soil erosion and their control; flood causes, frequency, prediction and control; snow melt;

- Hail: occurrence and frequency of hail storms; extent and pattern of hail damage; meteorological conditions favourable for the formation of hail; types of hailstones; artificial prevention of hail; statistical evaluation of experimental results; experimental procedure for growing artificial hailstones; radar studies in connexion with hail storms;

- Dew: the theory of dew formation; conditions favouring the formation of dew; the importance of dew for plants, plant diseases, animals and insects.

12.2.8 Biological measurements (phenology)

- Introduction: definition, history; the need for phenological data and studies for agriculture;

- Phenological observations for agriculture: phenological observations of plants; plants (native and cultivated) and their growth phases; time of germination, emergence, shooting, flowering, ripening, harvesting, defoliation, etc.; measurement of plant-growth (phenometry); leaf-size, length of stalks, thickness of tubers, etc.; observations of birds, insects and diseases; migration; appearance; outbreak of diseases and epidemics; collection of data; networks and stations; phenological gardens;

- Evaluation of phenological data: examination of data and possible errors; statistical methods; mean values, parallelism of different phases, duration of growing periods, etc.; representation of data, diagrams, maps, profiles, etc.;

- Research: research on observations made at one station (time sequence, etc.); research on observations at different stations (area analysis, etc.); periodicity and prediction; influence of weather, climate, topography, soil, etc., on biological events;

- Application to agriculture: delimitation of natural growing (farming) areas; phenological climatology; management decision, irrigation, etc.; improvement of cultural practices; forecasting of biological phenomena for crop production; plant disease-control and seasonal operations; advising for agricultural trade and commerce (export, import, etc.).

12.2.9 Weather and climate in relation to plants, crops, animal production, insects and plant diseases

- Plants and crops: growth and development in plants - annual life cycle, phasic divisions of the plant, measurement of growth and development, effect of weather factors on the growth and development of plants and on quality and quantity; air temperature: plant temperatures; cardinal temperatures; optimal temperature ranges; temperature efficiency; temperature and transpiration; thermoperiodism; low temperatures - stimulating effects, cold injury, the hardiness problem, frost damage and

frost resistance; insufficient cold during dormant period; delayed foliation of deciduous fruit trees; high temperature injury; sun-scald; importance of temperatures over the whole growing season and during critical growth periods; heat unit systems; intensity, duration and quality of light; effects on photosynthesis; optimum leaf area index; photoperiodism; trans piration; germination; reproduction; growth forms; physiological characteristics; atmospheric humidity; optimum humidity ranges for growth; effects on transpiration and plant diseases; wind: effects on transpiration, desiccation, dwarfing, deformation, anatomical modifications, pollination, dissemination, soil temperature, soil moisture; the climatic requirements of crops, e.g. corn, wheat, small grains, sorghum, cotton, tobacco, sugar cane, sugar beet, fruit trees (tropical, subtropical and deciduous), vines, berries, vegetables, etc.; the adaptation of plant to the environment; use of climographs in introducing new varieties; plant-climate relationships and the use of phenology in ascertaining the thermal and photo-thermal requirements of crops, e.g. wheat, barley, rye; well-established relations between weather and climatic factors, severally or jointly, on the growth and quantitative yield of crops; critical periods for growth and production; significance of such studies for crop forecasting; influence of weather and climate over the growing season upon the quality of the crop, the length of its storage life or storage behaviour, e.g., deciduous fruit;

- Animal production: thermal balance - the necessity of maintaining a thermal balance in animals between heat production or gain from the environment and heat lost to the environment; the thermal balance equation; the direct effects of weather and climate upon livestock production; the effects of solar radiation, temperature (high or low), atmospheric humidity, length of day and altitude, severally or jointly, upon respiration, pulse rate and body temperature; loss of water from the body; growth rate and body weight; reproduction; grazing habits and food intake; mild production; sunburn, skin cancers and photosensitive disorders; the indirect effects of weather and climate upon livestock production; effects of weather on the gross yield and quality of feed supply and hence on rate of growth and on milk production; regional effects of seasonal weather and climate upon the type, spread and intensity of parasitic diseases; influence of weather on diseases caused by viruses, bacteria, protozoa, helminths and metabolic disorders; use of meteorological data for forecasting disease outbreaks; effects of weather on the storing and handling of animal products;

- Acclimatization: comfort zone for different breeds of animals; differences between species and breeds in their ability to withstand extreme climatic conditions; symptoms of inadaptability; adaptation to new environments; heat stress in relation to acclimatization; the Bergman law; physiological adaptation; use of climographs in evaluating the possibility of adaptation to new environments; overcoming climatic disadvantages by selecting and breeding;

- The climatic aspects of livestock production in super-humid, humid, subhumid, semi-arid and desert areas;

- Protection against cold and excessive radiation: loss of stock in cold weather; the need for shelter - shade trees, artificial shelters and air conditioned barns; protection against excessive radiation - ameliorating

thermal stress on animals by such methods as shading, sprinklers, mechanical air circulation, wallows and air conditioning; the effect of heated barns on milk and butterfat production; effect of shade on rate of growth;

- Research: instrumentation - direct observations in the field; psychrometric chambers; thermometers, thermocouples and thermistors for measuring rectal and skin temperatures; instruments for measuring the cooling power of the air, e.g. the katathermometer, frigorimeter, coolmeter, hot-wire anemometer; climatic indices for indicating heating or cooling power of the air;

- Insects: effects of weather factors on insect life and activity - the effect of radiation, temperature, atmospheric pressure and electricity on such physiological processes and insect activities as respiration, development, duration of life, reproduction, stridulation, movement, flight and dispersion; effect of daily and seasonal changes in weather on the daily rhythm and seasonal cycles of insects;

- Climate and insect distribution: vital limits for insect life; climatic factors assisting and limiting the dispersal of insects; the importance of ecoclimates and microclimates in the distribution of insects; use of climographs in studying insect distribution; acclimatization;

- Effect of climate on abundance: direct effect of temperature, precipitation, wind, atmospheric pressure, thunderstorms or a combination of these factors in insect abundance; influence of climate upon the number of generations; indirect effects of climate on food and natural enemies; climate in relation to control, course and periodicity of outbreaks;

- Bioclimatic studies on insect pests: procedure; field studies; physiological life-history; climatic observations (normal and microclimatic); analysis of meteorological data; quantitative studies on insect abundance; correlation of climatic data with quantitative data; artificial climatic studies; controlled climatic chambers, biotron;

- Plant diseases: weather factors conducive to infection; temperature; optimum temperatures for infection; effect of temperature on incubation period; effect of high temperatures on sporulations of fungus pathogens and longevity of spores; temperature in relation to disease proneness of the host; humidity - the importance of free water (rain, fog, dew, water of guttation), snow cover, and duration of surface wetness for spore germination and infection; the effect of high atmospheric humidity on sporulations of fungus pathogens and on longevity of spores; light-injuries to infection process by light; wind-dissemination of fungus spores and bacteria by wind; windbreaks in relation to infection; electrostatic charge - possible effects of electrostatic charges carried by fungus spores on epidemiology of disease;

- Effects of temperature and moisture on the seasonal and geographic distribution of diseases;

- Methods and techniques: correlations between natural or induced diseases and meteorological records or of synthesized environments; the need for microclimatic observations; artificial climates - greenhouses and phytotrons;

- Disease forecasting;

- Treatment of a few plant diseases, e.g., apple scab, caused by fungus Venturia inaequalis; potato late blight, a fungus disease caused by Phytopthora infestans; wheat stem rust caused by fungus Puccinia graminis tritici. (Diseases appropriate to the area concerned.)

12.2.10 Agroclimatic classifications

- Existing classifications: the need for agroclimatic classifications; existing classifications (or details, see section 7.3 of the Guide to Agricultural Meteorological Practices, WMO-No 134, TP.61); limitations of the present classifications;

- Factors to be considered in agroclimatic classifications: elements important to the vegetative growth of plants, e.g., water balance, temperature, duration of frost-free period, duration of sunshine; elements important to the development of successive phases in plant life, e.g., day length; annual temperature variation; daily temperature range, both in the warm and cold seasons; duration of frost-free period; duration of rainy and dry seasons.

12.2.11 Frost and protection against frost

- Economic phases of frost protection; the extent of damage to crops by frost during the growing season and by freezing temperatures during the winter; the possibility of minimizing frost damage to plants;

- Physical processes involved: causes of frost;

- Radiation and advective frosts: seasonal occurrence; related weather patterns; donor areas and the flow and pooling of cold air; temperature inversions; effect of soil conditions, ground cover and cultural practices on frost intensity;

- Physiological processes involved: theories on mechanism of frost injury; frost hardiness; critical temperatures for plants and crops;

- Frost protection methods: diminution of frost damage by changing the microclimate by temporary or permanent measures; passive methods; location of growing areas; choice of growing season; time of planting and sowing; selection and breeding; cultivation practices - soil management, plant management, use of growth regulators; active methods - pre-irrigation, coverings, smoke and artificial fogs, wind machines, sprinkler irrigation, orchard and soil heating, a combination of two or more of these methods;

- Frost combating: operational procedure; applicable frost protection methods; critical temperatures and when to protect; coverage economic phases of frost protection; type of crop to be protected; installation, overhead, operation, fuel storage costs; comparative costs of frost protection methods;

- Advisory services to farmers: climatological temperature surveys and microclimatological variations; advice to farmers on choice of crop species and varieties, choice of growing areas, choice of planting dates, source regions of cold air, frost risks, average date of last frost in spring and first frost in fall, length of growing season, probability of frost occurrence, frequency and severity of frosts; establishment of microclimatic frost stations; local frost-fighting organizations;

- Frost forecasts and warnings.

12.2.12 Windbreaks and shelterbelts

- Introduction: definition of windbreaks and shelterbelts; the need for protecting soil, soil water, plants and animals, or for improving the soil micro and crop climates by windbreaks or shelterbelts;

- Effects of shelterbelts on the micro and soil climate: the modification of the microclimate, especially wind speeds, by using shelterbelts and windbreaks;

- On airflow: the effect of width, shape and density of shelterbelts on airflow when wind is blowing perpendicular, oblique or parallel to the belt; the effectiveness of different systems (parallel rows or networks of belts) on air flow; wind conditions at the ends of and at gaps in shelterbelts; the effect of surface roughness and thermal stratification; the effect of topography;

- On heat balance: radiation; air and soil temperature;

- On water balance: atmospheric humidity; dew-fall and fog precipitation; precipitation; snow-cover; evapotranspiration; soil moisture;

- Counteracting wind and water erosion by shelterbelts;

- Effects of shelterbelts: on crops, livestock, fauna and buildings;

- Climatological information required in the regional planning of shelterbelts and windbreaks;

- Meteorological, agricultural and biological observations in long term trials on the effects of shelterbelts and windbreaks;

- Selecting, planting, care and maintenance of shelterbelts.

12.2.13 Information, forecasts and warnings for agriculture and forestry

- Agrometeorological information: bulletins (pentad, weekly, decadal, monthly); organization of information service - code, network, communications, sending in reports, synoptic method of working out bulletins, issue and distribution;

- General weather forecasts: weather forecasts covering a period of time as required by agriculture (period of vegetation, ten days, a week,

five days) given in simple clear wording; stress on factors particularly important for agriculture such as strong winds and cold waves, frost possibility, heavy rain, storms, droughts, etc.; daily weather forecasts on a regional scale giving a rough estimate of the essential factors, e.g., temperature, cloudiness, precipitation (seasonal and climate change forecasts);

- Special weather forecasts and warnings: weather forecasts relating to the seasonal requirements of cultivated plants, e.g., the planting and growing season, frost, plant diseases, noxious insects, spraying and dusting operations, irrigation requirements, harvest conditions, post-harvest and storage conditions, weather during transport of agricultural products, forestry operations, fire weather (including forest fire warnings), agricultural aviation, etc.;

- Agrometeorological forecasts: local frost forecasts; formulae for predicting minimum air temperature; the importance of the "no-danger" forecast; soil humidity forecasts; forecasts of dates of successive phases of plants development; forecasts of yield and crop quality; forecasts and warnings concerning livestock; disease forecasting; forecasts on relative abundance, expected periods of increase or decrease, time of peak infestation; forecasts on the distribution, outbreaks and seasonal events of insects (pests and beneficial); parameters used in forecasting; the most widespread methods; issue of forecasts and warnings.

12.2.14 Artificial climates

- Glasshouses, cloches, hotbeds, etc.: ventilation; heating and cooling; illumination; soil moisture and evapotranspiration;

- Growth cabinets, growth room, phytotron, climatron, biotron: the variation of all meteorological entities over a wide range;

- Animal and poultry houses: site orientation; colour; texture; construction; ventilation; heating and cooling; air composition; humidification; illumination; photoperiodicity; quality of light; air and litter moisture content; air circulation;

- Storage rooms, clamps, pits.

12.3 SYLLABUS II - FOR AGRICULTURAL SCIENTISTS (CLASS I)

12.3.1 Introduction

- The concepts of weather and climate (macro-, meso- and microclimate);

- The importance of weather and climate for agricultural production; the adaptation of plants, crops and animals to climate; the necessity of

INDEX

adjusting farming systems to the natural environment; critical plantgrowth periods in relation to temperature and soil moisture; the importance of weather and climate data in determining the irrigation requirements of crops; climate in relation to insect pests and plant diseases; production and cultivation practices in relation to climate; climatic hazards affecting agricultural output, e.g., drought, hail, frost, strong winds, etc.;

- Agricultural meteorology: definition, aims and scope; difference between meteorology and agricultural meteorology; a short history of agricultural meteorology in relation to the needs of agriculture and the development of meteorological apparatus;

- National Meteorological Services and the World Meteorological Organization (WMO); national agrometeorological organizations and the Commission for Agricultural Meteorology (CAgM).

12.3.2 The atmosphere and pressure variation

- Its nature, composition and properties; air pollution; carbon dioxide; extent and structure - troposphere, stratosphere, mesosphere, inosphere and exosphere; pressure of the atmosphere; units; variation of pressure with height; mercury barometers; the aneroid barometer; the barograph; altimeters;

- Daily and seasonal variations; some effects of variations in air pressure upon animals and insects.

12.3.3 Radiation in the atmosphere

- Sources of heat for the atmosphere; the sun and radiant energy; the electro-magnetic spectrum; Wien and Stefan-Boltzman radia tion laws; Lambert's law; the solar constant;

- Seasonal and latitudinal variation in length of day; factors influencing the amount of radiation incident upon the earth's surface; absorption, reflection and transmission; albedo; terrestrial radiation;

- Instruments for measuring incoming solar radiation; pyrheliometers of Angstrom and Abbot (silver disk) for measuring direct radiation; the Eppley and Moll Gorczynski actinometers and the Robitzch bimetallic actinograph for measuring direct and diffuse radiation;

- Energy in different parts of the spectrum and its biological significance; illumination; penetration of radiation through a crop canopy;

- Radiation balance: its importance to plant and animal processes; bright sunshine duration and its measurement, e.g., with the Campbell-Stokes, Marvin and Jordan photographic recorders.

12.3.4 Meteorological elements

12.3.4.1 Air temperature

- Different temperature scales; representative air temperature and its measurement; thermometers and thermographs (liquid-in-glass, deformation, liquid-in-metal, electrical resistance thermometers, thermocouples, thermistors); maximum, minimum and mean air temperature; daily and seasonal variations; vertical temperature gradient; temperature inversion; isotherms; the importance of temperature in the growth of plants; frost-free growing season; vegetative period;

12.3.4.2 Atmospheric humidity

- Water vapour in the atmosphere and its variation with height; importance in determining the possibility of rain, snow and hail and its role in the development of thunderstorms; importance in the growth of plants; effect on the loss of heat from the human and animal body; absolute humidity, relative humidity, saturation deficit, dew point, specific humidity, mixing ratio, vapour pressure; daily variation of the absolute and relative humidity, and their variation with height and latitude; instruments for measuring humidity; absorption hygrometers; the psychrometric formula;

12.3.4.3 Condensation, precipitation and evaporation

- The process of condensation in the atmosphere; its importance in the formation of fog, clouds, rain, hail, snow, frost and dew; fog and cloud formation - a simple classification of clouds, cloud covers; thunderstorms: formation, frequency; lightning; precautions against lightning; hail; the structure of hailstones; theories of hail formation; precipitation; the size and rate of fall of raindrops; types of rain; seasonal variation of rainfall; the measurement of rainfall (the ordinary raingauge and continuous rainfall recorders, rate-of-rainfall recorder); snow and its measurement; statistics on extreme precipitation; the process of evaporation; factors influencing the rate of evaporation; simple formulae for calculating the rate of evaporation; instruments for measuring evaporation; the relation between evaporation from a free water surface and evaporation from moist soil and leaf surfaces; degrees of error inherent in measurements and in estimates from calculations;

12.3.4.4 Winds and circulation patterns

- Winds and air currents; the cause of winds; direction, speed and pressure; wind roses; daily and seasonal variations and variation with height; the measurement of wind direction and speed isobars, field of pressure, pressure gradient;

12.3.4.5 The general circulation of the atmosphere

- The effect of the earth's rotation on the flow of winds across the isobars; Buys-Ballot's law; planetary, terrestrial and continental winds;

land and sea breezes, mountain and valley winds of local importance, e.g., Foehn, Chinook, Bora, Harmattan, Mistral, Sirocco; the tropical cyclone or hurricane; tornadoes; water-spouts; dust storms; the extra-tropical cyclone; its origin; the polar front theory; air masses; weather along the cold and warm fronts; the occluded front; anticyclonic or high pressure systems and associated weather.

12.3.5 Climatology

- Same as in section 3.3.5.

12.3.6 Ecology of crops, animals and insects

- Well-established relations between meteorological and climatic factors, severally and jointly, on the growth and yield of crops and animals; effect of weather and climate on insect pests and plant diseases; climatic requirements of crops, fruit trees and animals with respect to heat, light and moisture; adaptation of plants and animals to the climate.

12.3.7 Agroclimatic stations

- Classification (principal, ordinary and auxiliary); networks; observations; equipment; relevant biological observations;
- The processing, tabulation and interpretation of agrometeorological data; statistical and mathematical methods of analyses.

12.3.8 Crop forecasts

- Crop forecasting techniques and examples of forecasting time of emergence of seed, vegetative growth periods, flowering, maturity and yield of crops.

12.3.9 Investigations and research

- Development of crop-weather relationships; use of semi-empirical models.

12.3.10 Forest meteorology

- The microclimate within and above forest canopies;
- The microclimate of small clearings and new plantations;
- Topoclimatology in forested areas with emphasis on temperature inversions, freezing temperatures and low relative humidities;

- Forests in relation to regional energy and CO_2 balances;
- Climatic requirements of various tree species;
- Forest fires and fire-weather forecasts.

12.3.11 Satellite applications in agrometeorology

- Same as in section 18.1.16.

12.3.12 Special weather forecasts for agriculture

- Elementary forecasting technique, interpretation of daily weather charts; frost danger warning for crop protection; veld and forest fire warnings; planting and harvesting weather forecast; insect and disease forecast; postharvest and storage forecast; agricultural aviation forecast; warm and cold spells; wet and dry spells; severe weather.

12.3.13 Practical work on meteorological instruments and methods of observation

- Pressure: units and relation between different units; reduction of pressure to other levels; mercury barometers; method of observation; correction of barometer readings to standard conditions - index error, gravity correction, temperature correction; exposure, transportation and installation of the mercury barometer; the barograph - care and maintenance, evaluation of the records; the aneroid barometer;
- Surface wind: units; relation between different speed units; determination of true North, the compass points; estimation of wind speed, the Beaufort scale; different types of anemometer and anemograph; evaluation of the records; exposure of wind equipment;
- Temperature: Fahrenheit, Celsius and Absolute temperature scales, liquid-in-glass thermometers - the ordinary thermometer, the maximum thermometer, the minimum thermometer, the soil thermometer; reading a thermometer; electrical thermometers - the resistance thermometer, thermocouples, the thermistor; auxiliary electrical equipment; thermographs - the bimetallic type, the Bourdon-tube type, the mercury-in-steel type; evaluation of the records; thermometer and thermograph exposure; general requirements in order to obtain representative air temperature; thermometer screens; artificial ventilation; exposure of soil thermometers and grass minimum thermometers; the importance of calibration certificates; possible sources of defects in thermometers and the various procedures to rectify them;
- Duration of sunshine: sunshine recorders; exposure and installation of sunshine recorders; evaluation of the records;
- Atmospheric humidity: units and methods; simple psychrometer without artificial ventilation; the sling psychrometer; the Assmann type psychrometer; exposure and observational procedure; care of the wet

bulb; operation of wet bulb below freezing; sources of error in psychrometry; the psychrometric formula; tables and slide-rules; hair hygrographs - general requirements, exposure, management and transportation; accuracy and sources of errors; washing the hairs; evaluation of the records; dew-point and frost-point hygrometers; electrical absorption-type hygrometers;

- Precipitation: units; errors and accuracy of reading; the ordinary and totalizer raingauges; rainfall recorders; rainfall intensity recorders; evaluation of the records; exposure of raingauge, general rules; influence of strong and gusty winds; rainfall measurement on slopes; snow measurements; dew and leaf-wetness measurements;

- Evaporation: the main classes of evaporimeter; large evaporation tanks; small evaporation tanks; porous bodies; porous paper wick devices; exposure, maintenance, scale, observations and entries; calculations;

- Soil moisture: units of measurement; visual observation; gravimetric method; obtaining percentage moisture by volume; tensiometers; electrical methods; thermal methods; neutron scat tering method; gamma-ray absorption method;

- Radiation: units, types of instrument; estimates from simple data.

12.3.14 Practical work based on the theoretical course

- Climatological analysis: processing of observation data preparatory to ultimate use and interpretation, e.g., averages, normals, frequencies, standard deviation, etc.; study of the climate of the region or continent concerned - statistical analysis of representative climatic elements, the drawing of isopleths, etc.

- Calculation of derived parameters, e.g., evaporation, radiation, climatic indices; testing of "models";

- A study of the variation of temperature, humidity and wind in the microlayer; a microclimatological study of a suitable area;

- A study of the influence of different windbreaks and shelterbelts on the microclimate;

- A study of frost-protection methods;

- A study of meteorological aids to irrigation practices;

- Analysis and interpretation of elementary synoptic charts; preparation of routine forecasts; examples of special weather forecasts for agriculture;

- Practical crop-forecasting, including yields, quality, sowing and harvest dates;

- A monograph by each student on the application of agrometeoro logy to his or her particular field of study in agricultural science.

12.4 SPECIALIZATION IN AGRICULTURAL METEOROLOGY (CLASS II)

12.4.1 Agricultural and biological sciences (Reference: section 12.2.1)

- Soil science;
- Botany; plant and crop physiology; plant pathology;
- Field and horticultural crops; agricultural economics; pastures;
- Zoology; animal anatomy and physiology; animal husbandry and diseases of livestock; entomology;
- Ecology.

12.4.2 Agricultural meteorology

12.4.2.1 The boundary layer

- Radiation balance; heat exchange;
- Microclimate (description); topoclimate;
- Influence of surface nature and plant cover;
- Its importance to agriculture and forestry.

12.4.2.2 Soil physics

- Heat diffusivity and conductivity;
- Soil temperature; soil moisture constituents, content, energy, movement and balance.

12.4.2.3 Influence of weather on plant development and growth

- Soil moisture, rainfall, transpiration, internal moisture stress and nutrition;
- Temperature, respiration, development, heat stress and vernaliza tion;
- Solar radiation, photosynthesis and light quality;
- Photoperiod and the effect of light quality;
- Other factors: dew, soil temperature, plant nutrition, atmos pheric humidity and winds;
- Influence of soil moisture content and potential on plant growth.

12.4.2.4 Influence of weather on animals

- Heat and cold stress and thermal balance;
- Water stress;
- Acclimatization;
- Animal protection from unfavourable weather.

12.4.2.5 Insects and diseases

- Temperature and humidity;
- Weather and epidemiology; transport of insects and diseases.

12.4.2.6 Observations and instruments (macro-)

- Agrometeorological stations and networks; networks for acquisition of crop data;
- Special equipment: evaporimeters, soil thermometers and soil moisture equipment; dew gauges, thermal radiation equipment and spectral light meters;
- Biological and phenological observations.

12.4.2.7 Boundary layer modification

- Irrigation scheduling;
- Windbreaks and shelterbelts;
- Freezing temperatures and protection;
- Protection of perishable goods during transport and storage;
- Soil surface mulches;
- Glass houses and plastic tents.

12.4.2.8 Processing and dissemination of agrometeorological data and information

- Information required by agriculture: climatic summaries and special analyses;
- The use of punch cards and machine processing of data; analysis and interpretation of climatic data; statistical methods; climatic trends; harmonic analysis;
- Presentation: maps, charts, tables and texts;
- Special methods for micro- and topoclimatological data.

12.4.2.9 Satellite applications in agrometeorology

- Same as in section 18.1.16.

12.4.2.10 General knowledge of agricultural and meteorological organizations and activities

- Local and national;
- National co-ordination of agrometeorological activities;
- World Meteorological Organization (WMO) and the Commission for Agricultural Meteorology (CAgM);
- Food and Agriculture Organization (FAO);
- Scientific societies and journals.

12.4.3 Optional courses

In some cases agrometeorologists (Class II) may be assigned to units where their responsibilities may be confined to one or two problem areas. In-depth training in these problem areas may be difficult on a class basis. For general training all topics may be covered in a general manner. Where the student already knows to which problem area he is to be assigned, it may be desirable to have him do a special thesis-type project on this particular problem area. Suggested problem areas are:

12.4.3.1 Special weather forecasts for agriculture

- Warnings of freezing temperatures;
- Wind warning for spraying;
- Storm warnings for livestock protection;
- Haying and harvest conditions;
- Conditions favourable for insect and disease epidemics.

12.4.3.2 Special analysis for crop zonation and land use

- Systematic appraisal of problems, availability of data and possible solutions;
- Soil moisture budget calculations;
- Irrigation and water requirements;
- Probabilities of beginning and ending of freeze-free periods; dry and wet periods;
- Biometeorological time scales;

INDEX

- Rainfall and soil moisture probabilities: distribution functions; gamma functions;
- Probability of wet and dry days; Markov chains;
- Joint distributions (e.g. drought and excessive temperature).

12.4.3.3 Weather, crop-condition and yield surveillance

- Economics of world food supply, demand and distribution;
- Crop-condition reporting services;
- Crop statistics: national; FAO;
- Yield-weather models: empirical models; linear regression models; physiological models;
- Application to areal surveillance;
- WWW data and world crop conditions.

12.4.3.4 Micrometeorology

- Definition and scope;
- Radiative heat balance of earth's surface;
- Fluxes of sensible heat, water vapour and carbon dioxide above growing vegetation;
- Turbulent transport and diffusion of air pollution, spores and other particulates;
- Instrumentation.

12.4.3.5 Climatological requirements of specific crops

- Wheat; rice; oil palm; maize; coffee; sugar cane; pineapple; pasture crops vs. seed crops; etc.

12.4.3.6 Forest meteorology

- The microclimate within and above forest canopies;
- The microclimate of small clearings and new plantations;
- Topoclimatology in forested areas with emphasis on temperature inversions, freezing temperatures and low relative humidities;
- Forests in relation to regional energy and CO_2 balances;

- Climatic requirements of various tree species;
- Forest fires and fire-weather forecasts.

12.4.4 Projects and seminars

Projects and seminars should be selected bearing in mind the specific regional interests of the participants.

12.5 SPECIALIZATION IN AGRICULTURAL METEOROLOGY FOR AGRICULTURAL ENGINEERS

12.5.1 Synoptic meteorology

- Same as in section 5.3.3.

12.5.2 Climatology

- Same as in section 5.3.4.

12.5.3 Agricultural meteorology

- Same as for Class II, section 12.4.2.

12.6 SPECIALIZATION IN AGRICULTURAL METEOROLOGY (CLASS III)

- Biological sciences: an elementary knowledge of appropriate biological sciences;
- Scope of agricultural meteorology: definition, aims; the relationship between weather, climate and agriculture; soils; plants; farm animals; diseases and pests of crops and animals; farm buildings and equipment; artificial modifications of the meteorological and hydrological regime; a short history of agricultural meteorology in relation to the needs of agriculture and the development of meteorological instruments; national Meteorological Services; the World Meteorological Organization (WMO) and the Commission for Agricultural Meteorology (CAgM).

12.6.1 Agrometeorological observations

- Meteorological observations: units; accuracy; importance; exposure of instruments and general rules for the observation of pressure, air

temperature, atmospheric humidity, wind, sunshine and radiation; precipitation; evaporation; soil temperature; soil moisture content and soil moisture tension; interpretation and analysis of autographic charts; cloud classification; genera; species and varieties; the synoptic classification; significant cloud; cloud cover; estimation of cloud base; horizontal visibility; existing weather conditions; state of the ground (dew, etc.);

- Biological observations: observations on native plants and on cultivated crops and trees, farm animals, diseases, insect pests, and general activities on the land.

12.6.2 Agrometeorological instruments

- The choice of site for an instrument enclosure; a detailed study of the procedures for installation, maintenance, checking and calibration of the following instruments:

- Pressure: the mercury barometer, method of observation; exposure; transportation and installation; correction of barometer readings to standard conditions; index error; gravity correction; temperature correction; the barograph; the aneroid barometer;

- Surface wind: the pressure plate anemometer; cup and propeller anemometers; the hand anemometer; the totalizing anemometer; contact and generator type of anemometer and anemograph; the pressure-tube anemograph; the hot-wire anemometer; etc.;

- Radiation: the exposure and maintenance of the major instruments for measuring short-wave, long-wave, and net radiation; spectral distribution; the measurement of illumination; evaluation of the records;

- Duration of sunshine: sunshine recorder; exposure and installa tion; maintenance; evaluation of records;

- Temperature: liquid-in-glass thermometers; ordinary thermometers; maximum thermometers; minimum thermometers; soil thermometers; reading a thermometer; electrical thermometers; resistance thermometers; thermo-couples; thermistors; auxiliary electrical equipment; thermographs; the bimetallic type; the Bourdon-tube type; the mercury-in-steel type; thermometer and thermograph exposure; general requirements in order to obtain a representative air temperature; thermometer screens; artificial ventilation; exposure of soil thermometers and grass minimum thermometers; the importance of calibration certificates; possible sources of defects in thermometers and the various procedures to rectify them;

- Atmospheric humidity: psychrometers; simple psychrometer with out artificial ventilation; the sling psychrometer; the Assmann-type psychrometer; exposure and observational procedure; care of the wet bulb; operation of wet bulb below freezing; sources of error in psychrometry; the psychrometric formula; tables and slide-rules; hair hygrographs; general requirements; exposure; maintenance and transportation; accuracy and sources of error; washing the hairs;

dew-point and frost-point hygrometers; electrical absorption-type hygrometers;

- Precipitation: the ordinary and totalizing raingauges; rainfall recorders; rainfall intensity recorders; snow measurements; depth and density;

- Dew and leaf wetness: the Duvdevani dew block; Leick plates; weighing type of apparatus; leaf wetness recorders;

- Evaporation and evapotranspiration: the main classes of evaporimeter; large evaporation tanks; small evaporation tanks; porous porcelain bodies; porous paper wick devices; lysimeters; exposure; maintenance; scale; observations and entries; calculation;

- Soil moisture content and soil moisture tension: tensiometers; the gravimetric determination of soil moisture content; resis tance of porous blocks; the neutron moisture meter.

12.6.3 Processing of agrometeorological data

- Statistics: meaning of an observation; errors of observation; observations as samples of a population; quality control and processing of observation; climatological data; collection; treat ment; storage; cataloguing; publication;

- Statistical methods: frequency distributions; relative frequency; cumulative frequency; histogram; statistical parameters; mode; median; quartiles; percentiles; arithmetic mean; standard deviation; variance; weighted and adjusted means; means from grouped data; significance tests; Student's t-test; the Chi-square test; regression; significance of a regression coefficient; correlation; significance of a correlation coefficient; analysis of variance.

12.6.4 Microclimatology

- Importance of the air layer near the ground for agriculture; variations of leaf and air temperature; humidity and wind in the microlayer; influence of topography; soil type; soil condition and vegetation on the microclimate.

12.6.5 Soil temperature

- Flow of heat in the soil; diurnal and seasonal variation of soil temperature at different depths; factors affecting soil temperature; the importance of soil temperature for plant growth.

12.6.6 Soil moisture

- The hydrological cyle; the importance of soil moisture for plant growth.

12.6.7 Weather hazards adversely affecting agricultural output

- Droughts: definition; frequency; long-term planning against drought; the possibility of cloud stimulation;
- Hail: frequency of hail storms; hail damage and its prevention;
- Frost: extent of frost damage; sensibility of plants to low temperatures; radiation and advective frosts; taking account of frost in agricultural planning; ways of diminishing frost damage; artificial methods of combating frost damage - e.g., orchard heating, sprinkler irrigation;
- Strong winds: the importance of windbreaks and shelterbelts; the detrimental effects of strong winds on plants, animals and the soil; the effects of windbreaks upon the environment; different types of windbreak; the advantages and disadvantages of shelterbelts; trees and types of shelterbelt suitable for local conditions.

12.6.8 Practical applications

- Practical applications of meteorological and climatological data of plants, crops, animals, insects and plant diseases.

12.6.9 Agrometeorological research

- A discussion on research problems applicable to the region or country concerned.

12.6.10 Practical training

- The theoretical course must be supplemented by an intense training in outdoor practical work, specially concerned with the maintenance of instruments and the taking of observations.

12.7 CLASS IV PERSONNEL ENGAGED IN AGRICULTURAL METEOROLOGY

12.7.1 General meteorology

- (See section 7.2.1).

12.7.2 Meteorological instruments and methods of observation

- (See section 7.2.2).

12.7.3 Climatology

- (See section 7.2.3).

12.7.4 Air and soil temperature

- Air temperature measurements; daily and annual variation of air temperature; vertical air temperature distribution; temperature inversions; horizontal distribution of air temperature; charts of isotherms at sea-level and at surface; soil temperature measurements; daily and annual variation of soil temperature; factors influencing soil temperature; influence of air and soil temperature upon plants and the processes of growth; photosynthesis and respiration; resistance of plants to high and low temperature; frost and frost protection.

12.7.5 Water vapour in the atmosphere and soil moisture

- Atmospheric humidity; definitions, significant values, measurements; evaporation; evaporation process; measurement of evaporation from water and land surfaces; transpiration and evapotranspiration; soil moisture, kinds of soil water; agrohydrological soil properties; soil moisture measurements; soil water balance.

12.7.6 Biological measurements (phenology)

- Importance of phenology for meteorology and agriculture; phenological observations; phenological seasons; phenological cartography.

- Stress to be laid on observations dealing with practical agriculture.

12.7.7 Agrometeorological stations

- Organization, equipment, measurements, observations and informa tion provided.

CHAPTER 13

SPECIALIZATION IN HYDROMETEOROLOGY

FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL

INDEX

INDEX

13.1 SPECIALIZATION IN HYDROMETEOROLOGY (CLASS I)

Increasing demands for water irrigation, transport, power and industrial and domestic purposes, as well as demands for mitigation of flood losses (including loss of life) are making it necessary for more and more countries to undertake comprehensive water management measures. These measures in turn call for detailed timely investigations of the hydrological regimes of rivers and lakes.

The planning, design and operational phases of water management all require joint consideration of meteorological and hydrological phenomena, and thus the need for trained meteorologists who are specialists in the atmospheric phase of the hydrological cycle and are competent in water management applications of meteorology; i.e., meteorologists with specialized training in hydrometeorology. It should be emphasized that this specialized training is not intended to qualify a meteorologist for employment also as a hydrologist.

A distinction is made among the following four categories of personnel:

(a) Class I hydrometeorologists (specialists with a University degree);

(b) Class II hydrometeorologists (specialists with a thorough training in hydrometeorology but who need not necessarily have obtained a University degree;

(c) Class III hydrometeorologists (specialists trained to a semi-professional technician level);

(d) Class IV hydrometeorologists (specially trained observers).

This section is devoted to the syllabi for training Class I hydrometeorologists, but it will be seen from section 13.2 that the specialized training for Class II hydrometeorologists is much the same. The syllabi presented below are considered to be modest in terms of an optimum programme, and it is assumed that the student has had a course in general hydrology (section 3.3.6) during his basic training for Class I category. It should be recognized however that some modifications may be in order, depending on cir- cumstances such as the qualifications of the student and the nature of the employment involved.

13.1.1 Analysis of meteorological data for design purposes

Computation of mean annual basin precipitation taking into account physiographic factors; rainfall intensity-frequency data for a point; relationship between point and areal rainfall intensities of specified frequency; depth-area-duration data for storm precipitation; probable maximum precipitation (PMP); snowmelt computations; maximization of snowmelt in conjunction with PMP; estimates of free-water evaporation and actual evapotranspiration; conjunctive design of climatological and hydrometric networks; time trends in meteorological data.

13.1.2 Analysis of hydrological data for design purposes

Methods of computing runoff hydrographs: mass curves of runoff; flow-duration curves; design floods; probable maximum flood; minimum flow

computations; flood frequency analysis; empirical flood formulae; flood plain mapping; co-ordinated mapping of precipitation, evaporation and runoff; time trends in-flow data.

13.1.3 Meteorological aspects of water management operations

Meteorological effects on the runoff cycle; precipitation types and related intensities; calculation of mean basin storm precipitation; radar measurement of precipitation; water management requirements for quantitative precipitation forecasts; meteorological basis for flash flood warnings; causes and predictability of droughts; irrigation requirements.

13.1.4 Hydrological aspects of water management operations

Hydrometric measurements; relationship between discharge and stage; rainfall-runoff relations and conceptual models for predicting the discharge hydrograph; hydrological basis for flash flood warnings; long-range forecasts of seasonal flow volume and ice phenomena, such as formation and break-up.

13.2 SPECIALIZATION IN HYDROMETEOROLOGY (CLASS II)

Class II hydrometeorological personnel must have a thorough training in hydrometeorology to enable them to carry out some of the functions of the Class I personnel. Their duties, though of an essentially routine and practical nature, demand complete understanding of the principles involved. Therefore the syllabi for training Class II personnel in this field are essentially the same as those given for Class I in sections 13.1.1 to 13.1.4.

It should be mentioned, however, that for Class II personnel more emphasis should be placed on practical aspects of the programme. Due consideration should be given also to the eventual field in which the student would be employed.

13.3 SPECIALIZATION IN HYDROMETEOROLOGY (CLASS III)

Class III hydrometeorological personnel are qualified specialists thoroughly trained in the conduct of all types of hydrometeorological and meteorological observations, the processing of observation data and their preparation for publication in yearbooks or reference books, the installation, checking and field repair of hydrometeorological instruments and equipment, and the management and control of hydrometeorological station networks.

The recommended standard curricula for training Class III hydrometeorological personnel are given below. These are considered to be modest in terms of an optimum programme. For this reason, the content of the courses may be modified in the light of circumstances and the qualifications of the students, and the nature of the employment involved.

13.3.1 Analysis of meteorological data for design purposes

Computation of mean annual basin precipitation taking into account physiographic factors; rainfall intensity-frequency data for a point; relationship between point and areal rainfall intensities of specified frequency; depth-area-duration for storm precipitation; probable maximum precipitation (PMP); snowmelt computations; maximization of snowmelt in conjunction with PMP; estimates of free water evaporation and actual evapotranspiration; conjunctive design of climatological and hydrometric networks.

13.3.2 Meteorological aspects of water management operations

Meteorological effects of the runoff cycle; precipitation types and related intensities; calculation of mean basin storm precipitation; water management requirements for quantitative precipitation forecasts, meteorological basis for flash flood warnings; causes and predictability of droughts; irrigation requirements.

13.4 CLASS IV PERSONNEL ENGAGED IN HYDROMETEOROLOGY

The following syllabus covers only the rudiments, without mathematical development.

- Rudiments of hydrology, and hydrological measurements; the hydrological cycle;
- Intensity and frequency of precipitation at a given point;
- Estimating evaporation from a free surface and actual evapotranspiration;
- Snow; evaluating snow storage; snowmelt;
- Influence of meteorological elements on the hydrological cycle;
- Relationships between climatological and hydrometric networks;
- "Height/amount of precipitation" relationships;
- Calculation of the average annual depth of water falling as precipitation over a basin;
- Depth/area/duration relationships;
- Probable maximum precipitation (PMP);
- Calculation of average depth of water falling as precipitation in a shower over a basin;

- Critical examination of time series of precipitation; homogeneity of series;
- Forecasting precipitation;
- Meteorological elements in forecasting floods;
- Causes and characteristics of droughts and excess precipitation;
- Water and its users; requirements (in particular for irrigation).

CHAPTER 14

SPECIALIZATION IN ATMOSPHERIC CHEMISTRY

AND

AIR-POLLUTION METEOROLOGY

FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL

INDEX

14.1 GENERAL

Atmospheric chemistry and air-pollution meteorology examine the conditions and establish the physical and chemical processes and properties which determine the transport, transformation, distribution and removal of man-made and natural substances released into the atmosphere. Particular emphasis is placed on those substances which may affect weather, climate, and the well-being of man and ecosystems. The results of such studies lead to a better understanding of the atmosphere and its interaction with other media and are an essential input to air pollution control measures and thereafter make it possible to ascertain the pollution of adjacent media via the atmosphere.

14.2 SPECIALIZATION IN ATMOSPHERIC CHEMISTRY AND AIR-POLLUTION METEOROLOGY (CLASS I)

14.2.1 Principles of atmospheric chemistry and air-pollution

14.2.1.1 Definitions of atmospheric chemistry and air-pollution

14.2.1.2 History of our notion about the composition of the atmosphere and of air pollution problems

14.2.1.3 Types and sources of pollutants

- Kinds and categories of air pollution (natural and anthropogenic); abundance of important pollutants; pollution levels and their variation in time over global, regional and local scales; emission inventories of important pollutants.

14.2.1.4 Atmospheric chemistry

- Review of basic chemistry: periodic table; chemical reactions; chemical equilibria; ionic and molecular species and their general properties; chemical nomenclature; stoichiometric relationships; photochemical processes; SI units;

- Atmospheric composition: major components and trace constituents; mean concentrations and variabilities in time statistical frequency distributions; evaluation of the composition of the atmosphere; composition of planet atmosphere;

- Atmospheric physical chemistry: reaction rates, catalysts, synergisms; special application of thermodynamics to the chemistry of air pollutants in background and in polluted air, in cloud and fog;

- Sources: natural and anthropogenic sources; direct and indirect methods of estimating source strengths; emission inventories of important pollutants on the urban, synoptic, regional and global scales;

- Atmospheric aerosols: definitions of "aerosols"; stratospheric, tropospheric abundance; horizontal and vertical profiles; typical concentration levels in different scales of background and local pollution; variation with time; physical and chemical nature of composition; distribution by size, number, mass, aerodynamic properties; natural and anthropogenic sources; physical and chemical formation and transformation; resuspension; life cycles;

- Atmospheric photochemistry: precursors, NO_x; oxidant production and destruction processes; SO_2-sulphate conversions; elements of stratospheric photochemistry; modelling;

- Removal processes: dry and wet deposition; deposition velocities; reentrainment;

- Residence times; transit times; turnover times;

- Biogeochemical cycling: the global cycles of nitrogen, sulphur, carbon, mercury, DDT.

14.2.1.5 Air pollution control and air resource management

- A general introduction;

- Concepts: air pollution control agencies and their functions; interjurisdictional co-operation; sources of air pollution information;

- Standards: emission standards vs. air quality standards; best practicable technology; legal standards.

14.2.2 Principles of air pollution meteorology

14.2.2.1 A general introduction

14.2.2.2 Air pollution climatology

- Air pollution frequency distributions: log-normal; exponential; other;

- Pollution potential climatology: wind roses; mixing height and ventilation climatologies;

- Climatological classifications: Pasquill-Gifford; other;

- Climatological air pollution models: point sources; multiple sources;

- Mesoclimatological applications;

- Environmental impact assessment: objectives; techniques; the role of the meteorologist; field surveys.

14.2.2.3 Atmospheric diffusion and transport

- Boundary layers: surface; planetary; convective; surface mixed; internal;
- Flux-gradient theory: Fickian diffusion; mixing length; diffusivities; diffusion of momentum, heat and matter;
- Statistical theory of turbulence: isotropy; homogeneity; stationarity; autocorrelation function; power spectrum; intertial subrange; Lagrangian and Eulerian reference frames; the Hay-Pasquill relation;
- Similarity theory: Monin-Obukhov length; Richardson number; wind and temperature profiles;
- Diffusion equations: Taylor's theorem; diffusion from instantaneous and continuous point; line and volume sources in homogeneous and in shear flows; peak-to-mean concentration ratios;
- Plume rise: jets, buoyant plumes; entrainment; design of chimneys and cooling towers;
- Aerodynamic effects of obstacles: downwash, entrainment, cavities, wind tunnel modelling;
- Mesoscale diffusion: valleys, cities, coastlines;
- Transport of pollutants: tropospheric and stratospheric transport on synoptic and global scales; trajectory analysis.

14.2.2.4 Modelling

- Requirements for emission and meteorological data;
- Single source models: nomograms and other aids for computing dispersion patterns;
- Multiple-source computer models: requirements for emission and meteorological data; urban, meso- and synoptic-scale models for flat and for complex terrain; chemical transformations; validation techniques and sensitivity analyses;
- Trajectory-based models: urban, meso- and synoptic-scales; chemical transformations;
- Regional and global models: box models; diffusion-transport models; large-scale diffusivities; general circulation models; validation techniques;
- Climatological air pollution models: point sources; multiple sources.

14.2.2.5 Prediction

- Synoptic predictions: mixing heights; ventilation coefficients; stagnation episode forecasting; adaptation of synoptic prediction to local conditions.

14.2.3 Monitoring and instrumentation

- Monitoring: purposes of monitoring; selection of parameters; modes of monitoring and representativeness of observations; the WMO Background Air Pollution Monitoring Network; the WHO urban air pollution network; GEMS; integrated monitoring;

- Siting and network density criteria; siting criteria for various monitoring purposes; the WMO and WHO siting criteria for their air pollution networks; network density criteria;

- Establishment of a sampling station (including feasibility studies); interference through local and nearby sources of pollutants; logistic considerations including erection of equipment, availability of pollution-free power supplies, telecommunications and transportation;

- Meteorological instruments used for air pollution surveys; sensitive anemometers, bidirectional vanes, three-component turbulence sensors; temperature and temperature difference measuring devices; precipitation collectors (wet and dry); minisondes; tethered balloons; instrumented towers; remote sensors (ground-based, aircraft-based, satellite-based);

- Sampling: elaboration of sampling programmes; general sampling precautions; field sampling techniques (aerosol and gas samplers, optical samplers, samplers for wet and dry deposition);

- Equipment and measurements: required resolution in time and space and its implication on the provision of instrumentation and manpower; measurement techniques for CO, CO_2, NO_x, SO_2, O_3, C_mH_n and suspended particulates; understanding the operation of equipment to cover the WMO monitoring programme, in particular, turbidity, wet precipitation sampling, suspended particulates by high volume sampler, and CO_2 measurements;

- Quality control and data handling: interlaboratory comparisons; SI units and conversions; principles and application of elementary statistics and calibration standards.

14.2.4 Effects of air pollution

14.2.4.1 Effects on weather and climate

- The atmospheric greenhouse effect: basic theory; CO_2; halocarbons; other gases; the effect of greenhouse warming on the general circulation and on surface climate;

- The climatic effects of aerosols: natural vs. anthropogenic aerosols; urban effects; global effects; regional sulphate hazes;

- Synoptic effects: on visibility, cloudiness, atmospheric electricity, precipitation.

14.2.4.2 Effects on humans and their welfare

- Health effects: physiological studies, epidemiological studies;

- Effects on vegetation: direct and invisible damage;

- Effects on property: soiling, corrosion, rubber and nylon oxidant damage;

- Acid rains: mechanisms; effects on ecosystems including those in lakes and rivers;

- Air quality criteria: dose-response relationships; sampling and averaging times; adaptation; variability within populations; physiological factors; synergisms.

14.3 SPECIALIZATION IN ATMOSPHERIC CHEMISTRY AND AIR-POLLUTION METEOROLOGY (CLASS II)

As for specialization in Atmospheric Chemistry and Air-Pollution Meteorology (Class I), section 14.2. The topics should be selected and the material covered to the degree appropriate to the purpose of the Class II training being given.

14.4 SPECIALIZATION IN ATMOSPHERIC CHEMISTRY AND AIR-POLLUTION METEOROLOGY (CLASS III)

14.4.1 Principles of air-pollution

- Atmospheric chemistry: review of basic chemistry; explanation of the most important technical terms; normal composition of dry air; water vapour content, properties of important pollutants (gases and aerosols).

- Types and sources of pollutants: definition of air pollution; history of air pollution problems; kinds and categories of air pollution; natural and anthropogenic sources; abundance of important pollutants; pollution levels and their variation in time over global, synoptic, regional and local scales; concentration gradients near the ground; emission inventories of important pollutants.

- Removal of pollutants: sedimentation; rainout; washout; impact and adhesion; chemical transformations of gases into aerosols;

- Air pollution meteorology: transport of pollutants (gases and particulates); elements of chimney design; plume rise; temperature inversions; air flow and topography on meso and micro scales; urban temperature and flow fields.

- Synoptic predictions: mixing heights; ventilation coefficients; stagnation episodes and forecasts.

- Air pollution climatology: mixing heights; inversion frequency; wind and pollution roses; stability classes; air pollution trends.

- Main effects of air pollution: short-term and long-term effects on physical properties of the atmosphere, like turbidity and visibility; effects on climate; effects on human health and welfare; effects on plants, etc.

- Air resource management concepts: air pollution control agencies and their functions; sources of additional information on air pollution; air quality standards; meteorological control, including episode control through short-term forecasting.

14.4.2 Monitoring and measurements

- Monitoring: purpose of monitoring; modes of monitoring and representativeness of observations; the WMO monitoring network; description of programmes; network operations.

- Siting and establishment of a monitoring station: WMO siting criteria for baseline and regional stations; interference through local and nearby sources of pollutants; establishment of a sampling site; protection and security precautions for sampling site; safety precautions; provision of housing and transportation, etc., for personnel and instruments; provision of pollution-free power supplies; understanding of electric wiring and laying of cables; performance of experimental tests for site representativeness;

- Sampling: elaboration of sampling programmes; general sampling precautions; field sampling techniques (deposition, filtration, absorption); wet precipitation sampling; storage and dispatch of samples not to be analysed locally; sampling interferences; sampling height effects;

- Instruments and measurements: description of air pollution measuring instruments used at baseline and regional stations; good understanding of basic laboratory techniques; volume and mass determinations; preparation of solutions; acids, bases and titration; use of analytical instrumentation; sources of interferences in analytical determinations and through corrosion and malfunction of instruments; laboratory techniques such as cleaning procedures, etc.; air flow close to ground and around obstacles; interference of instruments to airflow; instrument maintenance; calibration standards; maintenance of standards; checking of instrument performance; calibration programmes; measurement techniques for CO, CO_2, NO_x, SO_2, O_3, C_mH_m; turbidity measurements; wet precipitation sampling; suspended particulate sampling;

- Data validation and reporting: quality control procedures; data reporting and coding procedures; station operations and records; application of simple mathematical statistics; presentation of results in tables and diagrams; SI units and conversions;

- On-site training: training at a field monitoring station in the use of air pollution measuring instruments and the application of field sampling techniques; care and maintenance of instruments; meteorological observations; data reporting; data coding; data transmissions; station records; technical and administrative aspects of station operation.

14.5 CLASS IV PERSONNEL ENGAGED IN ATMOSPHERIC CHEMISTRY AND AIR-POLLUTION METEOROLOGY

14.5.1 Principles of air-pollution

- Air chemistry; air pollution and chemical nomenclature; explanation of most important technical terms; normal composition of dry air; water vapour content;

- Types and sources of pollutants: definition of air pollution; history of air pollution problems; main air pollutants and their properties; natural and anthropogenic sources (power generation, heating, traffic, industry); content of main air pollutants by volume and mass concentration;

- Removal of pollutants: absorption, deposition, cleansing by rain cloud processes (rainout, washout), impact, adhesion; chemical reactions causing a transition of material as a removal mechanism (e.g., transformation of gases into aerosols);

- Main effects of air pollution: effects on physical properties of the atmo- sphere (e.g. visibility), effects on vegetation; biological effects; effects on human health; effects on materials;

- Air pollution control: air quality standards, meteorological control through short-term forecasting; air pollution climatology (mixing heights, inversion frequencies, wind and pollution roses) and its use in land use planning.

14.5.2 Air-pollution monitoring

- Introduction: purposes of monitoring and parameters (quantities) to be monitored; the WMO Background Air Pollution Monitoring Network; observation programmes at different types of stations; other international monitoring programmes (e.g. WHO impact level networks);

- Establishment and equipment of sampling sites: physical preparation of site; security precautions; avoidance of interference from nearby sources of pollution and from topography; logistic requirements (e.g.,

pollution-free power supply, telecommunications, shelters for instrument and staff, waste disposal); laying of cables (power and signal lines); understanding of simple principles of electrical laws and wiring;

- Sampling procedures and equipment: collection of wet precipitation by manually-operated or automatic rain gauges; collection of suspended particulate matter by high-volume samplers; collection of gases by surface-active monitors; sampling of gaseous pollutants by wet absorption and by dry filtration with chemically prepared filters; chemical and physical properties of sample containers with regard to possibility of spoiling sample; some examples of sampling interferences and errors; change of filters and precipitation buckets; storage and dispatch of samples; principles of air pumps; air flow-rate determination and control, critical orifices; pressure, temperature, humidity corrections, their necessity and applicability;

- Observation procedures and equipment: meteorological observations; use of special wind sensors (quick response and high sensitivity); turbidity observations; sunphotometers;

- Measurement procedures and equipment: simple discussion of principles and analytical procedures for the determination of main pollutants such as CO_2, sulphur compounds, hydrocarbons, nitrogen oxides, oxidants, CO; main principles for the analysis of particulate matter removed (sampled) from air by filtration, impact, etc.; understanding of technical terms and nomenclature regarding the aforementioned measurements; calculation of concentration from sample mass and volume of air sample; discussion of performance of manual vs. automated instruments; use of SI units and conversions;

- Operational requirements in monitoring: maintenance of equipment, cleaning, lubrication, replacement of essential spare parts, of fuses and motor brushes, drive belts; checking of mechanical connexions; corrosion problems; familiarization with manufacturers instructions and specifications; calibration procedures and elaboration of calibration programmes; primary, secondary and working calibration standards; interlaboratory comparison exercises; verification of errors in reading meters; keeping of various kinds of records; personnel (change, leave), unusual events, sampling conditions, calibration data and circumstances, power failure, accidents, floods, changes in vegetation, operation and exchange of individual equipment, vandalism, etc., dispatch of samples, organizational parameters (reporting, visits, provision of supplies);

- Evaluation, quality control and dissemination (or reporting) of results of measurements: discussion of accuracy, precision and reproductibility of sampling, observation and measurement procedures or instruments; simple statistical checks, calculation of averages, means, standard deviation, determination of outliers; data reporting: tabulation of values, preparation of diagrams (histogrammes, time series), filling in of WMO data-reporting forms;

- On-site training: two or three week familiarization with routine activities at a monitoring station; use of equipment (detection of malfunction, simple repairs, maintenance); taking of samples, observations, measurements of meteorological and pollution parameters; emergency, safety and security precautions; general operational aspects, recording and reporting.

CHAPTER 15

SPECIALIZATION IN METEOROLOGICAL INSTRUMENTS

FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL

INDEX

15.1 SPECIALIZATION IN METEOROLOGICAL INSTRUMENTS (CLASS I)

Class I meteorological instruments specialists are highly qualified personnel whose main functional duties are to supervise the installation, repair, maintenance and calibration of specialized and sophisticated instruments such as storm detection radars, meteorological rockets and atmosphere simulators, as well as instruments aboard meteorological satellites including APT photographic systems, scanning radiometers and high resolution infrared radiometers. They also draw up specifications for meteorological instruments as required by their Services and may assist in the design and development of new instruments according to their special aptitudes.

They should have a University or equivalent degree in mathematics and physics or in light currents, electronics or mechanical engineering. Class I instruments personnel are an integral part of a Meteorological Service and play an important role in the development of meteorology as an observational science. For this reason they should have a good grounding in meteorology. The syllabi for their meteorological training will therefore be much the same as those for all Class I meteorological personnel. Topics should, however, be taught with a view to their practical applications and instrumentation needs and requirements.

Syllabi for the additional specialized training of Class I instruments specialists are given below.

15.1.1 Technical practices

- Engineering drawings: geometrical constructions; methods of indicating dimensions, tolerance and other working instructions; drawing of spare parts; cross-sections; orthographic projection; drawing for working purposes; electric graphical symbols; circuit analysis; printed circuit drafting;

- Workshop technology: materials, metal joining; machining; lathe work; drilling; slotting; shaping; milling; grinding and hacksawing machines;

- Electric and electronic practices: soldering techniques; use and care of hand tools; electric switch boards; overload devices; electric connexions; electronic circuit assembling; kit contructions; printed circuit boards; electronic switching and timing; telecommunication equipment; microelectronic repair techniques;

- Safety and security precautions: electric and electronic technicians must learn and follow safety rules. Instructors should explain and demonstrate all safety procedures related to high-voltage power supplies, low voltage circuits, RF power output, cathode-ray tubes, selenium rectifiers and proper handling of tools and soldering irons.

15.1.2 Electronics

The material given in paragraph 15.2.2 for Class II and paragraph 15.3.1 for Class III should be revised in more detail and special emphasis given to the following:

- Power supplies for electronic instruments;
- Amplification by vacuum tubes and transistors;
- Servo systems;
- Electronic switching and timing;
- Telecommunications;
- Radar principles;
- Electrical and electric measuring and testing instruments;
- Digital circuits; logical design of digital computers; digital computers and peripheral equipment; principles of programming; programming languages; BASIC and Fortran; digital data transmission.

15.1.3 Meteorological instruments

- Meteorological transducers: pressure transducers: resistive, capacitive, piezoelectric, electrokinetic, thermal (hypsometry) transducers; temperature transducers: resistive (metallic, semi conduction, electrolysis and ionized gas), inductive, capacitive, thermoelectric; change of vibration; acoustic humidity transducers: resistance variation (hygristors), thermal (dewcel) electrolysis, capacitive, microwave refractometer - air flow speed transducers: thermal (hot wire), sonic and transportation of electric charge - radiation transducers: photo-emissive, photoconductive, photovoltaic, thermo elements;
- Meteorological instruments for special investigations: ozone sondes; atmospheric electricity sondes; radio activity sonde; radiometer sondes; atmospheric direction finders; lasers and atmospheric lidar; dewcel, frost-point and infrared hygrometers; hot wire and acoustic anemometers; aeroplane thermometers and psychrometers; neutron soil moisture meter;
- Meteorological rockets: types of meteorological rocket; instruments built in rockets; carrier for ejected chemical tracers; acoustic grenades and radar-chaff; vehicle to transport rocketsonde to the apogee where it is ejected; destructible meteorological rockets; recoverable and reusable sounding rockets; recent development of sounding rockets; rocket dropsondes; metallized parachute for radar tracking; sensors; sources of errors; corrections; calibrations; comparison of rocketsonde sensors during actual flights;
- Meteorological satellites: types of meteorological satellites; spot frequencies utilized; working principles of APT, SR and VHRR instruments on board satellites; temperature sounding by using selective chapper radiometer; ground receiving and recording station: automatic, programmed and manual tracking station; photographic and facsimile recorders.

15.2 SPECIALIZATION IN METEOROLOGICAL INSTRUMENTS (CLASS II)

Class II instruments specialists are required to carry out all field and laboratory tests, comparison and calibration of all meteorological instruments. They also supervise the storage, installation, repair and maintenance of the instruments.

Instruments specialists of this Class must be well qualified. Although a University degree is not absolutely necessary they should have had at least 12 years instruction in metal work technology, electricity and electronics, and some practical experience. They should also have received a fundamental meteorological training appropriate to their work.

The syllabi for additional specialized training are given below.

15.2.1 Technical practices

- Engineering drawings: geometrical constructions; methods of indicating dimensions; tolerance and other working instructions; drawing of spare parts; cross-sections; orthographic projection; drawing for working purposes; electric graphical symbols; circuit analysis; printed circuit drafting;

- Workshop technology: materials; metal joining; machining; lathe work; drilling; slotting; shaping; milling; grinding and hacksawing machines;

- Electric and electronic practices: soldering techniques; use and care of hand tools; electric switch boards; overload devices; electric connexions; electronic circuit assembling; kit constructions; printed circuit boards; electronic switching and timing; telecommunication equipment; microelectronic repair techniques;

- Safety and security precautions: the electric and electronic technicians must learn and follow safety rules. Instructors should explain and demonstrate all safety procedures concerning high-voltage power supplies, low voltage circuits, RF power output, cathode-ray tubes, selenium rectifiers and the improper handling of tools and soldering irons.

15.2.2 Electronic principles

For Class II instruments specialists, the basic electricity and electronics for Class IV and for Class III should be supplemented by the following:

- Sweep circuits: thyratron, hard tube, trapezodial and transistor circuits; circuit operation; linearity; sweep amplitude and duration; circuit parameter changes; trouble-shooting;

- Microwave principles: artificial transmission lines: operation time delay, charge and discharge time; circuit parameter changes; pulse

modulation: application, types, peak and average powers; range; wave-guides; propagation of energy, modes of operation, coupling and matching; cavity resonators: types, sizes, frequency uses; UHF and micro-wave oscillators and amplifiers; UHF tubes, klystron, travelling wave tubes, magnetron, parametric amplifiers;

- Special electronic circuits: generation circuits; non-sinusoidal waves; repetition-rate oscillator; sawtooth generator; reshaping circuits; limiting circuits; types and applications; differentiator and integrator circuits; clampling circuits; phase shifter counting circuits;

- Radar principles: principles of operation; radiowave reflection; radar detection methods; types of presentation and types of scanning; range and bearing determination; search and follow methods; performance characteristics of radar systems; antenna, power supply;

- Electronic test equipment: the study of general principles; applications;, circuit analysis; trouble-shooting; repair and main tenance of the following measuring instruments: cathode-ray oscilloscope, snychroscope, absorption wave meter, grid-dip meter, frequency standards, field intensity meter, spectrum analyser, universal CLR bridges, vacuum tube tester, transistor tester, multimeter, vacuum tube voltmeter.

15.2.3 Meteorological instruments

- Radiosonde systems: study of general characteristics; working principles; sensors used in measuring pressure, temperature and humidity; sources of errors of each sensor; transmitter; working frequency; power supply and ground equipment of the radiosonde systems in general use such as: chronometric, coding, radio frequency variation and audio modulated frequency variations field baseline checks and comparison equipment; laboratory test and calibration chambers: general requirements; working principles; sources of errors; atmosphere simulators; systematic errors; atmosphere simulators; systematic errors of radio-sondes: methods of assessment; sources of errors; magnitude of errors;

- Windfinding systems: study of general characteristics; basic theory; balloon-borne equipment; ground equipment; working frequency; orientation of radio and optical axis; ground reflection; instrumental errors and cut-off angles; observational errors and their magnitude; windfinding systems in general use such as radio direction finder systems, radiotheodolites, primary radars and secondary radar systems; comparison between altitudes computed from observations taken by primary, secondary radars and radiosonde ascents at the same time;

- Sounding balloons: types; treatment before inflation; nozzle weights and balances; parachutes; radar reflector; launching equipment;

- Weather radars for clouds and precipitation study: general principles; main features for weather radar equipment: aerial with turning gears and control unit; transmitter receiver unit; working frequency; output power;display unit (A, PPI, and RHI scopes) controls; auxiliary

INDEX

equipment: reflection plotter; camera; radargraph and cappigraph; calibrated IF attenuator; types of weather radar;

- Detailed study of required specific upper-air sounding system or systems and weather radar together with method of installation, repair, maintenance, test and calibration of these systems.

15.3 SPECIALIZATION IN METEOROLOGICAL INSTRUMENTS (CLASS III)

The duties of Class III instruments personnel include the installation, repair, maintenance, inspection and field comparison of all mechanical, electrical and in some cases electronic instruments as indicated in the syllabi below. They should have received a fundamental training in meteorology appropriate to their level. The syllabi for the additional specialized training required are given below.

15.3.1 Technical practices

- Engineering drawing: working sketches and drawings for mechanical spare part fabrication; electric graphical symbols and circuit diagrams analysis; electronic components graphical symbols and circuit analysis; printed circuits drafting;

- Workshop technology: material specifications; metal joining; lathe work; drilling; slotting, shaping, milling, grinding and hacksawing machines;

- Electric and electronic practices: soldering techniques; use and care of hand tools; electric switch boards; overload devices; electric connexions; electronic circuit assembling; kit constructions; printed circuit boards; electronic switching and timing; telecommunication equipment; microelectronic repair techniques;

- Safety and security precautions: the electric and electronic technicians must learn and follow safety rules. Instructors should explain and demonstrate all safety procedures concerning high-voltage power supplies, low voltage circuits, RF power output, cathode-ray tubes, selenium rectifiers and the improper handling of tools and soldering irons.

15.3.2 Meteorological instruments

The syllabus of meteorological instruments for Class IV personnel should be revised and supplemented by the course given below. Practical training on the exposure, setting, installation, repair and maintenance is restricted to those types of meteorological instruments currently in use by the Service concerned.

- The study of the general principles, classifications, scales, construction, accuracy, response, sources of instrumental and systematic errors, exposure, setting, installation, repair, maintenance and field tests and comparisons of the following meteorological instruments;

- Radiation instruments: direct solar radiation pyrheliometers: Angstrom compensation, silver disc, Michelson bimetallic, Linke-Feussner, Eppley, Moll-Gorczynski and Yanishevesky thermo-electric pyrheliometers, global radiation pyranometers, Moll-Gorczynski, Eppley, Volochine, Dirmhirn-Sauberer and Yanishevesky thermo-electric pyranometers, Robitzsch bimetallic actinograph; sky radiation: shading disc and ring attachments, total and net radiation pyrradiometers and net pyrradiometers, galvanometric and electronic compensation recorders for radiation instruments;

- Videometers and videographs: Gold visibility meters; transmitter, receiver and recorder of pulsating and modulated light beam videographs; television camera videometer;

- Ceilometers and ceilographs: continuous light beam projectors; zenith pulsating light beam with fixed transmitter and receiver; modulated light beam with rotating transmitter and fixed receiver or vice-versa;

- Ozone spectrophotometer: Dobson spectrophotometer; Konhyr oxident meter for ozone measurements;

- Facsimile chart transmitter and recorder; index of co-operation; scanning density; transmission and recording speeds; carrier frequency; transmission characteristics; land-line and wireless operation;

- Automatic meteorological stations: types; meteorological elements to be measured; sensors; coding devices; transmission systems; programming unit; power supplies, land-line or wireless transmission systems;

- Meteorological instruments used for measuring and recording the following elements: atmospheric pressure, air and soil temperature, atmospheric humidity, surface winds, precipitation, evaporation, sunshine duration, upper-winds by pilot balloons.

15.4 CLASS IV PERSONNEL ENGAGED IN METEOROLOGICAL INSTRUMENTS

Personnel at this level are required to install and, to a certain extent, repair and maintain simple meteorological instruments used for surface observations in most weather stations. These include meteorological screens, barometers and barographs, thermometers and thermographs, psychrometers, hygrometers and hygrographs, anemometers and anemographs, raingauges and rainfall recorders, solarimeters, simple optical theodolites, cloud base light projectors, generators, etc.

The syllabi for the additional training required are given below.

15.4.1 Electricity and electronics

- General introduction: constitution of matter; composition of atom; conductors and insulators; electric current; resistance; electromotive

force; electric units; magnetism and magnetic field; electromagnetism; inductance, magnetomotive force;

- Sources of electricity: mechanical electric generators; chemical primary cells and accumulators; photo-electric cells; thermo-electric cells; piezoelectric cells;

- Direct current: definition; current; voltage and resistance; Ohm's law; temperature effect on resistance; skin effect; series and parallel resistance circuits; voltage drop; potential difference; power and energy; capacitance; inductance; units;

- Alternating current: essential feature of an alternator; frequency period and phase; inductance; capacitance; Ohm's laws;

- Transformers: elementary theory of ideal and actual transformers; voltage and turns ratio; effect of secondary current; losses; heating and efficiency; single-phase transformer; autotransformer; three-phase transformers;

- Motors and generators: elementary theory of motors and generators; single and three-phase motors connexions;

- Electronics: simple descriptive treatment of electron emission; electronic valves; power supplies; oscillatory circuits; detectors and amplifiers; transmission lines; antennas; wave propagation;

- Measuring instruments: measuring instruments in general use and their applications; voltmeters; ammeters and ohmmeter circuits; wheatstone bridge; universal bridge; principle of operation for moving coil; moving iron and thermo-couple instruments; frequency meter and watt-meters.

15.4.2 Engineering drawing

The purpose of this course is to increase the ability in reading and interpreting engineering drawings and also conveying ideas and instructions with the help of these drawings. It should include:

- Geometrical construction: plans; elevations and sections; isometric and other forms of pictorial drawings; methods of indicating dimension; tolerances; material and other working instructions;

- Drawing of standard parts: cross-sections to show the details of standard parts; orthographic projection to include both building up and braking down of assemblies;

- Drawing for working purposes: simplified drawing for machining; drawing of teeth in mesh and of various types of drive such as gearing; belt chains;

- Electric graphical symbols and circuit diagrams analysis; electronic components graphical symbols and circuit analysis; printed circuit drafting.

15.4.3 Workshop technology

- Materials: main properties and use of various metals, glass, plastic and ceramics; concept of ductility; hardness and machine ability; materials specifications; material workshop tests; metallurgical changes produced by hot and cold working in ferrous and non-ferrous metals, light alloys and steel;

- Metal joining: soldering and brasing; oxy-acetylene welding; use of bolts, studs and rivets; modern adhesives; sheet metal working;

- Machining: use of different hand tools in workshops; methods of handling machine tools; motors and generators; introduction to the theory of cutting tools; heat produced by cutting and its effects; the applications of cutting fields and their effects;

- Lathe work: arrangements for speed and feed changes; choice of speeds and feeds; calculation of gears arrangements and setting for the production of standard screw threads; use of attachments for lathes;

- Drilling machines: sensitive and compound table, radial arm machines; typical drills and related tools: choice of drilling speed and feeds;

- Slotting and shaping machines: principles of their operations; main setting and controls;

- Milling machines: different types and their uses; range of common cutters; methods of mounting and positioning cutters and work for typical jobs;

- Grinding machines: setting for plain work; choice of speeds; feeds and traverse rates;

- Hacksawing machines: care and use of typical types; selection and setting of blades for various purposes;

- Electric and electronic practices; soldering technique; use and care of hand tools; electric switching board; electric kit constructions; schematic interpretation; trouble shooting technique;

- Industrial safety and security precautions: this subject is very important. Instructors must explain and demonstrate all safety procedures to avoid any danger which may occur through carelessness, rushing work, handling tools improperly, operating machines without taking necessary safety measures and touching live electric power supplies.

15.4.4 Meteorological instruments

- General requirements of meteorological instruments: instruments required for various types of meteorological stations; general characteristics of meteorological instruments with respect to reliability, response, sensitivity, accuracy, readability, simplicity, robustness and

durability; indicating and recording instruments; types of recording systems; causes of errors affecting records; necessary care; choice of suitable site for meteorological station;

- Standard meteorological screens: general requirements; construction; the use of different sizes; location, orientation and installation;

- The study of the general principles, scales, constructional features, exposure conditions, setting, installation and transportation; practical field training to carry out these duties with respect to the meteorological instruments generally used for measuring the following elements:

- Atmospheric pressure; mercury barometers (Kew and Fortin types); aneroid barometers; hypsometers; barographs and micro -barographs;

- Air and soil temperature: mercury-in-glass thermometers (ordinary, maximum and soil thermometers); spirit-in-glass thermometers (minimum and grass minimum thermometers); resistance and thermo-couple thermometers; thermographs (mercury-in-steel, bimetallic, Bourdon tube and electrical);

- Atmospheric humidity: psychrometers; hair hygrometers; recording psychrometers and hair hygrographs;

- Surface wind: wind vanes; cup; fan; pressure plate and pressure tube anemometers; anemographs (electrical and pressure-tube);

- Precipitation: ordinary and shielded raingauges; rainfall recorders (float, tipping bucket and weighing types); rainfall intensity recorders; snowgauges; recording snowgauges; totalizer gauges; Duvdevani dewgauge; dew recorders;

- Evaporation: evaporometers or atmometers (Piche, Bellani and Livingstone types); evaporation pans (USA Class "A" and USSR GG1-3000); evatranspirometers;

- Sunshine duration and radiation: sunshine recorders (Campbell-Stokes, Jordan and Marvin); bimetallic Robitzsch actinograph;

- Cloud base height: light beam projector; alidades and clinometers;

- Instruments used in upper-wind observations by pilot balloon methods: transportation, handling and storage of lifting gas cylinders; construction and care of high pressure and low pressure hydrogen generators; construction, installation, setting and levelling of simple optical theodolite; accessories for balloon ascents.

INDEX

CHAPTER 16

SPECIALIZATION IN METEOROLOGICAL TELECOMMUNICATIONS

FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL

INDEX

16.1 SPECIALIZATION IN METEOROLOGICAL TELECOMMUNICATIONS (CLASS I)

The efficient and reliable operation of the Global Telecommunication System requires sufficiently qualified personnel at all meteorological telecommunication centres. There is an urgent need, particularly in developing countries, for personnel trained in the operation and maintenance of telecommunication facilities.

All Meteorological Services should have personnel of Class II, Class III and Class IV specialized in meteorological telecommunications. The need for Class I personnel depends on the responsibilities of a Meteorological Service in the Global Telecommunication System.

The main duties of Class I meteorological telecommunications personnel are the planning and supervision of installation and operation of telecommunication centres using modern techniques including electronic computers and satellites. They also draw up specifications for meteorological telecommunication equipment as required by their Services.

They are the valuable intermediaries between the Meteorological Services and telecommunication industries. They should have a university or equivalent degree in electronics and telecommunications or in mathematics and physics. These specialized personnel are an integral part of a Meteorological Service and play an important role in the development of operational meteorology and research programmes.

For Class I personnel specialized in meteorological telecommunications, only a basic knowledge of general meteorology, synoptic meteorology, climatology, meteorological instruments and methods of observation, and interaction of the ocean and the atmosphere is required. Appropriate syllabi are given in section 16.1.1.

Syllabi for specialized training of Class I meteorological telecommunications personnel are given in sections 16.1.2 to 16.1.6.

16.1.1 Fundamental meteorological education for Class I meteorological telecommunications personnel.

16.1.1.1 General meteorology

- Same as for Class III (section 6.3.1)

16.1.1.2 Synoptic meteorology

- Same as for Class II (section 5.3.3)

16.1.1.3 Climatology

- Same as for Class II (section 5.3.4)

16.1.1.4 Meteorological instruments and methods of observation

- Same as for Class II (section 5.3.7).

16.1.1.5 Interaction of the ocean and the atmosphere

- Same as for Class I (section 3.3.8)

16.1.2 Electronics

The material given in courses for Class II (section 16.2.2) should be revised in more detail, special emphasis being given to the following:

- Power supplies for electronics instruments;
- Amplification by vacuum tubes and transistors;
- Servo-systems;
- Electronic switching and timing;
- Special electronic circuits;
- Electrical and electronic measuring and testing instruments.

16.1.3 Meteorological telecommunications

16.1.3.1 General introduction to telecommunications

- Definitions and explanations of essential telecommunication terms: telecommunications; telephony; telegraphy; facsimile; satellite communications; point-to-point communications; broadcast communications;
- Cable and landline facilities: general characteristics of telephone and telegraph circuits; simplex circuit; duplex circuit; half-duplex circuit; low-, medium- and high-speed data transmission; facsimile transmission in pictorial and digital form;
- Radio-communication facilities: classification of radio-transmissions; frequency subdivision and frequency range; radio-teleprinter broadcast; radio-facsimile broadcast; data collection and distribution by satellite communications.

16.1.3.2 Technical characteristics and specifications of meteorological transmissions

- Transmission of alpha-numerical data: telegraph-type, telephone-type, land line circuits; HF radio circuits; HF radio broadcast satellite circuits; medium/high-speed data transmission;
- Transmission of processed information in pictorial and digital forms: facsimile transmission over telephone-type circuits; radio-facsimile broadcast; telephone-type circuits; radio-facsimile broadcast; characteristics of facsimile chart transmitters and recorders; index of co-operation; scanning density; transmission and recording speeds;

direct broadcasting from polar orbiting and geostationary meteorological satellites, including Automatic Picture Transmission (APT) Service and Weather Facsimile (WEFAX) Service.

16.1.3.3 Engineering of a meteorological telecommunication centre

- General functions of a meteorological telecommunication centre: collection of meteorological reports; editing of meteorological messages; application of standard transmission procedures; transmission of meteorological messages; reception and transmis sion of processed information;

- General functions of an automated telecommunication centre: automatic editing of meteorological messages; automatic switching of messages; speed conversion between high, medium and low transmission speeds; recognition of addressed messages; error control; relay facilities; checking and correction in order to maintain standard transmission procedures.

16.1.4 Other related subjects

- Advanced mathematics: operational calculus; boolean algebra; mathematical models;

- Communications engineering: basic knowledge of acoustics, electricity and electronics and their applications;

- Basic knowledge of information theory;

- Principles of cybernetics for communication systems: statistical methods; queues; servos;

- Theory of lines, networks and circuits: filters; equalizers; transfer of information between interconnected networks;

- Coding: error protection; redundancy;

- Automatic processing of information: electronic data-processing systems; analogue, digital and hybrid machines; principles of analysis and programming; languages; general-purpose computers; special computers for data transmission and conversion;

- Space communication techniques: characteristics; service types; service performance; antenna gain; interface with terrestrial network; satellite communication system;

- Technology and hardware for telecommunications and data transmission; telecommunication computers; electronic and electromechanical peripheral devices; instruments and measurements;

- Environment requirements: power supplies; no-break power-supply system; conditioning; masonry; acoustics; human and ecological factors; timetable;

- Approach to design: manufacturing; installation and management of communication systems, with particular regard to meteorological telecommunications circuits and centres.

16.1.5 Technical practices

- Engineering drawing: geometrical constructions; methods of indicating dimensions; tolerances and other working instructions; drawing of spare parts; cross-sections; orthographic projection; drawing for working purposes;

- Electrical graphic symbols and circuit-diagram analysis: electronic components, graphic symbols and circuit analysis; printed-circuit drafting;

- Workshop technology: materials; use of various metals, glass, plastic and ceramics; metal joining; modern adhesives; machining; lathe work; drilling, slotting, shaping; milling; grinding and hack-sawing machines;

- Electrical and electronic practices: soldering techniques; use and care of hand tools; electric switchboards; over-load devices; electrical connexions; electronic circuit assembling; kit construction; printed-circuit boards; electronic switching and timing; trouble shooting techniques; micro-electronic repair techniques;

- Safety and security precautions: the electrical and electronic technicians must learn and follow safety rules. Instructors should explain and demonstrate all safety procedures concerning high-voltage power supplies, low-voltage circuits, HF power output, cathode-ray tubes and selenium rectifiers, as well as the proper handling of tools and soldering irons.

16.1.6 Organization and telecommunication procedures for the exchange of meteorological information

16.1.6.1 General knowledge of agencies and organizations concerned with meteorological telecommunications

- World Meteorological Organization (WMO)

- International Telecommunication Union (ITU)

- International Civil Aviation Organization (ICAO)

- Intergovernmental Oceanographic Commission (IOC)

- International Organization for Standardization (ISO).

16.1.6.2 Organization and procedures established by WMO

Organization of the Global Telecommunication System (GTS)

- Functions and organization of the GTS: engineering principles of the GTS; the Main Telecommunication Network and its branches; regional telecommunication networks; national telecommunication networks;
- Functions of the meteorological telecommunication centres: World Meteorological Centres; Regional Telecommunication Hubs; National Meteorological Centres;
- Main Telecommunication Network and its branches: configuration; routeing of traffic; exchange programmes for observational data and processed information on the MTN and its branches;
- Regional telecommunication networks: functions; telecommunication plan of the Region concerned;
- National telecommunication networks: functions;
- Radio broadcast of observational data and processed information;
- Responsibilities for transmission: general responsibilities of Regional Associations; general responsibilities of Members.

16.1.6.3 Meteorological telecommunication procedures

- Procedures applicable to the transmission of alpha-numerical data on the GTS: format of routine meteorological messages; message format for addressed messages; catalogue CLLLL of meteorological bulletins; optimum length of message; time delays; storage capabilities at WMCs and RTHs; order of priority in collective transmissions; monitoring and control of meteorological transmissions;
- Procedures applicable to the transmission of meteorological information in pictorial form over the GTS; format for meteorological information in pictorial form; storing and forwarding of facsimile transmission; monitoring and control of transmission of meteorological information in pictorial form.

16.1.6.4 Error-control procedures in respect of data transmission

- Software system: definition of essential terms; backward supervisory channel; organization into blocks; start of data-transmission procedures; data-transmission procedures; termination of data-transmission procedures; acknowledgement procedures; recovery procedures;
- Hardware system: CCITT recommendation V.41;
- Compatibility procedures.

16.1.6.5 Procedures for transmission and relay of pictorial information over circuits operated on a shared data/facsimile transmission basis

- Software procedures: storing and forwarding of facsimile transmissions; switching messages; data-to-facsimile switching procedures; facsimile-to-data switching procedures;
- Hardware procedures: switching messages; identification and mode switching procedures;
- Compatibility procedures.

16.1.6.6 Technical characteristics and specifications of meteorological transmissions

- Main Telecommunication Network and its branches: circuit characteristics; characteristics of transmissions over four-wire telephone-type circuits; transmission over high-capacity HF circuits and satellite channels; engineering of WMCs and RTHs;
- Regional meteorological telecommunications networks: circuit characteristics; characteristics of transmission over regional networks; engineering of RTHs;
- National meteorological telecommunications networks.

16.1.6.7 Organization and procedures established by ICAO

- Functions and organization of the Aeronautical Fixed Telecommunication Network (AFTN); telecommunication means; systems and plans for the concentration and diffusion of information location indicators; format of AFTN messages; maximum length of AFTN messages; priority for transmission of meteorological information; AFTN procedures.
- ICAO specialized networks for transmission of operational meteorological information: MOTNE system; exchange of AFC products; CIDIN.

16.1.6.8 Regulatory documents

Familiarization with the following documents:

WMO

- Technical Regulations (WMO-No.49), Chapter A.3.1 - Meteorological telecommunications.
- Manual on the Global Telecommunication System (WMO-No. 386) - Volume I - Global aspects, Volume II - Regional aspects.
- Weather Reporting (WMO-No.9) - Volume A. Observing Stations, Volume C Transmissions, Volume D Information for shipping.

ITU

- Radio Regulations
- Telegraph Regulations
- Data Transmission
- Rural Telecommunications

ICAO

- Locations indicators (Doc. 7910)

16.2 SPECIALIZATION IN METEOROLOGICAL TELECOMMUNICATIONS (CLASS II)

The main duties of the Class II meteorological telecommunications personnel are the supervision of the installation, repair and maintenance of meteorological telecommunication equipment. They are required to carry out calibration and laboratory testing of all telecommunication equipment used in their respective Services. They should have a complete secondary-school education followed by two years instruction in electronics and telecommunications and adequate practical experience.

For Class II personnel specialized in meteorological telecommunications, only a basic knowledge of general meteorology, synoptic meteorology, climatology and meteorological instruments and methods of observation is required. The syllabi given in sections 5.3.3, 5.3.4 and 5.3.7 could therefore be reduced for this category of personnel. The syllabus given in section 16.2.1.1 General meteorology, is designed for Class II meteorological telecommunications personnel.

The syllabi for specialized training are given in sections 16.2.2 to 16.2.8.

16.2.1 Fundamental meteorological education for Class II meteorological telecommunications personnel

16.2.1.1 General meteorology

- Same as for Class III (section 6.3.1).

16.2.1.2 Synoptic meteorology

- Syllabus for Class II could be reduced (section 5.3.3).

16.2.1.3 Climatology

- Syllabus for Class II could be reduced (section 5.3.4).

16.2.1.4 Meteorological instruments and methods of observation

- Syllabus for Class II could be reduced (section 5.3.7).

16.2.2 Electricity and electronics

For Class II meteorological telecommunications personnel, the basic study of electricity and electronics for Class III and Class IV, Category A (16.3.2 and 16.5.3.1) should be supplemented by the following:

- Sweep circuits: thyratron, hard tube, trapezoidal and transistor circuits; circuit operation; linearity; sweep amplitude and duration; circuit parameter changes; trouble-shooting;

- Microwave principles: artificial transmission lines; operation, time delay, charge and discharge time; circuit parameter changes; pulse modulation: application, types, peak and average powers; range; wave-guides; propagation of energy, modes of operation, coupling and matching; cavity resonators: types, sizes, frequency uses; UHF and microwave oscillators and amplifiers; UHF tubes, klystron, travelling-wave tubes, magnetron, parametric amplifiers, space communication techniques;

- Special electronic circuits: generation circuits; non-sinusoidal waves; repetition-rate oscillators; sawtooth generators; reshaping circuits; limiting circuits; types and application; differentiator and integrator circuits; clampling circuits; phase-shifter counting circuits;

- Digital computers: central unit and peripheral equipment; input/output devices; peripheral telecommunication equipment; interface; teleprocessing concept; principles of programming; programming languages; basic language.

16.2.3 Telephony and telegraphy

The material given in courses for Class III and Class IV, Category A (section 16.3.3 and 16.5.3.2) should be revised in more detail.

16.2.4 Radio techniques

The material given in courses for Class III and Class IV, Category A (sections 16.3.4 and 16.5.3.3) should be revised in more detail.

16.2.5 Technical practices

- Same as for Class I (section 16.1.5).

16.2.6 Meteorological telecommunications

- Same as for Class I (section 16.1.3).

16.2.7 Organization and telecommunication procedures for the exchange of meteorological information

16.2.7.1 General knowledge of agencies and organizations concerned with meteorological telecommunications

- Same as for Class I (section 16.1.6.1).

16.2.7.2 Organization and procedures established by WMO

Organization of the Global Telecommunication System (GTS)

- Same as for Class I (section 16.1.6.2).

16.2.7.3 Organization and procedures established by ICAO

- Same as for Class I (section 16.1.6.3).

16.2.7.4 Regulatory documents

- Same as for Class I (section 16.1.6.4).

16.2.8 Meteorological telecommunication equipment

The material given in courses for Class III and Class IV (16.3.6 and 16.5.3.5) should be revised in more detail, taking into particular account the duties of these Class II telecommunications specialists.

16.3 SPECIALIZATION IN METEOROLOGICAL TELECOMMUNICATIONS (CLASS III, CATEGORY A)

The main duties of the Class III, Category A, telecommunications personnel are the installation, repair and maintenance of all meteorological telecommunications equipment used in their Meteorological Services.

They should have a complete secondary school education followed by adequate training in electronics and telecommunications. Practical experience appropriate to their work is also required. Furthermore, they should have received fundamental training in meteorology appropriate to their level.

Within this category there are two fields of specialization. The first is related to installation, repair and maintenance of telegraph equipment including circuits and associated installations, and also, to a certain extent, of some automatic telecommunication devices. The second is related to installation, repair and maintenance of radio communication equipment, including transmission lines, aerials and associated installations.

The syllabi for the specialized training required for Category A are given below. The syllabi given in section 16.3.1 on fundamental meteorological education, are designed for Class III personnel specialized in meteorological telecommunications who are responsible for the installation, repair and maintenance of meteorological telecommunications equipment. The syllabi given in sections 16.3.3. and 16.3.6.1 are specially designed for the first field of specialization and those in sections 16.3.4 and 16.3.6.2 for the second field of specialization. The syllabi given in sections 16.3.2 and 16.3.5 are common to both fields of specialization.

16.3.1 Fundamental meteorological education for Class III meteorological telecommunications personnel (Category A)

- Syllabi given in section 16.4.1 to be reduced to essentials for this category of personnel.

16.3.2 Electricity and electronics

The syllabus of electricity and electronics for Class IV, Category A, personnel engaged in meteorological telecommunications (section 16.5.3.1) should be revised in more detail and supplemented by the following:

16.3.2.1 Electronic test equipment

- Study of general principles; applications; circuit analysis; trouble-shooting; use, repair and maintenance of the following measuring instruments: cathode-ray oscilloscope, synchroscope, absorption wave meter, grid-dip meter, frequency standards, field-intensity meter, spectrum analyser, universal CLR bridges, vacuum-tube tester, transistor tester, multimeter, vacuum-tube voltmeter.

16.3.3 Telephony and telegraphy

For Class III, Category A, telecommunications personnel, the basic telephony and telegraphy for Class IV, Category A (section 16.5.2.2) should be revised and supplemented by the course given below.

16.3.3.1 Data transmission

- Study of general notions and principles; synchronous transmission; error-detecting; data signal; block; information transfer; data transfer rate;

INDEX

- Terminal installation for data transmission: data terminal equipment; data source; data sink; conversion equipment; modem; intermediate equipment; interface; storage register;

- Channels for data transmission: information channel; forward channel; backward supervisory channel.

16.3.4 Radio technique

For Class III, Category A, telecommunications personnel, the basic radio technique for Class IV, Category A (section 16.5.3.3) should be supplemented by the following:

- Electrical circuit components: mutual inductance; coefficient of coupling; skin effect at radio frequencies; magnetic and electrostatic shielding;

- Transmission lines: fundamental relations; transmission-line constants; transmission-line diagram; artificial lines;

- Wave guides; cavity resonators; general principles;

- Modulation: amplitude-modulation waves; degree of modulation; carrier-suppression system; single-side-band; vestigial side-band system; frequency-modulated waves; phase modulation;

- Detectors and mixers: diode detectors; diode mixers;

- Space communication techniques.

16.3.5 Technical practices

16.3.5.1 Engineering drawing

- Geometrical construction: plans; elevations and sections; isometric and other forms of pictorial drawings; methods of indicating dimension; tolerances; materials and other working instructions;

- Drawing of standard parts and drawing for working purposes;

- Electrical graphic symbols and circuit-diagram analysis; electronic components, graphic symbols and circuit analysis; printed-circuit drafting.

16.3.5.2 Workshop technology

- Materials: main properties and use of various metals, glass, plastic and ceramics; concept of ductility; hardness and machinability; material specifications; material workshop tests;

- Metal joining: soldering and brazing; oxy-acetylene welding; use of bolts, studs and rivets; modern adhesives; sheet-metal working;

- Machining: use of different hand tools in the workshop; lathe work; drilling, slotting, shaping, milling, grinding and hacksaw ing machines;

- Electrical and electronic practices: soldering techniques; use and care of hand tools; electric switchboards; overload devices; electrical connexions; electronic circuit assembling; kit construction; printed-circuit boards; electronic switching and timing; trouble-shooting techniques; micro-electronic repair techniques;

- Industrial safety and security precautions: instructors should explain and demonstrate all safety procedures to avoid any danger which may occur through carelessness, rushing work, improper handling of tools and operating machines without taking necessary safety measures. Instructors should also explain and demonstrate all safety procedures concerning high-voltage power supplies, low-voltage circuits, HF power output, cathode-ray tubes and selenium rectifiers.

16.3.6 Meteorological telecommunication equipment

The purpose of this course is to increase the ability of this category of personnel in installing, repairing and maintaining meteorological telecommunication equipment employed in a meteorological telecommunication centre, including circuits and associated installations. Installation, repair and maintenance of data transmission equipment should, to a certain extent, be included in this course.

Instructors should explain and demonstrate all practical aspects of installation, repair and maintenance of equipment studied under sections 16.3.3 and 16.3.4, especially those currently in use by the Service concerned.

16.3.6.1 Telegraph equipment

The syllabus of telegraph equipment for Class IV, Category A, personnel engaged in meteorological telecommunications (section 16.5.3.5) should be supplemented by the following:

- Data transmission: general principles; terminal installation; data terminal equipment; conversion equipment, modem, intermediate equipment, interface, channels for data transmission;

- Maintenance and measuring apparatus for telephone and telegraph channels;

- Protection against interference.

16.3.6.2 Radio communication equipment

The syllabus for Class IV, Category A, personnel engaged in meteorological telecommunications (section 16.5.3.5) should be revised in more detail and supplemented by the following:

- Radio transmitters: AM/FM transmitter; LF transmitter; VHF transmitter; radio-teleprinter and radio-facsimile transmitters;
- Aerials: transmitting aerial characteristics;
- Satellite Earth Stations and associated receiving facilities.

16.4 SPECIALIZATION IN METEOROLOGICAL TELECOMMUNICATIONS (CLASS III, CATEGORY B)

The main duties of the Class III, Category B, telecommunications personnel concern the operation of a telecommunication centre. This category of personel includes operators of automatic telecommunication devices and radio-receiver and radio-transmitter equipment. They should have a complete secondary-school education followed by adequate training in electronics and telecommunications. Practical experience appropriate to their work is also required. Further, they should have received a fundamental training in meteorology appropriate to their level.

Within this category, it is again possible to identify two fields of specialization. The first is related to the use of automatic telecommunication devices. The second is related to the use of radio-receiver and radio-transmitter equipment. The syllabi for the specialized training required are given below. The syllabi given in sections 16.4.3 and 16.4.6.1 are specially designed for training operators of automatic telecommunications devices. The syllabi given in sections 16.4.4 and 16.4.6.2 are specially designed for training operators of radio-receiver and radio-transmitter equipment. The syllabi given in sections 16.4.2 and 16.4.5 are common to both fields of specialization.

The syllabi given in section 16.4.1 on fundamental meteorological education, are designed for Class III personnel specialized in meteorological telecommunications who are responsible for the use of meteorological telecommunications equipment (Category B).

16.4.1 Fundamental meteorological education for Class III meteorological telecommunications personnel (Category B)

16.4.1.1 General meteorology

- Same as for Class IV (section 7.2.1).

16.4.1.2 Meteorological instruments and methods of observation

The syllabus for Class IV (section 7.2.2) should be supplemented by the following:

- Upper-air measurement;
- Pilot balloons: principles and uses;
- Wind measurement: principles;
- Radiosondes and rawins: principles and uses;

- Meteorological codes;
- Knowledge of symbolic forms of international meteorological codes.

16.4.2 Electricity and electronics

For Class III, Category B, telecommunications personnel, the basic electricity and electronics for Class III, Category A (section 16.3.2) should be supplemented by the following:

- Industrial safety and security precautions: instructors should explain and demonstrate all safety procedures concerning high-voltage power supplies, low-voltage circuits, HF power output, cathode-ray tubes and selenium rectifiers.

16.4.3 Telephony and telegraphy

Same as for Class III, Category A, telecommunications personnel (section 16.3.3).

16.4.4 Radio technique

Same as for Class III, Category A, telecommunications personnel (section 16.3.4).

16.4.5 Organization and telecommunication procedures for the exchange of meteorological information

For Class III, Category B, telecommunications personnel the syllabus for Class IV, Category B (section 16.5.4.4) should be supplemented by the following:

16.5 CLASS IV PERSONNEL ENGAGED IN METEOROLOGICAL TELECOMMUNICATIONS

16.5.1 Categories of meteorological telecommunications personnel

Category A - The training of this category of personnel will require particular emphasis on the repair and maintenance of simple telecommunication equipment. They are called upon to assist personnel of Class III in the installation, repair and maintenance of all telecommunication equipment used in their respective Services.

Category B - The training of this category of personnel will place special emphasis on the operation of telecommunications centres using manual techniques.

This category includes operators of radio-receiver, teletype and facsimile equipment. They should have received appropriate training in basic meteorology.

The syllabi for specialized training of these two categories of Class IV personnel are given below.

16.5.2 Meteorological education for Class IV personnel engaged in meteorological telecommunications

16.5.2.1 General meteorology and climatology

- For Class IV meteorological personnel specialized in meteorological telecommunications who are responsible for the use of telecommunication equipment (Category B), the syllabi given in section 7.2.1, general meteorology, could be reduced;
- For Class IV meteorological personnel specialized in meteorological telecommunications who are responsible for the maintenance of the telecommunication equipment (Category A) the syllabus given in sections 7.2.1, general meteorology, and 7.2.3, climatology, should be reduced to essentials.

16.5.2.2 Meteorological instruments and methods of observation

Surface observations

- Basic notions

Upper-air observations

- Basic notions

Meteorological codes

- Knowledge of symbolic forms of international meteorological codes.

16.5.3 Category A meteorological telecommunications personnel

There are two fields of specialization in this category. The first is related to installation, repair and maintenance of telegraph equipment (teleprinter and facsimile). The second is related to installation, repair and maintenance of radio-receiver equipment.

The syllabi given in sections 16.5.3.2 and 16.5.3.5 (Telegraph and facsimile equipment) are specially designed for personnel responsible for telegraph equipment. The syllabi given in sections 16.5.3.3 and 16.5.3.5 (Radio-receiver equipment) are specially designed for personnel responsible for radio-receiver equipment.

The syllabi given in sections 16.5.3.1 and 16.5.3.4 are common to both fields of specialization.

16.5.3.1 Electricity and electronics

- General introduction: constitution of matter; composition of the atom; conductors and insulators; electric current; resistance; electromotive force; electrical units; magnetism and magnetic field; electromagnetism; inductance; magnemotive force;

- Sources of electricity: mechanical electric generators; chemical primary cells and accumulators; photo-electric cells; thermo-electric cells; piezo-electric cells;

- Direct current: definition; current; voltage and resistance; Ohm's law; temperature effect on resistance; skin effect; series and parallel resistance circuits; voltage drop; potential difference; power and energy; capacitance; inductance; units;

- Alternating current: essential features of an alternator; frequency period and phase; inductance; capacitance; Ohm's law;

- Transformers: elementary theory of ideal and actual transformers; voltage and turns ratio; effect of secondary current; losses; heating and efficiency; single-phase transformer; autotransformer; three-phase transformers;

- Motors and generators: elementary theory; single- and three-phase motor connexions;

- Electronics: simple descriptive treatment of electron emission; electronic valves; power supplies; oscillatory circuits; detectors and amplifiers; transmission lines; antennas; wave propagation;

- Measuring instruments: measuring instruments in general; use and applications; voltmeters; ammeter and Ohmmeter circuits; Wheat stone bridge; universal bridge; principle of operation for moving coil; moving iron and thermocouple instruments; frequency meter and wattmeters.

16.5.3.2 Telephony and telegraphy

- Acoustics: nature of sound; wave motion and sound; determination of frequency; vibrating systems producing sound; resonance; composition and resolution of harmonic vibration;

- General transmission processes: study of general characteristics; circuits; channels; two-wire circuits; four-wire circuits; audio-frequency; voice frequency; quantities and units used in transmission; definition of noise and disturbance on transmission channel;

- Telephony: study of general notions and principles; telephone circuits;

- Telephone-type equipment: types of telephone set; microphone; telephone receiver; dial; bell set;

- Telephone switching and signalling systems and equipment;

- Telegraphy: study of general notions and principles; codes; alphabets; signals; telegraph modulation; modulation rate; mark and space significant conditions; telegraph distortion;

- Telegraph channels: definition; repeater and converter; regenerative repeater; single-current transmission; double-current transmission; simplex circuit; duplex circuit; half-duplex circuit;

- Apparatus for telegraphy: study of general characteristics; synchronous system; start-stop system; margin of telegraph apparatus; teleprinter; automatic transmitter; tape-reader; key board perforator; shift from letter-case to figure-case or vice versa; telegraph relay;

- Facsimile: study of general principles; transmitter and recorder; index of co-operation; scanning density; transmission and recording speeds; carrier frequency; transmission characteristics; landline operations;

- Telegraph switching: general principles; switching centre; reperforator switching; push-button switching; automatic switching; concentrator.

16.5.3.3 Radio technique

- Radio communication principles: radio waves; propagation of radio waves; reflection of radio waves; the ionosphere; solar activity; classification of radio waves; radio-frequency power; modulation; amplitude modulation, frequency modulation, analysis of modulated waves; reception of radio signals: selectivity, detection of radio waves;

- Electrical circuit components: inductance; permanent magnetic materials; condensers; air dielectrics; solid dielectrics; electrolytic condensers; resonant circuits; coils; property of circuits; circuits with lumped constants; series and parallel resonance;

- Electron tubes: fundamental properties; thermo-ionic emission; diodes; triodes; characteristic curves of the triode; grid current; amplification factor; plate resistance; transconductance; pentodes; screen-grid tubes; vacuum-tube amplifiers;

- Vacuum-tube oscillators: oscillator circuit; crystal oscillator; VHF oscillator;

- Power for vacuum-tubes: cathode heating power; anode power rectifiers; characteristics of typical rectifier tubes; rectifier circuits;

- Transistors: basic concept; semiconductor; the junction diode; the p-n junction; the junction transistor; transistor types: specifications and use;

- Aerials: general considerations; principles of radiation; elementary doublet; aerial wire; gain; aerial systems; directional systems; transmitting and receiving aerials;

- Radio transmitters: general description of transmitter equipment; frequency determination; amplifiers and power-output stages; modulation and keying; single-side band operation; AM transmitters; FM transmitters;

- Radio receivers: general considerations; specification of receiver characteristics: sensitivity; selectivity; fidelity; noise figure; automatic volume control: LF receivers; VHF and UHF receivers; receiver noise; pulse-communication systems.

16.5.3.4 Technical practices

Engineering drawing

- Same as for Class III Category A (section section 16.3.5.1)

Workshop technology

- Same as for Class III Category A (section 16.3.5.2).

16.5.3.5 Meteorological telecommunication equipment

The purpose of this course is to increase the ability of this category of personnel in installing, repairing and maintaining simple meteorological telecommunication equipment. Instructors should explain and demonstrate all practical aspects of installation, repair and maintenance of simple equipment studied theoretically under syllabi sections 16.5.3.2 and 16.5.3.3.

Telegraph equipment

- General principles: start-stop system; codes; modulation and demodulation; modulation rate; distortion; margin;

- Telegraph equipment: teleprinter; keyboard transmitter; printing receiver; tape-reader; keyboard perforator; telegraph relay;

- Voltage power supplies.

Facsimile equipment

- General principles: modulation and demodulation; synchronization; phasing; index of co-operation; scanning density; drum speed; transmission and recording speeds; carrier frequency;

- Facsimile equipment: general characteristics; transmitter; recorder; magnetic tape recorder;

- Facsimile transmission channels; landline and wireless transmission systems;

Radio-receiver equipment

- Basic principles: amplifier stages; frequency changers; frequency control; sensitivity; selectivity; signal/noise ratio;
- Radio receivers: LF, HF and VHF receivers; radio-teleprinter receivers; radio-facsimile receivers;
- Aerials: receiving aerials.

16.5.4 Category B meteorological telecommunications personnel

Within this category it is also possible to identify two fields of specialization. The first is related to the use of teleprinter equipment, the second is related to the use of radio-receiver equipment. The use of facsimile equipment (landline or wireless operations) can be included in both fields of specialization.

The syllabi given in sections 16.5.4.2 and 16.5.4.5 (telegraph and facsimile equipment) are designed for training operators of teletype and landline facsimile equipment. The syllabi given in sections 16.5.4.3 and 16.5.4.5 (facsimile and radio-receiver equipment) are designed for training operators of radio-receiver equipment (including radio-facsimile). The syllabi given in sections 16.5.4.1 and 16.5.4.4 are common to both fields of specialization.

16.5.4.1 Electricity and electronics

For Class IV, Category B, telecommunications personnel the basic electricity and electronics for Class IV, Category A, personnel engaged in meteorological telecommunications (section 16.5.3.1) should be supplemented by the following:

- Industrial safety and security precautions: instructors should explain and demonstrate all safety procedures concerning high-voltage power supplies, low-voltage circuits, HF power output; cathode-ray tubes and selenium rectifiers.

16.5.4.2 Telephony and telegraphy

- Same as for Class IV, Category A, telecommunications personnel (section 16.5.3.2).

16.5.4.3 Radio technique

- Same as for Class IV, Category A, telecommunications personnel (section 16.5.3.3).

16.5.4.4 Organization and telecommunication procedures for the exchange of meteorological information

Organization and procedures established by WMO

- Organization of the Global Telecommunication System: functions and organization of the GTS; the Main Telecommunication Network and its branches; regional telecommunication networks; national telecommunication networks;

- Meteorological telecommunication procedures applicable to the transmission of alpha-numerical data on the GTS; format of routine meteorological messages; message format for addressed messages; catalogue CLLL of meteorological bulletin; optimum length of message; order of priority in collective transmissions; monitoring and control of meteorological transmission;

- Meteorological telecommunications procedures applicable to transmission of meteorological information in pictorial form over GTS; format for meteorological information in pictorial form; storing and forwarding of facsimile transmission; monitoring and control of transmission of meteorological information in pictorial form.

Organization and procedures established by ICAO

- Organization of the Aeronautical Fixed Telecommunication Network: functions and organization of the AFTN; telecommunication means; systems and plans for the concentration and diffusion of information; location indicators; format of AFTN message; maximum length of AFTN message; priority for transmission of meteorological information; AFTN procedures;

- ICAO specialized networks for transmission of operational meteorological information: MOTNE system; exchange of AFC products; CIDIN;

Regulatory documents

Familiarization with the following documents:

WMO

- Manual on the Global Telecommunications System (WMO-No. 386) - Volume I - Global aspects, Volume II - Regional aspects;

- Weather Reporting (WMO-No. 9) - Volume A. Observing Stations. Volume C. Transmissions, Volume D. Information for Shipping.

ICAO

- Location indicators (Doc. 7910).

16.5.4.5 Meteorological telecommunication equipment

The purpose of this course is to increase the ability of this category of personnel in the use of simple meteorological telecommunication equipment. Within this category will be operators of radio-receiver, teletype and facsimile equipment.

Instructors should explain and demonstrate all practical aspects of operations needed for the use of simple equipment studied theoretically under sections 16.5.4.2 and 16.5.4.3. Practical application of the meteorological telecommunication procedures (section 16.5.4.4) is also required.

Telegraph equipment

- General principles: start-stop system; codes; modulation and demodulation; modulation rate; distortion; margin;
- Telegraph equipment: teleprinter; keyboard transmitter; printing receiver; tape-reader; keyboard perforator; telegraph relay;

Facsimile equipment

- General principles: modulation and demodulation; synchronization; phasing; index of co-operation; scanning density; drum speed; transmission and recording speeds; carrier frequency;
- Facsimile equipment; general characteristics; transmitter; recorder; magnetic tape recorder;
- Facsimile transmission channels: landline and wireless transmission systems;
- Automatic Picture Transmission (APT) service.

Radio-receiver equipment

- Basic principles: amplifier stages; frequency changes; frequency control sensitivity; selectivity; signal/noise ratio;
- Radio receivers: LF, HF and VHF receivers; radio teleprinter receivers; radio-facsimile receivers;
- Aerials: receiving aerials.

INDEX

CHAPTER 17

SPECIALIZATION IN METEOROLOGICAL DATA PROCESSING

FOR ALL CLASSES OF METEOROLOGICAL PERSONNEL

INDEX

17.1 SPECIALIZATION IN METEOROLOGICAL DATA PROCESSING (CLASS I)

Class I personnel specialized in meteorological data processing will be engaged in the research and development of numerical methods for weather analysis and forecasting. They will deal with system analysis as well as planning and supervision of programming activities. They may also be responsible for the organization and efficiency of a meteorological computer centre.

Depending upon the extent of the activity, it could be advisable to split the responsibilities in such a way that the supervision of the computer hardware and software support is maintained by an expert in these areas who does not necessarily have a meteorological background. Corresponding modifications should then be introduced in the syllabus.

The following processes are the most important at a meteorological computer centre:

- Decoding of meteorological reports;
- Quality control and checking of meteorological observations;
- Presentation of observations;
- Analysis of meteorological charts and soundings;
- Assimilation of non-synoptic data;
- Initialization for numerical forecasts;
- Numerical forecasts;
- Local weather forecast by statistic/dynamic methods;
- Preparation of output products;
- Further processing and presentation of products from other centres;
- Storage and retrieval of meteorological data.

It is obvious that these different kinds of tasks demand theoretical knowledge in numerical analysis and meteorology as well as detailed insight of computer systems. Class I personnel specialized in meteorological data processing should therefore have a thorough knowledge of dynamic meteorology (section 4.2) and synoptic meteorology (section 4.4), supplemented by training indicated by the syllabi in paragraphs 17.1.1 to 17.1.6 below. Theoretical and practical experience in the field of computer hardware and software is also desirable.

It should be pointed out however that it is in general impossible for one single person to cover the whole field of meteorological data processing. In practice, a team of people is responsible for the processing system and each individual is specialized in particular areas of the overall system. It is therefore understood that extracts from the syllabi can be used for planning appropriate education and training programmes in the field of meteorological data processing.

17.1.1 Numerical analysis

- Numerical computations: number representation; truncation errors; rounding errors;
- Matrices: definition; norms; matrix operations; special matrices; eigenvalues and eigenvectors; transformations; House holder's method; the LR-method; the QR-method; (symmetric, tridiagonal, Hessenberg form);
- System of linear equations and matrix inversion: direct methods; pivoting; Gauss' method; Crout's method; Jordan's method; factorization methods; triangulation; Choleski's method; iterative methods; Jacobi's method; Gauss-Seidel's method; accelerated Gauss-Seidel's method (the successive over-relaxation method);
- Interpolation method: Lagrange's interpolation formula; interpolation with differences; least square approximations; trigonometric approximations; interpolation with splines;
- Spectral analysis: harmonic analysis; Fourier transforms; the fast Fourier transform algorithm;
- Methods for smoothing and filtering;
- Numerical differences; difference equation;
- Numerical quadrature: Cote's formulas; Simpson's formula; Richardson's extrapolation technique (Romberg's formula);
- Ordinary differential equations: difference approximations; Euler's method; implicit methods; midpoint rule; leap-frog method; Runge-Kutta's method; predictor-corrector methods; methods for ordinary differential equations of stiff type; stability; error estimates;
- Partial differential equations: convergence; stability; elliptic equations; direct and iterative methods for elliptic equations; alternating direction implicit methods for parabolic equations; Crank-Nicholson's formula; successive over-relaxation; hyperbolic equations; explicit and implicit methods for hyperbolic equations; non-linear instability; initial boundary-value problems for hyperbolic equations; staggered grid nets;
- Monte Carlo method;
- Linear programming.

17.1.2 Computers and programming

- Computers: historical background; number systems; storage principles; logic circuits; central processing unit; main storage; secondary storage; random and sequential access memories; input units; output units;

- Programming: computer instructions, stored programme concept; assembler languages; procedure-oriented languages; ALGOL, FORTRAN, COBOL, PL/I; compilers;
- Operating systems; batch systems; remote batch systems; real-time systems;
- Communication systems; computer/computer transmissions;
- Computer sorting; archiving and retrieval systems;
- Graphical equipment: displays; microfilm plotters; mechanical and electrostatic plotters; digital-analogue converters; facsimile systems; digital facsimile;
- System analysis;
- Organization of a computer centre.

17.1.3 Objective weather analysis

- Theory of stochastic processes; averaging probability distributions; moments; properties of stochastic processes;
- Statistical structure of meteorological fields: normal fields, variance fields and spacial autocorrelation; properties of correlation and correlation functions;
- Observational techniques: radiosonde observations; satellite radiation measurements and temperature inversion techniques; observations from constant level balloons and drifting buoys; structure of the observational errors;
- Interpolation methods: the optimum interpolation method (multi-regression); the correction method; the polynomial method; use of orthogonal polynomials; spline interpolation techniques; weight ing functions for wind component analysis;
- Methods for elimination of erroneous observations: spatial interpolation methods; spatial comparison methods; time-interpolation methods; dynamical co-ordination methods; filtering with empirical orthogonal functions;
- Methods for information mixing and dynamical co-ordination: use of normal values and forecast values in the analysis; use of wind data in height analysis; estimation of upper-air data from surface data; optimum statistical mixing; calculus of variation (Euler-Lagrange's equation, Lagrange's multipliers and Zazaki's method);
- Methods for analysis of asynoptic observations: continuous four-dimensional data assimilation; intermittent data assimilation;
- Special analysis methods: frontal location analysis; analysis of meso-scale phenomena; analysis of vertical cross-sections.

17.1.4 Numerical weather prediction

- Projection of equations on polar stereographic and Mercator charts; the equation of motion; the equation of continuity; the thermo-dynamic equation; the vorticity equation; the divergence equation, the ω-equation, and vertical coordinate system;

- Different wave solutions of simplified systems: vertical sound waves; horizontal sound waves; internal gravity waves; external gravity waves; inertial oscillations; geostrophic adjustment process; "noise" waves generated by imbalance in the initial state;

- Difference schemes for simple equations: advection equation; non-linear instability; finite differences for Jacobian operators; Lagrangian schemes; spectral methods;

- Barotropic filtered models: equivalent barotropic models; the inclusion of the Helmholz term; energetics of barotropic models; barotropic instability;

- Barotropic non-filtered models: the shallow water equations; explicit time-difference schemes; implicit, semi-implicit and split-explicit schemes; staggered and non-staggered grids; lateral boundary conditions; nested grids; initialization models;

- Baroclinic filtered models: integrated and discrete models; the two-level model; wave solution of the two-level model; energetics of the two-level model; baroclinic instability of the two-level model; multilevel models; numerical solution of the ω-equation; baroclinic instability of multilevel models; non-geostrophic effects;

- Baroclinic non-filtered models: the structure of different models for short-range forecasts; the structure of different models for the general circulation; finite difference schemes; lateral boundary conditions; nested grids; initialization methods;

- Inclusion of physical effects in prediction models: friction; diffusion; topography; sensible heat; moisture clouds and large scale precipitation; latent heat; convection; radiation;

- Mesoscale models: parameterization of topography and cumulus convection; cumulus convection models; frontal and squall-line models; boundary layer models; models for tropical cyclones; air pollution models;

- Local forecasting by use of statistic-dynamic interpretation of forecasts;

- Trajectory computations;

- Computer methods for analysis and forecasting in the tropics: dynamic methods; statistical methods;

- Smoothing methods;
- Numerical solution of the balance equation;
- Verifications of different models.

17.1.5 Meteorological data handling

- Principles of meteorological telecommunication procedures; error-control procedures;
- Decoding of meteorological telegrams: SYNOP, TEMP, PILOT, GRID, AIREP, etc.; quality control and checking of meteorological elements; hydrostatic check of TEMP; correction or completion of missing values; satellite soundings;
- Methods for automatic presentation of weather symbols and level charts; interpolation from grid values to curves; conversion between vector and matrix representation of graphical products;
- Storage and retrieval systems for meteorological data;
- Utilization of special data, such as data from research satellites, air pollution data and radiation data;
- Verification methods for numerical forecasts;

17.1.6 Organization

- General knowledge of WMO programmes, particularly the World Weather Watch (WWW);
- General knowledge of ICAO, and in particular the Area Forecast System.

17.2 SPECIALIZATION IN METEOROLOGICAL DATA PROCESSING (CLASS II)

The duties of Class II personnel specialized in meteorological data processing include programme analysis (design) and programming of meteorological applications under the leadership of Class I personnel and the application of efficient numerical methods. They may be engaged in modification of the supporting software (operating systems, etc.). They may also be responsible for the organization and supervision of the daily routine operations in the computer centre. Although a fundamental meteorological education, as given in section 5.3, can be of great value for most purposes a much less comprehensive training in these subjects is sufficient.

17.2.1 Numerical analysis

- Essentially the same as for Class I personnel specialized in meteorological data processing, section 17.1.1, but particular emphasis should be placed on practical applications.

17.2.2 Computers and programming

- Same as for Class I, section 17.1.2.

17.2.3 Numerical weather analysis and prediction

- General principles of data assimilation, objective analysis and numerical weather prediction models. Incorporation of asynoptic (satellite) data in NWP.

17.2.4 Meteorological data handling

- Same as for Class I, section 17.1.5.

17.2.5 Laboratory and practical work

- Special training in programming and organization of computations in meteorological programme systems is best achieved by laboratory and on-the-job practical work under the supervision of Class I personnel specialized in meteorological data processing.

17.3 SPECIALIZATION IN METEOROLOGICAL DATA PROCESSING (CLASS III)

Class III personnel specialized in meteorological data processing will carry out application programming as required, under supervision of Class I or Class II personnel. In addition they will be engaged in those routine operations which require a thorough knowledge of the computer system, of the methods whereby the computations are monitored by the operating system and of meteorological data handling.

17.3.1 Computers and programming

- Computers: storage principles; central processing unit; main storage; secondary storage; in- and output devices;

- Programming: computer instructions; stored programme concept; assembler and procedure-oriented languages; compilers;
- The principles of operating systems.

17.3.2 Meteorological data handling

A brief description of the general principles of meteorological data handling by computer, including:

- Decoding of meteorological reports;
- Checking and quality control of meteorological reports;
- Presentation of meteorological data and products;
- Storage and retrieval of meteorological data.

17.3.3 Numerical weather analysis and prediction

General principles of data assimilation, objective weather analysis and numerical prediction. Incorporation of asynoptic (satellite) data in NWP.

17.3.4 Laboratory and practical work

Special training in programming is achieved by laboratory and on-the-job practical work under the supervision of Class I or Class II personnel.

17.4 CLASS IV PERSONNEL ENGAGED IN COMPUTERIZED METEOROLOGICAL DATA PROCESSING

Class IV personnel engaged in meteorological data processing will carry out routine operations on computer installations. They should be well versed in the available computer equipment and in the operational procedures. Because of the widely varying types of computers in use, an all-embracing syllabus in these aspects cannot be given here. However, many computer manufacturers offer training in these areas.

INDEX

CHAPTER 18

SPECIALIZATION IN SATELLITE APPLICATIONS

FOR CLASSES I AND II METEOROLOGICAL PERSONNEL

INDEX

18.1 SPECIALIZATION IN SATELLITE APPLICATIONS (CLASS I)

18.1.1 Introduction (a brief history)

- Description of various satellites that have been launched and how they have been modified to accommodate new demands.

18.1.2 Satellite systems

- A basic description of orbital elements;
- Types of orbits (polar, sun-synchronous, geostationary, highly elliptical, etc.);
- Viewing geometry;
- Data flow from satellite to ground stations and to the user;
- Gridding, registration and conversion of image projection;
- Data archiving;
- Reception area - APT PREDICT and FANAS messages, their interpretation and use.

18.1.3 Satellite sensors

- Survey of spectral regions of atmospheric interest (reflection, emission, absorption) for various purposes;
- Sensor systems;
- Spatial, temporal and spectral resolution;
- Quantitative sensors (scanning radiometers, vertical temperature and humidity profiling radiometers, microwave sensors, sensors for energy balance measurements, ozone measurement, etc.).

18.1.4 Satellite data formats

- Images display and image enhancement;
- Application of time lapse techniques;
- Quantitative data for analysis and interpretation.

18.1.5 Extraction of cloud information (e.g., cloud amount, cloud top height, cloud types)

18.1.6 Interpretation of satellite imagery - Local phenomena

- Mesoscale organization like cellular patterns in clouds;
- Diurnal growth and decay of cloudiness, with particular emphasis on time lapse display;
- Orographic cloud features, Nephanalysis: rules for making them - Symbols - SAREP Code;
- Sea breeze and lake breeze phenomena;
- Fog, e.g., identification of patterns of formation and decay from geo-stationary satellite data;
- Ice and snow;
- Severe convective storms;
- Mesoscale convective complexes.

18.1.7 Interpretation of satellite imagery - Extra tropical systems

- Various stages of development in cyclones;
- Fronts and frontal waves;
- Vortices and vorticity centres;
- Troughs and ridges;
- Cut-off lows and blocking highs;
- Jet streams.

18.1.8 Interpretation of satellite imagery - Tropical systems

- Identification of tropical storms under various stages of development;
- Classification of tropical storms;
- Estimating maximum winds in the tropical storms, using enhanced IR imagery;
- Identification of the ITCZ;
- Cloud clusters;

- Sub-tropical cut-off lows and mid-oceanic troughs;
- Cross-equatorial flow;
- Estimation of the movement of tropical storms.

18.1.9 Determination of wind direction and speed from satellite data

- How certain types of cloud images can be used as tracers to determine wind vectors;
- Present techniques used in deriving the wind information (manual and automated methods to be described);
- Limitations of the current methods (relationship between cloud motion vectors and wind vectors, assignment of a height value based on cloud temperature determined from IR data, etc.).

18.1.10 Determination of vertical temperature and humidity profiles from satellite data

- Basic spectral frequencies necessary to determine these quantities;
- Present techniques used in obtaining the profiles from radiance data;
- Integration of IR and microwave sensors to obtain profile information;
- Data quality control and editing techniques.

18.1.11 Estimation of precipitation from satellite data

- Utilization of analogue and digital image information relating brightness values to precipitation and clouds;
- Microwave techniques to locate zones and amount of precipitation.

18.1.12 Radiation balance parameter from satellites

- Measurement of reflected short-wave and outgoing long-wave radiation over the globe and how they are obtained from the present satellite instruments;
- Results of some radiation budget studies that have utilized satellite data.

18.1.13 Satellite applications in oceanography

- Correction of temperature depression due to water vapour absorption;
- Sea-surface temperature distribution;

- Location of currents and current boundaries at the surface;
- Detection of pollutants using multispectral methods;
- Sea ice determination;
- Sea state determination using sun-glitter patterns.

18.1.14 Satellite applications in hydrology

- Determination of snow and ice boundaries using satellite imagery;
- Analysis of multispectral imagery to delineate flooded areas;
- Microwave measurements for soil moisture.

18.1.15 Satellite applications in air-pollution monitoring

18.1.16 Satellite applications in agriculture

- Use of geostationary and polar orbiter data to estimate amount and distribution of precipitation;
- Estimation of shelter temperature and daily maximum and minimum temperatures from satellite soundings;
- Estimation of solar radiation incident at the surface from satellite data;
- Global snow cover for use in agriculture;
- Vegetative index from multispectral satellite data.

18.1.17 Satellite applications in climatology

- Determination of cloud climatologies from satellite measurements;
- Satellite measurements of the time and space variations of radiation budget, snow cover, cloudiness, and other climate parameters.

18.1.18 Quality control of satellite data

- Dependence of data quality on design characteristics, orbit and life cycle (degradation) of satellites;
- Influence of atmospheric factors (clouds, dust) and underlying surface (water, soil) on data quality;

INDEX

- Comparison of satellite data with ground-based data (hydrometeorological and oceanographic ground observations, radiosonde and rocket soundings).

18.2 SPECIALIZATION IN SATELLITE APPLICATIONS (CLASS II)

18.2.1 Introduction

- A brief description of various satellite systems (polar orbiting, geostationary, sun-synchronous, etc.);
- Various kinds of data transmission from satellites (direct broadcasts like APT, HRPT, WEFAX, stored broadcast);
- Ground systems necessary to receive the satellite data;
- Various kinds of data display (images, enhanced images and computer print-outs);
- Viewing geometry;
- Use of computer graphics and video techniques;
- Interpretation and use of APT PREDICT and FANAS messages;
- Data archiving.

18.2.2 Satellite sensors

- Short review of various kinds of satellite sensors currently in use (cameras, scanning radiometers, etc.);
- Spatial and spectral resolutions of the instruments;
- Selection of spectral intervals for various needs (VIS, IR, microwave, etc.).

18.2.3 Image interpretation

- Extra-tropical weather systems (various stages of development in cyclones, fronts and frontal waves, vortices, cut-off lows, and jet stream location, etc.);
- Tropical weather systems (identification and location of tropical storms, classification of storms, estimating maximum winds and intensities from images, identification of ITCZ), tropical cloud clusters;

- Local weather phenomena (fog, snow and ice sea breeze and lake breeze, identification of cloud types, cellular clouds and orographic clouds), mesoscale convective complexes;

- Nephanalysis; rules for making them - symbols - SAREP code.

18.2.4 Quantitative information from satellites

- Determination of high-and low-level wind vectors from imagery using cloud motions as tracers;

- Determination of vertical profiles of temperature and humidity from satellite radiance measurements (both in the IR and microwave);

- Estimation of precipitation from satellite images and microwave data;

- Radiation budget parameters from satellite radiometers;

- Extraction of cloud information (cloud amount, cloud top height and cloud type).

18.2.5 Satellite applications to oceanography and hydrology

- Sea-surface temperature from IR measurements;

- Sea state from microwave and sun-glitter data;

- Sea ice information from VIS, IR microwave measurements;

- Determination of soil moisture using microwave and scanning radiometer data.

18.2.6 Future satellite systems

- More use of high resolution quantitative sensors;

- More use of direct broadcast information;

- Data collection capabilities;

- Satellite applications to climatology and agrometeorology.

CHAPTER 19

SPECIALIZATION

IN THE APPLICATION OF METEOROLOGICAL INFORMATION

TO ECONOMIC AND SOCIAL DEVELOPMENT

FOR CLASS I METEOROLOGICAL PERSONNEL

INDEX

19.1 SPECIALIZATION IN APPLICATION OF METEOROLOGICAL INFORMATION TO ECONOMIC AND SOCIAL DEVELOPMENT (CLASS I)

19.1.1 Operations research

- Simulation model design and application; queuing models; linear programming; theory of games; Monte Carlo techniques; random number generators; administration of operations research teams.

19.1.2 Economics and econometrics

- The general linear model; errors in variables; auto correlation; problems of multi-collinearity; laged variables; simultaneous equation systems; linear probability models; regression on principal components. Sources of economic and/or operational data. Examples of quantified estimates of relationship between weather events and economic activities (e.g., weather-electric power demand; weather-crop yields; weather-construction progress).

19.1.3 Statistics

- The same as in section 9.1.2.8 Climatology "climate methods".

19.1.4 Management science

- Construction management: contracts; specifications; bidding procedures; optimization of machinery; labour; critical path management and PERT techniques; simulation of major construction projects, including the effect of weather on variability of costs and completion dates;

- Farm management: resource appraisal; water management; investment criteria; financial records; decision strategies under conditions of imperfect knowledge; economics of natural resources; land economics;

- Industrial management: optimization of machinery; labour; minimization of energy costs; impact of weather on demand for products and/or cost and availability of raw materials; simulation of weather impact on production/distribution systems.

19.1.5 Communications

- Communication theory: communication systems; signal processing; noise to signal ratio; optimum receivers.

- Technical writing: organization of scientific and technical reports;

- Use of visual aids: radio; television and printed media to communicate technical/scientific ideas.

- Transport: minimization of weather-related damage to cargo, passengers and equipment; minimization of energy costs. Simulation of weather impact on alternate routes and/or alternate equipment systems.

19.1.6 Computer science

- Data preparation; quality control; fundamentals of FORTRAN, COBOL, ALGOL, PL/I; large scale information storage and retrieval systems. Experience in using meteorological observations on punched cards, magnetic tape, disc storage. Preparation and application of computer programmes designed to produce climatic information for specific management decision problems.

19.1.7 Mathematics

- Basic training in mathematics as outlined in section 3.2.1.

19.1.8 Dynamic meteorology

- Same as in section 3.3.1.

19.1.9 Climatology

- Same as in section 3.3.5.

19.1.10 Introductory level course work in one or more other weather sensitive disciplines

- Ecology: introduction to basic concepts of plant communities; climax vegetation; food chain; interdependence of plant and animal life;

- Agronomy: introduction to basic concepts in crop science; photosynthesis; use of water by plants (the transpiration process); production of dry matter as a function of solar energy;

- Architecture: introduction to basic concepts concerning site selection; orientation of structures with respect to solar radiation; wind, water drainage; design of insulation, cooling and heating systems; interior lighting with respect to climate;

- Electrical power distribution engineering (energy).

19.1.11 Thesis research

The thesis is one of the most important educational experiences in the training of a specialist in application of meteorology to economic development. In this work the student uses a real situation from his home country (or a similar country) in which he applies his training in atmospheric science, mathematics, computer science, statistics, econometrics and other related disciplines to:

1. Define an economically important weather-sensitive problem for which adequate solutions do not already exist;

2. Collect economic, operational and meteorological data relevant to his problem;

3. Perform mathematical, statistical or simulation model analysis of the data he has collected; and

4. Produce recommended courses of action which would result in economic gain through improvement in management use of meteorological information.

INDEX

INDEX

PART II

EDUCATION AND TRAINING OF PERSONNEL IN OPERATIONAL HYDROLOGY

INDEX

CHAPTER 1

INTRODUCTION

INDEX

1.1 GENERAL

The field of "operational hydrology"(*) is defined as follows:

(a) Measurement of basic hydrological elements from networks of meteorological and hydrological stations; collection, transmission, processing, storage, retrieval and publication of basic hydrological data;

(b) Hydrological forecasting; and

(c) Development and improvement of relevant methods, procedures and techniques in: network design; specification of instruments; standardization of instruments and methods of observation; data transmission and processing; supply of meteorological and hydrological data for design purposes; hydrological forecasting.

As indicated in Part I, in the present publication, meteorological personnel are classified into four categories: Class I personnel, comprising those who have a university degree or equivalent in meteorology; Class II personnel, who have completed secondary school education and specialized in meteorology (the period required for such specialization varies from 3-5 years); Class III personnel, whose basic education of complete secondary school should be supplemented by 12 months' specialization in meteorology; and finally Class IV personnel, who have a minimum of 9 years primary and secondary education plus specialization in meteorology (this latter lasts 9-12 months).

The situation is somewhat different in hydrology and operational hydrology. Most of the Hydrological Services have only three categories of personnel, namely, professional hydrologists, hydrological technicians and hydrological observers. Consequently the WMO Commission for Hydrology (CHy) has recommended that WMO should conform to this classification. A brief description of the knowledge required of each category and its duties is given below.

1.2 PROFESSIONAL HYDROLOGISTS

These are personnel with a university degree in civil engineering, agricultural engineering, mining, geology or geophysics or equivalent, who have subsequently specialized in hydrology or other fields related to water sciences. Their tasks and activities can range from management of Hydrological Services to research and training and may include hydrological design of water resources projects and analysis of hydrological data.

1.3 HYDROLOGICAL TECHNICIANS

The personnel of this category can be divided into two groups:

(a) Those with 12-14 years of primary, secondary and supplementary education including specialization in one of the hydrological activities; and

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(*) WMO Technical Regulations - Hydrology and International Hydrological Codes, 1980 (WMO-No.555)

INDEX

(b) Those with 10 years of primary and secondary education and technical hydrological training.

The personnel of the first group are referred to as senior technicians and the second group as junior technicians. Their duties include assisting the professional hydrologists and supervising the work of the hydrological observers. More specifically, they deal with duties such as special measurements, data collection and processing, installation of hydrological equipment and training of hydrological observers.

1.4 HYDROLOGICAL OBSERVERS

The basic education of this category is at least 9 years of primary and secondary schooling supplemented by technical training in one of the fields of hydrological activity. Their duties include taking observations, keeping records, and maintaining the less sophisticated instruments installed at their duty stations.

1.5 CURRICULA

Chapters 2, 3 and 4 of this Part present curricula for the education and training of professional hydrologists and senior and junior hydrological technicians respectively. Many of the topics are similar, if not identical, for two or all three of these categories. It is to be understood, however, that the material presented on such topics will be progressively less fundamental and theoretical and more descriptive and practical as one moves from professional to technician courses. No mention is made here of the form or duration of courses, but it is anticipated that those for technicians would include substantial elements of practical experience and on-the-job training.

Hydrological observers are normally trained on the job and formal training courses are not normally organized. Therefore, no curricula for the education and training of hydrological observers are included in this Part.

CHAPTER 2

CURRICULA FOR EDUCATION AND TRAINING

OF PROFESSIONAL PERSONNEL IN OPERATIONAL HYDROLOGY

(CORRESPONDING TO FULL UNIVERSITY EDUCATION)

INDEX

2.1 EDUCATION IN THE BASIC SCIENCES

2.1.1 Mathematics

(see Part I section 3.2.1).

2.1.2 Physics

(see Part I section 3.2.2).

2.2 EDUCATION IN OPERATIONAL HYDROLOGY AND RELATED SUBJECTS

2.2.1 Principles of descriptive geometry and technical drawing

- Principles of descriptive geometry; point; planes; methods of conversion of projections; axonemetric projections;
- Technical drawing: principles of projection and topographic drawing.

2.2.2 Theoretical mechanics and fluid mechanics

- Statics; composition of forces; parallel forces - theory of couples on a plane surface; plane and general system of forces; centre of parallel forces and of gravity;
- Kinematics: kinematics of a point; translation and rotation motion of a solid body; complex motion; plane-parallel motion of a solid body;
- Dynamics: differential equations of the motion of a material point; theorems on the amount of motion of a material point and system; theory of shocks; theorems on the moment of the amount of motion of a material point and on the kinematic moment of a system; theorems on the variation in the kinematic energy of a material point and system - general law of energy conservation; d'Alembert's principle and principle of virtual displacements;
- Fluid mechanics: kinematics of a liquid; hydrostatics; hydrodynamics of an ideal liquid; wave theory; dynamics of a viscous liquid.

2.2.3 General chemistry and hydrochemistry

- General chemistry: atomic-molecular theory; structure of the atom and the periodic system of elements; chemical combination and the structure of molecules; kinetics and chemical equilibrium; theory of solutions; heterogenic equilibrium; basic principles of electrochemistry; general properties of metals; alloys; first group of the periodic system

of elements; second group; third group; fourth group; organic combination; fifth group; sixth group; seventh group; eighth group; zero group;

- Hydrochemistry: water as a solvent; its properties; electrolyte solutions; principles of physico-chemical analysis; surface phenomena and absorption; basic problems of colloidal chemistry; chemical composition of natural water; chemical composition of atmospheric precipitation; chemistry of rivers, lakes and reservoirs; chemistry of ground water; chemistry of seas and oceans;

- Water pollution.

2.2.4 Principles of geophysics, geology, geomorphology and soil science

- Principles of geophysics and general information about the globe: shape, dimensions and types of motion of the globe; layers surrounding the globe - atmosphere, hydrosphere, biosphere, lithosphere and bathysphere; their composition, structure, thermodynamic conditions and state of aggregation; terrestrial magnetism, density of the Earth and distribution of gravity forces over its surface; distribution and relationship of water and land on the Earth's surface;

- Principles of geology: composition of the Earth's crust; distribution of chemical elements in the Earth's crust; minerals and rocks; geological processes; tectonics and mountain formation phenomena; historical geology methods;

- Principles of geomorphology: classification of types of relief - morphological, orographic and genetic; action of flowing water and erosion; rivers and climate; water-accumulation forms of relief; karst and glacier forms of relief; forms of relief in deserts and mountainous areas;

- Principles of soil science; soil formation, soil as polydispersion system; physics of soil; chemistry of soil; classification of soils; soil and water; movement of soil water; hydrological properties of soils; soil-water balance.

2.2.5 Surveying

- Plan and map: principles of theory of errors in measurements; measurement of lines in the field; optical parts of geodetic instruments; theodolite and theodolite survey; levelling; combined planimetric/altimetric surveys; approximation surveys; geodetic network; geodetic applications in stationary and field hydrological surveys; principles of aerial photography; principles of cartography.

2.2.6 Hydraulics: open-channel flow dynamics and channel processes (river bed formation)

- General hydraulics: hydrostatics; principles of hydrodynamics; flow through small and large orifices at constant and variable pressure;

steady flow in open channels; pressure flow of a liquid in pipes; non-steady flow; spillways and flow over structures; hydraulic jump and energy dissipators;

- River hydraulics: non-uniform flow in channels; flow with a variable discharge; unsteady flow in open channels; hydraulics of bifurcations and estuaries;

- Principles of similitude;

- Principles of the dynamics of streams with a non-erodable bed: mechanics and structure of two-dimensional channel flow; hydromechanical analysis of two-dimensional turbulent flow; non-rectilinear flow and additional resistance of channel to flow;

- Physical and hydromechanical basis of the theory of flow in an eroding channel: main mechanical and hydraulic characteristics of river beds and sediments; mechanism of sediment transport;

- Channel processes: hydrodynamic and hydromorphological approach to the channel processes theory; basic river-bed processes produced by the construction of hydraulic structures.

2.2.7 General meteorology and climatology

- General properties of the atmosphere: composition of structure of the atmosphere; basic gas laws applicable to the atmosphere; principles of atmospheric statics;

- Radiant energy in the atmosphere: solar radiation; effective radiation and radiation balance;

- Heat exchange in the soil, water and atmosphere: heat regime of the soil and bodies of water; principle of atmospheric thermodynamics; heat transfer in the atmosphere - air temperature; vertical distribution of air temperatures;

- Physical meteorology: cloud formation; the nucleation of water-vapour condensation; the nuclei of atmospheric condensation; the growth of droplets in cloud and fog; initiation of the ice phase in cloud; the formation of snow crystals; the physics of natural precipitation processes;

- Artificial modification of clouds and precipitation: suppression of large hail;

- Wind-measurement methods;

- Climatological problems and investigation methods - relationship with meteorology and hydrology: climatological data-processing methods; basic factors of climate formation; influence of relief on climate; influence of snow and ice on climate; geographical distribution of climate elements over the globe; classification of climates; micro climate and local climate; changes in climate and climatic fluctuations; climates of the world;

- Network of meteorological stations - observation times and the transmission of information.

2.2.8 Synoptic meteorology

- General information on synoptic meteorology and short-range weather forecasts: basic synoptic codes - prospects of using meteorological satellite data - elements of World Weather Watch; compilation and analysis of weather charts; analysis of the fields of meteorological elements; air masses - their classification and properties; atmospheric fronts; cyclone activity; analysis and short-range forecasts of the synoptic position and weather conditions; quantitative precipitation forecasting;

- Macro-synoptic processes and long-range weather forecasts: laws of general atmospheric circulation; peculiarities of circulation in various areas of the globe and types of macro-synoptic processes; methods of long-range weather forecasts covering long and short periods.

2.2.9 Physical meteorology (cloud microphysics)

- Nucleation of the liquid phase from the vapour; condensation nuclei, their properties and distribution; ice nuclei and their properties and distribution in time and space; growth of cloud drops and ice crystals by diffusion, snow crystal habit; size, number, fall speed of drops and crystals; limit on diffusional growth and need for precipitation mechanisms; Bergeron-Findeisen process; coalescence of cloud drops; growth of warm rain; formation of graupel and hail, growth of precipitation in convective, stratiform and orographic clouds; icing of aircraft; artificial modification of clouds; critical assessment of techniques for stimulation of rain, prevention of hail, dissipation of fog and cloud.

2.2.10 Hydrological instruments and methods of observation

- Precipitation: gauge location; recording and non-recording gauges; snowfall; observations by radar; dew;

- Snow cover: water equivalent; depth and extent of snow cover; ground surveys; radioisotope snowgauges; snow pillows; natural gamma radiation;

- Evaporation and evapotranspiration: pan evaporation; soil evaporimeters and lysimeters; snow evaporimeters; short- and long-wave radiation; indirect methods;

- Water levels of rivers, lakes and reservoirs: gauges and procedures for measurement of state; frequency of gauge measurements;

- Discharge measurements: current meters; float method; dilution method; measurement of corresponding stage; moving-boat method;

ultrasonic method; electromagnetic method; indirect methods; measurement under ice cover;

- Stream-gauging stations: purposes; selection of site; control sections: artificial controls; stage-discharge relationships;

- Sediment discharge: measurement of suspended-sediment discharge; measurement of bed-sediment discharge;

- Water temperature: instruments for point-to-point and continuous measurements; observational procedure; infra-red radiation thermometer; measurement of water-surface temperature for lake and reservoir evaporation;

- Ice on rivers, lakes and reservoirs: elements of ice regime; methods of observation; times and frequency of observations;

- Soil moisture: weight method; electrical resistance method; tensiometric method; neutron method; gamma-ray method;

- Groundwater levels: methods of measurement; selection of observation wells.

2.2.11 Design of networks

- General principles for design of networks: general requirements; optimum network; minimum network; optimum use of existing stations in organizing a minimum network; data to be considered in determining network density; quality of data to be collected;

- Density of observation stations for a minimum network: factors affecting the density; minimum density limit of climatological networks; hydrometric network of minimum density;

- Integration of bench-mark stations and representative basins in the network.

2.2.12 Collection, processing and publication of data

- Collection: observational procedures; transmission of hydrological observations: quality control; storage and cataloguing;

- Use of satellites in operational hydrology: types of sensor; platforms; hydrological applications; data-transmission systems;

- Streamflow computation: computation of average gauge height; computation of average discharge; computation of average discharge under ice cover; quality control of streamflow data;

- Special data collection: requirements; "bucket surveys" of storm rainfall; weather-radar data; extreme river stages and discharges;

- Processing: general methods; special applications;

- Publication: purpose; requirements of hydrology; frequency of publication; contents and formats.

2.2.13 Hydrological analysis

- Interpretation of precipitation data: adjustment of data; double-mass curve analysis; interpolation of data; spatial distribution; isohyetal maps; evaluation of physiographic effects; average depth over a catchment; storm rainfall studies, depth-area-duration analysis; probable maximum precipitation (PMP); rainfall frequencies, drought severity; rainfall intensities; snowmelt; interpretation of soil-moisture data;

- Evaporation and evapotranspiration: derivation of lake and reservoir evaporation; water-budget method; energy-budget method; aerodynamic approach; combination of aerodynamic and energy-balance equations; pan-coefficient method; estimates of basin evapotranspiration; water-budget; energy-budget method; aerodynamic approach;

- Interpretation of streamflow data: adjustment of data; spatial distribution; maps of average annual runoff; temporal distribution of runoff volume; unit hydrograph; isochrone method; streamflow routeing; low-flow analysis; flow duration curves; low-flow frequencies; statistical analysis of droughts; recession curve analysis; flood frequencies; statistical analysis of floods; regional generalization of flood characteristics; long-term trends;

- Runoff relations - rainfall and snowmelt: regression analysis; runoff by storm periods; antecedent moisture-index method; initial base flow as index to rainfall runoff; moisture accounting techniques; runoff from short-period snowmelt; monthly, seasonal and annual water-budget.

2.2.14 Hydrological forecasting

- Hydrological forecasts and warnings: classification of hydrological forecasts;

- Hydrological forecasting services: operations; organization; co llection of data and issue of forecasts and warnings; data requirements; accuracy and frequency of data measurements; operational data acquisition; use of radar observations for hydrological forecasting; use of snow and ice observations from meteorological satellites; technical equipment for hydrological forecasting services;

- Forecast methods: theory of rainfall and snowmelt; floods and methods for their computation; forecasting runoff from snowmelt, seasonal and annual flow forecasts; stages and flows; flood forecast; rainfall runoff computations; conceptual catchment models (numerical runoff models);

streamflow simulation; short- and long-term forecasts of ice formation and break-up; updating of forecasts;

- Formulation, evaluation and verification of hydrological forecasts: formulation of hydrological forecasts; evaluation of forecasting methods; verification of operational forecasts; relation between meteorological and hydrological forecasting; cost-benefit analyses for hydrological forecasting.

2.2.15 Applications to water management

- Estimation of available surface-water supplies: factors to be evaluated; suitability of available records; synthesis of hydrological data; probabilistic approach; time-series approach;

- Estimation of water demand and losses: estimation of components of water demand; estimation of water losses from surface-water systems;

- Estimation of required reservoir storage capacity: data adaptation; probabilistic approach; discharge frequency; volume frequency; time-series approach; mass curves; Hurst phenomenon; Markovian process; multipurpose storage requirements; reservoir system design; environmental effects;

- Estimation of design floods: definitions; types of design flood; determination of optimum design probabilities of flood discharge and the probability distribution used in hydrologic design; data preparation; use of streamflow data in computing flood-frequency curves; techniques for computation of design floods; determination of design floods;

- Design of flood-control works; design of flood protection reservoirs; operational considerations for design purposes; operation of reservoirs for flood control; further considerations concerning reservoirs; channel modification; levees; flood proofing; other flood protection structures, non-structural measures; flood-plain refulation; flood warning;

- Design of urban and small rural watershed drainage works: rational method; unit hydrograph and time-area curves; distributed system models; rainfall data required for design of drainage works;

- Estimation of maximum reservoir levels: wind set-up; wind-generated waves; periodic undulations of water surface;

- Sediment transportation: erosion of watersheds; sedimentation;

- Influences of hydrological factors on water quality: streamflow lakes and reservoirs;

- General causes of water-quality changes: reaction to pollutants; eutrophication; self-purification; absorption and accumulation; rise in water temperature.

2.2.16 Organization of Hydrological Services

- Functions of Hydrological Services: basic data functions; reports on water resources; hydrological forecasts; analysis and design studies; research; training;
- Organization of Hydrological Services: existing patterns; technical considerations in organizational planning.

CHAPTER 3

CURRICULA FOR EDUCATION AND TRAINING

OF SENIOR TECHNICAL PERSONNEL(*) IN OPERATIONAL HYDROLOGY

(*) Defined in section 1.3 (a)

INDEX

3.1 EDUCATION IN THE BASIC SCIENCES

3.1.1 Mathematics

(see Part I, section 7.2.1).

3.1.2 Physics

(see Part I, section 7.2.2).

3.2 EDUCATION IN OPERATIONAL HYDROLOGY AND RELATED SUBJECTS

3.2.1 Descriptive geometry and technical drawing

- Basic principles of descriptive geometry: points; planes; projections;
- Technical drawing practice: materials, instruments; basic techniques and constructions; projection and topographic drawing.

3.2.2 Technical practices

- Engineering drawing: working sketches; electric graphical symbols; electronic components; graphical symbols;
- Workshop technology: material specifications; metal joining; lathe work; drilling; slotting; shaping; milling; grinding and hacksawing machines; use and maintenance of essential tools;
- Electric and electronic practices: soldering techniques; use and care of hand-tools; electric switchboards; overload devices; electric connexions; electronic circuit assembling; kit constructions; printed circuit boards; electronic switching and timing; telecommunication equipment; microelectronic repair techniques;
- Safety and security precautions: technicians must learn and follow safety procedures, including those relating to high-voltage power supplies and the proper handling of tools;
- Elementary construction technology: design of foundations and support structures; basic construction techniques for building hydrometric structures; field application of physical principles.

3.2.3 General chemistry and hydrochemistry

- General chemistry: atomic-molecular theory; structure of the atom and the periodic system of elements; chemical combination and the

structure of molecules; theory of solutions; basic principles of electrochemistry; general properties of metals; alloys;

- Hydrochemistry: water as a solvent; its properties; electrolyte solutions; principles of physico-chemical analysis; chemical composition of natural water; chemical composition of atmospheric precipitation; chemistry of rivers, lakes and reservoirs; chemistry of groundwater; chemistry of seas and oceans;

- Water pollution; waterborne diseases.

3.2.4 Principles of geophysics, geology, hydrogeology, geomorphology and soil science

- Principles of geophysics and general information about the globe: shape, dimensions and types of motion of the globe; layers surrounding the globe - atmosphere, hydrosphere, biosphere, lithosphere and bathysphere; distribution and relationship of water and land on the Earth's surface;

- Principles of geology: composition of the Earth's crust; minerals and rocks; geological processes; tectonics and mountain-formation phenomena; historical geology methods;

- Principles of hydrogeology: groundwater, its occurrence, characteristics and natural fluctuations;

- Principles of geomorphology: classification of types of relief - morphological, orographic and genetic; action of flowing water and erosion; rivers and climate; determination of physical characteristics of drainage areas;

- Principles of soil science: soil formation; classification of soils; soil and water; movement of soil water; hydrological properties of soils; soil-water balance.

3.2.5 Surveying

- Plan and map: principles of theory of errors in measurements; measurement of lines in the field; optical parts of geodetic instruments; theodolite and theodolite survey; levelling; combined planimetric-altimetric surveys; approximation surveys; principles of cartography; basic techniques in electronic distance measuring and computerized surveying.

3.2.6 Hydraulics: open-channel flow dynamics and channel processes (river-bed formation)

- General hydraulics: hydrostatics; principles of hydrodynamics; flow through small and large orifices at constant and variable pressure;

steady flow in open channel; pressure flow of a liquid in pipes; non-steady flows; spillways and flow over structures; hydraulic jump and energy dissipators;

- River hydraulics: non-uniform flow in channels; flow with a variable discharge; unsteady flow in open channels; hydraulics of bifurcations and estuaries;

- Channel processes: hydrodynamic and hydromorphological approach to the channel processes theory; basic river-bed processes produced by the construction of hydraulic structures.

3.2.7 General meteorology and climatology

- General properties of the atmosphere; composition of structure of the atmosphere; basic gas laws applicable to the atmosphere;

- Water cycles in the atmosphere: evaporation; air humidity and methods of measurement; condensation of water vapour; cloud formation; physics of natural precipitation process; international cloud classification;

- Wind measurement methods;

- Climatological problems and investigation methods - relationship with meteorology and hydrology: climatological data-processing methods; basic factors of climate formation; influence of relief on climate; influence of snow and ice on climate; geographical distribution of climatic elements over the globe; classification of climates; microclimate and local climate; changes in climate and climatic fluctuations; climates of the world;

- Network of meteorological stations - observation times and the transmission of information.

3.2.8 Synoptic meteorology

- General information on synoptic meteorology and short-range weather forecasts: prospects of using meteorological satellite data - elements of World Weather Watch; compilation and analysis of weather charts, basic synoptic codes;

- Quantitative precipitation forecasts;

- Radar precipitation measurements.

3.2.9 Hydrological instruments and methods of observation

The study of the general principles, classifications, scales, construction, accuracy, response, sources of instrumental and systematic errors, exposure, setting,

installation, repair, maintenance and field tests and comparisons of instruments used for the following measurements:

- Precipitation: gauge location; recording and non-recording gauges; snowfall; observation by satellite; dew;
- Snow cover: water equivalent; depth and extent of snow cover, ground surveys; radioisotope snowgauges; snow pillows; natural gamma radiation;
- Evaporation and evapotranspiration: pan evaporation; soil evaporimeters and lysimeters; snow evaporimeters; short- and long-wave radiation; indirect methods;
- Water levels of rivers, lakes and reservoirs: gauges and procedures for measurement of state; frequency of gauge measurements;
- Discharge measurements: current meters; float method; dilution method; measurement of corresponding stage; moving-boat method; ultrasonic method; electromagnetic method; indirect methods; measurement under ice cover;
- Stream-gauging stations: purposes; selection of site; control sections; artificial controls; stage-discharge relationships;
- Sediment discharge: measurement of suspended-sediment discharge; measurement of bed-sediment discharge;
- Water temperature: instruments for point-to-point and continuous measurements; observational procedure; infra-red radiation thermometer; measurement of water-surface temperature for lake and reservoir evaporation;
- Ice on rivers, lakes and reservoirs: elements of ice regime; methods of observation; times and frequency of observations;
- Soil moisture: weight method; electrical resistance method; tensiometric method; neutron method; gamma-ray method;
- Water quality: sampling equipment and procedures;
- Groundwater levels: methods of measurement; selection of observation wells.

3.2.10 Design of networks

(See section 2.2.11).

3.2.11 Collection, processing and publication of data

- Collection: observational procedures; transmission of hydrological observations; coding and decoding; quality control; storage and cataloguing;

- Streamflow computation: computation of average gauge height; computation of average discharge; computation of average discharge under ice cover; quality control of streamflow data;

- Special data collection: requirements; "bucket surveys" of storm rainfall; weather-radar data; extreme river stages and discharges;

- Processing: general methods; special applications;

- Publication: purpose; requirements of hydrology; frequency of publication; contents and formats.

3.2.12 Hydrological analysis

- Interpretation of precipitation data: adjustment of data; doublemass curve analysis; interpolation of data; spatial distribution; isohyetal maps; average depth over a catchment; storm rainfall studies; rainfall frequencies; snowmelt;

- Interpretation of streamflow data: adjustment of data; spatial distribution; maps of average annual runoff; temporal distribution of runoff volume; streamflow routeing; low-flow analysis; recession curve analysis; flood frequencies;

- Evaporation and evapotranspiration: derivation of lake and reservoir evaporation; water-budget method; energy-budget method; aerodynamic approach; combination of aerodynamic and energy-balance equations; pan-coefficient method;

- Application of mathematical statistics and probability theory to data analysis and the study of hydrological processes.

3.2.13 Hydrological forecasting

- Hydrological forecasts and warnings: classification of hydrological forecasts;

- Hydrological forecasting services: operations; organization: collection of data and issue of forecasts and warnings; data requirements; accuracy and frequency of data measurements; operational data acquisition; use of radar observations for hydrological forecasting; use of snow and ice observations from meteorological satellites; technical equipment for hydrological forecasting services.

3.2.14 Applications to water management

- Estimation of available surface-water supplies: factors to be evaluated; suitability of available records; synthesis of hydrological data; probabilistic approach; time-series approach;

- Estimation of water demand and losses: estimation of components of water demand; estimation of water losses from surface-water systems;

- Estimation of design floods: definitions; types of design flood; data preparation;
- Inland water protection;
- International river basins.

3.2.15 Organization of Hydrological Services

(See section 2.2.16).

C H A P T E R 4

CURRICULA FOR EDUCATION AND TRAINING

OF JUNIOR TECHNICAL PERSONNEL(*)

IN OPERATIONAL HYDROLOGY

(*) Defined in section 1.3 (b)

INDEX

4.1 EDUCATION IN THE BASIC SCIENCES

The basic education of this category is at least nine years of primary and secondary schooling and it is assumed that it will have included an adequate coverage of such basic sciences as mathematics, physics and chemistry.

4.2 EDUCATION IN OPERATIONAL HYDROLOGY AND RELATED SUBJECTS

4.2.1 Technical drawing

- Technical drawing practice: materials; instruments; basic techniques and constructions.

4.2.2 Technical practices

- Rudiments of engineering drawing: reading working sketches and drawings; electric graphical symbols; electronic components; graphical symbols;
- Rudiments of workshop technology: material specifications; use and maintenance of essential tools;
- Electric and electronic practices: soldering techniques; use and care of hand-tools; electric connexions; telecommunication equipment; microelectronic repair techniques;
- Safety and security precautions: observers must learn and follow safety procedures, including those relating to high-voltage power supplies and the proper handling of tools.

4.2.3 Hydrochemistry

- Hydrochemistry: water as a solvent; its properties; electrolyte solutions; chemical composition of natural water; chemical composition of atmospheric precipitation; chemistry of rivers, lakes and reservoirs; chemistry of groundwater; chemistry of seas and oceans;
- Water pollution.

4.2.4 Principles of geophysics

- Rudimentary principles of geophysics and general information about the globe: shape, dimensions and types of motion of the globe; layers surrounding the globe - atmosphere, hydrosphere, biosphere, lithosphere and bathysphere; distribution and relationship of water and land on the Earth's surface;

- Rudimentary principles of geology: composition of the Earth's crust; geological processes; historical geology methods;

- Rudimentary principles of geomorphology: classification of types of relief - morphological, orographic and genetic; action of flowing water and erosion; rivers and climate;

- Rudimentary principles of soil science: soil formation; classification of soils; soil and water; movement of soil water; hydrological properties of soils.

4.2.5 Surveying

- Plan and map: measurement of lines in the field; optical parts of geodetic instruments; theodolite and theodolite survey; levelling; combined planimetric-altimetric surveys; approximation surveys.

4.2.6 General meteorology and climatology

- General properties of the atmosphere; composition of structure of the atmosphere;

- Water cycles in the atmosphere: evaporation and methods of measurement; air humidity and methods of measurement; condensation of water vapour - international cloud classification; precipitation and methods of measurement; snow pack and snow surveys;

- Wind-measurement methods;

- Climatological problems and investigation methods - relationship with meteorology and hydrology; climatological data-processing methods; basic factors of climate formation;

- Network of meteorological stations - observation times and the transmission of information.

4.2.7 Synoptic meteorology

- General information on synoptic meteorology and short-range weather forecasts: basic synoptic codes; compilation and analysis of weather charts;

- Radar precipitation measurements.

4.2.8 Hydrological instruments and methods of observation

(See section 3.2.9).

4.2.9 Collection, processing and publication of data

- Collection: observational procedures; transmission of hydrological observations; quality control; storage and cataloguing;
- Streamflow computation: computation of average gauge height; computation of average discharge; computation of average discharge under ice cover; quality control of streamflow data;
- Special data collection: requirements; "bucket surveys" of storm rainfall; weather radar data; extreme river stages and discharges;
- Processing: general methods; special applications;
- Publication: purpose; requirements of hydrology; frequency of publication; contents and formats.

4.2.10 Hydrological forecasting

(See section 3.2.13).

4.2.11 Organization of Hydrological Services

- Functions of Hydrological Services: basic data functions; reports on water resources; hydrological forecasts; analysis and design studies; research; training.

INDEX

WMO EDUCATION AND TRAINING PUBLICATIONS

Blue Series

General information

Compendium of Training Facilities for Meteorology and Operational Hydrology

Prepared by the WMO Secretariat (WMO - No. 240), Sixth edition; 1982; English.
This publication gives current information on approximately 900 meteorological and operational hydrology courses available at some 400 institutions in more than 95 countries.

Proceedings of the WMO/IAMAP Symposium on Higher Education and Training (Rome, April 1970)

Prepared by WMO Secretariat. (WMO-No.278); 1970; English, French.
The Symposium was organized jointly by WMO and IAMAP. Its purpose was to review educational programmes and teaching practices and facilities for the training of Class I and Class II meteorological personnel as well as questions relating to the training of personnel for research work.
This publication contains the full texts of a total of 36 papers presented, as well as a summary of the resulting discussions and the conclusions of the Symposium.

Proceedings of the Conference on Meteorological Education and Training in Developing Countries in Africa (Algiers, 1970)

Prepared by WMO Secretariat. (WMO-No.300); 1971; English, French.
This report contains the texts of the speeches, introductory lectures and reports presented to the conference. Thirty-one papers were contributed on a wide range of topics, including categories of personnel to be trained, training facilities in Africa, means of attracting young people into the meteorological profession, the impact on training of advances in the science of meteorology, and the role of universities in the education and training of meteorological personnel.

Proceedings of the WMO/IAMAP Symposium on Education and Training in Meteorology and Meteorological Aspects of Environmental Problems (Caracas, February 1975)

Prepared by WMO Secretariat. (WMO-No.432); 1975; English.
Contains full texts of all papers presented and summary of resulting discussions.

Classes I and II meteorological personnel

Problems in Dynamic Meteorology

Edited by A. Wiin-Nielsen. (WMO-No. 261); 1970; English.
The problems in the book are intended as basic material for practical lessons and test papers in dynamic meteorology, and cover a wide variety of topics. Short introductory notes are given in each section, and some of the problems have been solved to assist the student. The problems have been designed essentially for Class I personnel, but many are also suitable for training personnel of Class II.

Compendium of Meteorology for Use by Class I and Class II Meteorological Personnel

Edited by A. Wiin-Nielsen. (WMO-No. 364)

Volume I, Part 1	- Dynamic meteorology. Prepared by A. Wiin-Nielsen. 1973; English, Spanish.
Volume I, Part 2	- Physical meteorology. Prepared by B.J. Retallak, 1973; English, Spanish.
Volume I, Part 3	- Synoptic meteorology. Prepared by F. Defant with H.T. Morth. 1978; English.
Volume II, Part 1	- General hydrology. Prepared by A.I. Chebotarev. 1977; English.
Volume II, Part 2	- Aeronautical meteorology. Prepared by B.J. Retallak. 1978; English.
Volume II, Part 3	- Marine meteorology. Prepared by R.R. Fotheringham. 1979; English.
Volume II, Part 4	- Tropical meteorology. Prepared by T.N. Krishnamurti. 1979; English.

This compendium is intended for use by all students receiving an advanced level education in meteorology.

Compendium of Lecture Notes for Training Personnel in the Applications of Meteorology to Economic and Social Development

By E.A. Bernard. (WMO-No.382); 1974; English, French, Spanish.
The lecture notes are mainly intended for Class I and Class II meteorologists, particularly those from developing countries. The author provides basic knowledge of political economy, explains the role of meteorology in development, and finally deals with the organization of meteorological activities and world-wide meteorological co-operation.

Classes II and III meteorological personnel

Lecture Notes for Training Class II and Class III Agricultural Meteorological Personnel

Prepared by R.W. Gloyne and J. Lomas. (WMO-No. 551); 1980; English.
These lecture notes are primarily intended for the training of Class II agricultural meteorological personnel. However, some parts of it are suitable for Class III agricultural meteorological personnel. Theory and practice are treated in parallel to each other.

Classes III and IV meteorological personnel

Problem Workbook for the Training of Class III Meteorological Personnel

By P.S. Pant. (WMO-No.223); 1968; English, Arabic, French.
Contains a review of a specific subject followed by a set of sample problems with solutions and a further set of problems for solution by the student. Though designed for use in the training of meteorological assistants, it would also be useful in the training of staff of a higher professional grade.

Compendium of Lecture Notes for Training Class III Meteorological Personnel

Prepared by B.J. Retallak. (WMO-No.291); 1971; English, French, Spanish.
The lectures are based on the corresponding syllabi outlined in the first edition of the Guidelines for the Education and Training of Meteorological Personnel (WMO-No. 258); Topics covered include dynamic and synoptic meteorology, surface and upper-air observations and computations, meteorological codes and transmissions, and aeronautical meteorology.

Compendium of Lecture Notes in Climatology for Class III Meteorological Personnel

Prepared by W. Lowry. (WMO-No.335); 1972; English, French.
The major topics covered in the compendium for Class IV personnel are mentioned here in greater detail or in a more advanced manner. The first six chapters contain the preparatory material leading to the special concepts and special methods of climatological analysis covered in the next two chapters. Each chapter is followed by a set of questions.

Compendium of Lecture Notes in Marine Meteorology for Class III and Class IV Personnel

Prepared by H.O. Mertins. (WMO-No.434); 1976; English, Spanish.
Contains lecture notes for specialized training in marine meteorology and physical oceanography, extension of WMO-No. 266 and WMO-No. 291.

Compendium of Lecture Notes for Training Class IV Meteorological Personnel

Prepared by B.J. Retallak. (WMO-No. 266); 1970 (updated 1976); Volume I - Earth Science; Volume II - Meteorology; English, French, Spanish, Arabic.
This publication comprises two volumes and is designed to cater for the needs of persons who wish to undertake training as synoptic or aeronautical observers; it may also be used by students seeking a career as a climatological, agrometeorological or hydrometeorological observer. The two volumes can be used by both instructors and students.

Compendium of Lecture Notes in Climatology for Class IV Meteorological Personnel

Prepared by W. Lowry. (WMO-No.327); 1972; English.
This volume is an extension to the Compendium of Lecture Notes for Training Class IV Meteorological Personnel (WMO-No.266). It contains the knowledge of climatology necessary for all meteorological personnel and at the same time covers the additional knowledge required for Class IV personnel who will specialize in climatological work.

OTHER RELATED WMO EDUCATION AND TRAINING PUBLICATIONS

(Selected list)

International Cloud Atlas (Abridged edition)

1956; English, French.
Reference work on clouds and meteors (i.e. forms of precipitation and deposits, optical phenomena, etc.) for use in the daily practical work of meteorological observers at surface stations.

International Cloud Album for Observers in Aircraft

1956; English, French.
For use by observers in aircraft.

Cloud sheets

(1966 and 1975 editions)

Guide to Meteorological Instrument and Observing Practices (4th edition)

(WMO-No.8); 1971; English, French.
This guide lays down the basic standards of instrument and observing practices required by present-day international meteorology and provides the basis for the preparation by individual Meteorological Services of detailed instrument manuals for the use of observers.

Guide to Qualifications and Training of Meteorological Personnel Employed in the Provision of Meteorological Services for International Air Navigation

(WMO-No.114); 2nd edition 1974; English, French, Russian, Spanish.
This guide provides information on the desirable qualifications and training of meteorological personnel engaged in providing meteorological services for international air navigation as well as guidance material on the classification of this personnel into two main categories: the aeronautical meteorologist (Classes I and II) and the aeronautical meteorological assistant (Classes III and IV).

Guide to Agricultural Meteorological Practices

(WMO-No.134); 2nd edition 1981; English, French, Spanish (Russian in preparation).
Provides an integrated account of the practices, procedures, and specifications which agricultural Meteorological Services are recommended to follow, from the establishment of observing stations to the provision of forecasts and climatological information for purposes of agriculture and forestry.

Guide to Hydrological Practices

(WMO-No.168); 4th edition 1981; English, French, Russian (Spanish in preparation).
Provides guidance on modern instruments and methods of observation; design of networks; collection, processing and publication of data; hydrological analyses; hydrological forecasting; and applications to water management.

International Meteorological Vocabulary

(WMO-No.182); 1966; English, French, Russian, Spanish. (Out of print, new edition in preparation.)
This publication, compiled by working groups under the chairmanship of Dr. A. Vandenplas, contains some 2000 terms. The terms are given in all four languages but the definitions are only in English and French. Indexes are provided to enable the equivalent of a word in any one of the four languages to be found in all the others.

Manual of Aerodrome Meteorological Practices

(WMO-No.186); 1967; English, French. (English out of print.)
Provides Meteorological Services, especially those in process of development, with a comprehensive guide from the layout and location of an aerodrome meteorological office to the preparation of weather maps and issue of information to crews and operating staff.

International Meteorological Tables

Edited by S. Letestu. (WMO-No.188); 1st set 1966, 2nd set 1969, 3rd set 1973; English, French. (Out of print.)
This publication is made up of sets of tables and relevant introductions issued as

they are available and it covers a large field of dynamical and physical meteorology. The first three sets contain 48 main tables which are updated by amendments when required. This is an essential tool for all meteorologists.

Manual on Meteorological Observing in Transport Aircraft

(WMO-No. 197); 2nd edition 1978; English.
Observation of all elements from temperature to weather radar are covered and instructions given in the completion of AIREP forms.

Training of Hydrometeorological Personnel

(WMO-No.219); 1967; English. (Out of print.)
Detailed syllabi for training of staff in developing countries for the managements of water resources. Syllabi covers the work of three main levels of staff: professional, technical assistant, and observer.

Manual for Depth-Area-Duration Analysis of Storm Precipitation

(WMO-No.237); 1969; English. (Out of print.)
Describes procedures for determining the volume of precipitation during storms from discrete raingauge measurements and gives an example of an analysis made by computer.

International Noctilucent Cloud Observation Manual

(WMO-No.250); 1970; English.
Summarizes noctilucent cloud characteristics and gives instructions for making noctilucent cloud observations and for their international exchange.

WMO Sea-Ice Nomenclature. Volume I - Terminology, and Codes; Volume II - Illustrated Glossary

(WMO-No.259); 1970; English, French, Russian, Spanish.
The first part of this volume contains WMO sea-ice terminology adopted in 1968, and the second part presents black-and-white and coloured sea-ice photographs corresponding to the terminology.

Guide on the Global Data-processing System.

(WMO-No.305); 1982; English, French.
This complete guide describes in detail the practices, procedures and specifications relating to the Global Data-processing System. These are laid down in the WMO Technical Regulations.

International Glossary of Hydrology

1st Edition, 1974 (published jointly by WMO and Unesco) (WMO-No.385); English, French, Russian, Spanish.

1588 equivalent terms in English, French, Russian and Spanish, with definitions in these languages are included. They are distributed over the different fields of hydrology concerned with surface water, groundwater, hydrometeorology, soil moisture and related fields such as river hydraulics and water resources management. It also includes the Universal Decimal Classification (UDC) scheme for hydrology in English and Russian as well as tables recommended symbols and units for hydrological purposes.

Manual on the Observation of Clouds and Other Meteors (International Cloud Atlas - Volume I, revised edition)

(WMO-No.407); 1975; English, French.
Reference work on clouds and meteors, contains the descriptive text.

INDEX

WORLD METEOROLOGICAL ORGANIZATION

GUIDELINES FOR THE EDUCATION AND TRAINING OF PERSONNEL IN METEOROLOGY AND OPERATIONAL HYDROLOGY

Prepared by
The Executive Council Panel of Experts on Education and Training

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Third edition

WMO - No. 258

Supplement No. 1 February 1987

CORRIGENDUM - Insert the corrections indicated

CHAPTER 2 - Insert the replacement Chapter 2

INDEX

CORRIGENDUM

PAGE	LINE	READS	SHOULD READ	REMARKS
28	2	talent heat	latent heat	
28	-11	divergence and the velocity	divergence and vorticity	
32	-15	non-compensated heat; entropy	non-compensated heat; enthalpy	
59	15	b-plane	β-plane	
66	16	$e^x+iy=e^xe^{iy}=e^xe^{iy}=$	$e^{x+iy}=e^xe^{iy}=$	
66	-10	...+Gx+Jz+...	...+Gx+Hy+Jz...	
66	-1	areas of spherical triangle;	(delete)	Repetition
67	11	x^m (m 0),	x^m ($m\neq0$),	
72	-5	the velocity of the geostrophic	vorticity of the geostrophic	
74	-9	dry saturated lapse rates	dry and saturated lapse rates	
90	-8/-9	surface; tension of raindrops	surface tension of cloud drops	
91	16	temperature regions	temperate regions	
102	3	coding; meteors;	coding; methods;	
102	22	analysis of anemographs	analysis of anemograms	
102	-3	mi rage;	mirage;	
125	2	climatic controls;	(delete)	Repetition
130	-2	Meteorological Services	(1) Meteorological Services	
133	-8	United National Resolution	United Nations Resolution	
136	-9	temperature zones	temperate zones	
164	11	effects of climatic	effects of climate	
170	-21	mild production;	milk production	
172	8	(or details,	(for details,	
175	17	inosphere	ionosphere	
214	7	brasing	brazing	
244	5	House holder's method	Householder's method	
273	-12	kinematic moment	kinetic moment	Angular momentum
273	-11	kinematic energy	kinetic energy	
275	19	composition of structure	composition and structure	

INDEX

2.1 GENERAL

The establishment of a uniform classification of meteorological personnel is a difficult task. To be considered are the needs of the various branches of meteorology, as well as those of a heterogeneous group of national Meteorologial Services, and the increasing role of atmospheric sciences in a wide spectrum of interdisciplinary activities involving the biosphere, energy, social and economic problems, and many other spheres of human activity.

The variety of functions to be carried out by a national Meteorological Service which, in addition to fulfilling the requirements of its national community, has to participate in the different international programmes of the WMO and other governmental and non-governmental agencies, calls for a wide range of skills from its staff as well as for an appropriate and sufficiently flexible classification of grades.

Personnel grading systems differ from one country to another, as clearly demonstrated in the "Compendium of training facilities for meteorology and operational hydrology" (WMO-No. 240) and in the training curricula prepared by certain national meteorological training schools. In view of this situation and the need to co-ordinate and standardize meteorological, hydrological and related activities, it was felt that Members should be provided guidance on the training of those whose responsibility it is to realize the aims of the WMO Convention. This guidance should be in the form of appropriate syllabi for the different grades of personnel involved in the organization, operation and development of national Meteorological Services. As a first step, a clear idea is needed of the grades involved and, as far as possible, of the duties to be assigned to each grade.

There is no doubt that meteorological personnel can be graded in a number of ways, each with its own particular merit and convenience. It is equally certain, however, that no system will adequately define all the types of personnel required. It is therefore necessary to adopt a compromise classification, recognizing its deficiencies and limitations. Such a system of classification can be usefully employed as a basis for establishing syllabi for the education and training of meteorological personnel.

The following classification of meteorological personnel has been adopted on the basis of the qualifications required and duties to be undertaken. Provision should be made for identifying special aptitudes and potential for development through training during the early stages of a career as well as for bringing these guidelines into accordance with the activities envisaged in the WMO Long-term Plan.

It would be the responsibility of the Executive Council Panel of Experts on Education and Training to keep this classification up to date and to recommend any appropriate action to assist Members from developing countries in bridging the scientific and technical gap between their Meteorological Services and those of developed countries.

2.2 CLASS IV

Class IV personnel need to have had a basic education, i.e. a full primary

school plus basic secondary school* education, or equivalent, followed by appropriate training in earth sciences and in basic meteorology to the standard specified by the syllabi. The education in meteorology shall include the required practical training enabling these personnel to observe meteorological phenomena accurately and objectively and to understand the underlying significance of their routine tasks.

The duties of Class IV personnel include: making observations by visual estimation and instrument readings, calculating meteorological parameters from the latter, making phenological and biological observations, operating aerological sondes and APT receivers as well as using radio and other communication facilities such as teleprinters and facsimiles, maintaining all the observing site instruments, plotting synoptic charts and aerological diagrams, and performing such office work as keeping meteorological station files, weather data registers and other logs, and preparing climatological summaries.

2.3 CLASS III

Class III personnel need to have received a full secondary school education or equivalent and adequate training in the basic sciences and meteorology to the standard specified by the syllabi. They should preferably also have an adequate background knowledge in natural sciences, including chemistry and biology.

They should be suitably qualified to carry out a wide variety of tasks and appropriate complementary training should be provided along the lines suggested in the corresponding syllabi for fields of specialization. It should also be noted that this class of personnel constitutes the necessary link between Class IV personnel and those of Classes I and II, in the many diverse operations of Meteorological Services. The duties of Class III personnel include: supervision, instruction and management of Class IV personnel, quality control of observational data, inspection of sites, instrument care and calibration, preparation and checking of established summaries of meteorological and related parameters (either manually or by computer), assisting personnel of higher classes in the preparation of operational charts and diagrams and in the provision of services, including the provision of meteorological information, the operation, under supervision, of aerological and radiation stations and the processing of their data, and other related duties.

2.4 CLASS II

Class II personnel need to have received a complete secondary school or equivalent education and appropriate training in mathematics, physics and computer programing and to have successfully completed a meteorological training course to the standard specified by the syllabi; such training should be given at a university or other appropriate institution with Class I meteorological instructors.

*See paragraph 2.6 for the corresponding definitions.

The functions of Class II meteorological personnel include the carrying out of duties relating to the development and management of meteorological and related observation networks and systems as well as their associated telecommunication and data-processing facilities and services, and analysing and interpreting meteorological and related data. They are also responsible for providing users with appropriate meteorological and allied information and co-ordinating Meteorological Service activities with those of an interdisciplinary nature.

Assigned duties may include: analysis of synoptic and climatological data, interpretation and use of output products from computerized analyses and forecasts, weather and climate studies for different applications, basic computer programing, study of data relating to physical meteorology (radiation, ozone, pollution, etc.), technical and operational supervision of meteorological observing networks and systems (including inspection duties), development of meteorological instruments and observational methods and procedures and the preparation of advice for the various users of meteorological information.

To cope with some of these responsibilites, selected personnel should be provided with further training in management, communication and instrument techniques, specific aspects of interdisciplinary sciences and instruction techniques.

Except for the level of treatment, the fundamental meteorological training for Class II personnel should essentially be similar to that of Class I personnel. The distinction is that Class II personnel are more concerned with the applications of theory in order to provide services for users of meteorological information.

2.5 CLASS I

Class I personnel are university graduates in fields ranging from exact and natural to economic and social sciences, with adequate training in mathematics and physics, who have successfully completed training in meteorology to the standard specified by the syllabi. In this class there will be different areas of specialization; however, all graduates should acquire practical experience in an appropriate operational environment before embarking on a specialization.

All Meteorological Services should have personnel of this class. Their duties should include, inter alia, operational day-to-day work such as weather forecasting and applied climate services as well as the undertaking of meteorological modelling, advisory functions in meteorology and related activities, consulting, directing, decision-making and management. Clearly, they will also be responsible for research and development and training in universities and research institutes as well as for supervision and training of young researchers and, when necessary, of operational personnel of lower classifications.

Class I personnel should undertake postgraduate training to keep abreast of new developments in meteorology and allied sciences. This additional training may also be achieved as a result of personal study and research activities.

2.6 TOTAL PERIOD OF STUDY FOR VARIOUS CLASSES OF METEOROLOGICAL PERSONNEL

Since the duration of primary and secondary school courses and the school entry age vary from country to country, an indication of the total period of study is necessary. For the purposes of this classification it is assumed that the age at school entry is 6 (six) years and that primary education is of between 5 (five) and 7 (seven) years' duration. The basic cycle of secondary school is of between 3 (three) and 4 (four) years' duration.

CLASS IV: The background education indicated under section 2.2 should normally entail schooling of at least 9 (nine) to 11 (eleven) years, supplemented by a minimum of six (6) months' formal training in earth sciences and meteorology, and an appropriate period of on-the-job training of not less than four (4) months.

CLASS III: A minimum of twelve (12) years' schooling would be required before a candidate could start Class III training. The period of training in basic sciences and meteorology should be of a minimum of ten (10) months' theory supplemented by a period of not less than four (4) months' adequate practical and on-the-job training.

CLASS II: The same general background education as that required for Class III would be needed, i.e. a minimum of twelve (12) years' schooling to be supplemented by courses in mathematics, physics and computer programing and other prerequisite subjects, together with the meteorological training indicated under section 2.4, lasting two (2) years. A minimum of six (6) months' on-the-job training would be required to complete the training.

CLASS I: A background education, as indicated under section 2.5, would be required, i.e. full primary and secondary schooling plus adequate university training in prerequisite subjects including meteorology for a period of at least four (4) years. This should be supplemented by a minimum of six (6) months' on-the-job training in a particular branch of a national Meteorological Service.

The training centres and universities involved should recognize that training and work experience at each level provide adequate preparation for training at the next level. This will enable meteorologists to advance gradually in their career, whether technical or professional. It should be added in this context that, in the particular case of university training of Class II and Class I personnel, consideration should also be given to recognizing credits accumulated under Class II training to enable these individuals to further their training at the Class I level.

INDEX

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CHAPTER 16 Replace page 232 by the new pages 232 to 234 and renumber pages 233 to 239 accordingly.

INDEX

- Meteorological codes;

- Knowledge of symbolic forms of international meteorological codes.

16.4.2 Electricity and electronics

For Class III, Category B, telecommunications personnel, the basic electricity and electronics for Class III, Category A (section 16.3.2) should be supplemented by the following:

- Industrial safety and security precautions: instructors should explain and demonstrate all safety procedures concerning high-voltage power supplies, low-voltage circuits, HF power output, cathode-ray tubes and selenium rectifiers.

16.4.3 Telephony and telegraphy

Same as for Class III, Category A, telecommunications personnel (section 16.3.3).

16.4.4 Radio technique

Same as for Class III, Category A, telecommunications personnel (section 16.3.4).

16.4.5 Organization and telecommunication procedures for the exchange of meteorological information

For Class III, Category B, telecommunications personnel, the syllabus for Class IV, Category B (section 16.5.4.4) should be supplemented by the following:

Error-control procedures in respect of data transmission (WMO procedures)

- Software system: definition of essential terms; backward supervisory channel; organization into blocks; start of data-transmission procedures; data-transmission procedures; termination of data-transmission procedures; acknowledgement procedures; recovery procedures.

- Hardware system: CCITT recommendation V.41.

- Software and hardware compatibility procedures.

Procedures for transmission and relay of pictorial information over circuits operated on a shared data/facsimile transmission basis (WMO procedures)

- Software procedures: storing and forwarding of facsimile transmissions; switching messages; data-to-facsimile switching procedures; facsimile-to-data switching procedures.

- Hardware procedures: switching messages; identification and mode switching procedures.

- Compatibility procedures.

16.4.6 Meteorological telecommunication equipment

The purpose of this course is to increase the ability of this category of personnel in the use of meteorological telecommunication equipment employed in a meteorological telecommunication centre, including data-transmission equipment. Within this category will be operators of automatic telecommunication devices, radio receivers and radio transmitters.

Instructors should explain and demonstrate all practical aspects of operations needed for the use of each piece of equipment currently employed by the Service concerned, and studied theoretically under 16.4.3 and 16.4.4.

Practical application of meteorological telecommunication procedures (16.4.5) is also required.

16.4.6.1 Telegraph equipment

The syllabus of telegraph equipment for Class IV, Category B, personnel engaged in meteorological telecommunications (16.5.4.5) should be supplemented by the following:

- Data transmission: general principles; terminal installation: data terminal equipment, conversion equipment, modem, intermediate equipment, channels for data transmission.

16.4.6.2 Radio-communication equipment

The syllabus for Class IV, Category B, personnel engaged in meteorological telecommunications (16.5.4.5) should be supplemented by the following:

- Radio-transmitters: AM/FM transmitter; HF transmitter; LF transmitter; VHF transmitter; radio-teleprinter and radio-facsimile transmitter.

- Satellite Earth Stations and associated receiving facilities.

16.5 CLASS IV PERSONNEL ENGAGED IN METEOROLOGICAL TELECOMMUNICATIONS

16.5.1 Categories of meteorological telecommunications personnel

Category A - The training of this category of personnel will require particular emphasis on the repair and maintenance of simple telecommunication equipment. They are called upon to assist personnel of Class III in the installation, repair and maintenance of all telecommunication equipment used in their respective Services.

Category B - The training of this category of personnel will place special emphasis on the operation of telecommunications centres using manual techniques.

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