

WORLD METEOROLOGICAL ORGANIZATION

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

VOLUME I: METEOROLOGY

Editors: : I. F. Drăghici, G. V. Necco, R. W. Riddaway,
J. T. Snow, C. Billard, L. A. Ogallo

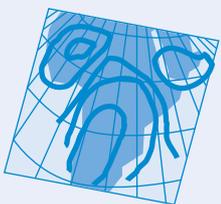
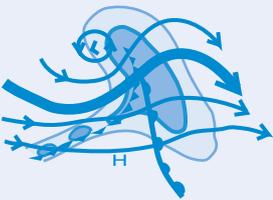
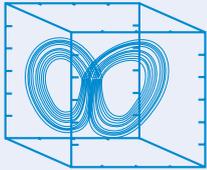
Prepared under the guidance of the
Executive Council Panel of Experts on
Education and Training

FOURTH EDITION



WMO-No. 258

Secretariat of the World Meteorological Organization
Geneva – Switzerland



WORLD METEOROLOGICAL ORGANIZATION

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

VOLUME I: METEOROLOGY

Editors: : I. F. Drăghici, G. V. Necco, R. W. Riddaway,
J. T. Snow, C. Billard, L. A. Ogallo

Prepared under the guidance of the
Executive Council Panel of Experts on
Education and Training

FOURTH EDITION



WMO-No. 258

Secretariat of the World Meteorological Organization
Geneva – Switzerland
2001

© 2001, World Meteorological Organization
ISBN 92-63-14258-0

NOTE

The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the World Meteorological Organization concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

TABLE OF CONTENTS

	FOREWORD	vii
	PREFACE	xi
	PART A GUIDANCE	xv
CHAPTER 1	WMO CLASSIFICATION OF PERSONNEL	1
1.1	Background information	2
	Need for change	2
	Basic assumptions	2
	Subsequent consultations	2
1.2	Classification of personnel in meteorology and hydrology	3
	Purposes of the new classification	3
	Categories of personnel	3
	Career progression	4
	Relation to the previous classification	4
1.3	Meteorological personnel	4
	Initial qualification of Meteorologists	4
	Initial qualification of Meteorological Technicians	5
	Career levels for Meteorologists	6
	Career levels for Meteorological Technicians	7
	Collective abilities and transferable skills	7
CHAPTER 2	THE DOMAIN OF METEOROLOGY	9
2.1	Atmospheric sciences – breadth and depth	10
	Mathematics, physics and chemistry	10
	Basic meteorological disciplines	10
	Earth System Science	11
2.2	Meteorological profession – competency requirements	12
	Training for job-competency	12
	Weather and climate – observing, monitoring and forecasting ...	13
	Meteorological applications and public services	16
	Meteorology-support branches	19
2.3	Academic specialities and job-specializations – the gap	21
CHAPTER 3	BASIC INSTRUCTION PACKAGE FOR METEOROLOGISTS (BIP-M)	23
3.1	Requisite topics in mathematics and physical sciences	24
	Mathematics	24
	Physics	24
	Chemistry	24
	Complementary requirements	24
3.2	Compulsory topics in atmospheric sciences	24
	Physical meteorology	24
	Dynamic meteorology	25
	Synoptic meteorology	25
	Climatology	25
3.3	Elective fields of specialisation in meteorology	25
	Aeronautical meteorology	26
	Agricultural meteorology	26
	Atmospheric chemistry	26
	Climate monitoring and prediction	26

	Mesoscale meteorology and weather forecasting	26
	Radar meteorology	26
	Satellite meteorology	27
	Tropical weather and climate	27
	Urban meteorology and air pollution	27
3.4	Other fields of specialization	27
	Biometeorology and human health	27
	Boundary layer meteorology	27
	Clouds and precipitation; weather modification	27
	Economic meteorology; marketing and management	28
	General hydrology and hydrometeorology	28
	General oceanography and marine meteorology	28
	Middle-upper atmosphere	28
	Numerical methods for mathematical modelling	28
3.5	Beyond the BIP-M	28
	Annex: Syllabus example for dynamic meteorology	30
CHAPTER 4	BASIC INSTRUCTION PACKAGE FOR METEOROLOGICAL TECHNICIANS (BIP-MT)	33
4.1	Requisite topics in basic sciences	34
	Mathematics	34
	Physics	34
	Chemistry	34
	Communication skills	34
4.2	Compulsory topics in general meteorology	34
	Introductory physical and dynamical meteorology	34
	Elements of synoptic meteorology and climatology	34
	Meteorological instruments and methods of observation	34
4.3	Elective options in operational meteorology	34
	Synoptic observations and measurements	35
	Other specialised observations and measurements	35
	Remote sounding of the atmosphere	35
	Aeronautical meteorology for technicians	35
4.4	Beyond the BIP-MT	35
	Annex: Syllabus example for aeronautical meteorology - technician level ..	36
CHAPTER 5	CONTINUING EDUCATION AND TRAINING (CET)	39
5.1	Introduction	40
	Factors affecting NMSs	40
	The learning organization	40
	Strategic approach to training and development	41
5.2	Basic concepts	42
	Continuing Education and Training (CET)	42
	Training and development	43
5.3	Getting the most from CET	44
	Importance of CET	44
	Making a success of CET activities	45
5.4	CET Methods	46
	General issues	46
	Delivery of CET	46
5.5	Some trends in CET	47
	Training plans	47
	Shorter courses	47
	Vocational qualification and accreditation	49
	Recruitment and induction	49
	Training the instructor and supervisor	50
5.6	Final remarks	50

PART B	EXAMPLES	51
CHAPTER 6	EXAMPLES OF BASIC INSTRUCTION PACKAGES	53
6.1	Example of a complete BIP-M programme	54
	Introduction	54
	Attributes of Bachelor's degree programs	54
	Preparation for selected careers in atmospheric science	55
6.2	Example of a condensed BIP-M programme	56
	Introduction	56
	Examinations scheme	57
	Core courses	57
6.3	Example of a complete BIP-MT programme	61
	Aims and organisation of the programme	61
	Description of courses	61
	Training periods	63
	Personal project	63
6.4	Example of a condensed BIP-MT programme	63
	Meteorology	63
	Instruments and methods of observation	65
	Coding of surface observations	67
CHAPTER 7	EXAMPLES OF ACTUAL JOB-COMPETENCY REQUIREMENTS	69
7.1	Weather analysis and forecasting	70
	Producing a generic forecast	70
	Producing forecasts for the user	71
	Providing any specialist or support work	72
	Managing the working environment	73
7.2	Climate monitoring and prediction	73
	Climate monitoring and prediction services	73
	Climate in the area of responsibility	73
	Relationship between large-scale climate and climate in the area of responsibility	73
	Prediction of climate	74
	Methods used in climate monitoring and prediction	74
	Verification of forecast (prediction)	74
	Data used in climate monitoring and prediction	74
	Climate monitoring operations	74
	Climate prediction operations	74
	Provision and explanation of climate information	75
7.3	Observations and measurements; instruments	75
	Introduction	75
	Branch management	76
	Network management	76
	Observing standards	77
	Systems engineering	77
	Provisioning and stores	78
	Project management and planning	78
	Measurement standards; instrument calibration; quality assurance	79
	Field installation and maintenance engineering	79
7.4	Information technology and data processing	80
	Information systems operating	80
	Database administration and programming	80
	Networking	81
	International meteorological telecommunication	81
	Operating/application systems design and maintenance	82
	Software engineering	83
7.5	Agrometeorology	83
	Developing weather forecasts for agriculture; products for the customer	83

	Developing an agrometeorological advisory service	85
	Computer-based information system for operational application	87
7.6	Aeronautical meteorology	88
	Major hazards to aviation	88
	Forecasting skills for aviation icing	89
	Forecasting skills for fog and low stratus	91
	Tools for forecasting	92
	Product dissemination	93
	Routine duties at a regional aeronautical meteorological office	93
	Knowledge and skills in weather watch and monitoring	94
	Skills in communicating with central offices and neighbouring stations	94
	Deriving user-oriented forecast and warning products	95
	Oral briefings to pilots and dispatchers; liaison with ATS	96
	Ongoing user training	96
7.7	Marine meteorology	97
	Marine forecasts	97
	Observing the characteristics of BLA and SLO	98
	Regime descriptions of marine areas	98
	Investigation of the BLA-SLO system	98
	Preparation of the products for the customer	98
	Performing other duties	99
7.8	Environmental meteorology	99
	Understanding the role of the NMHSs in addressing environmental issues	99
	Understanding environmental sciences and their applications	100
	Providing services; delivery of scientific advice and information	101
	Performing other related duties	102
7.9	Satellite meteorology	104
	Background	104
	Core competency requirements in satellite meteorology	104
	Satellite Meteorology Branch (SMB)	105
	APPENDICES	109
APPENDIX 1	PREFACE TO THE FIRST EDITION OF WMO-NO. 258	110
APPENDIX 2	THE FORMER CLASSES OF METEOROLOGICAL PERSONNEL	114
	Class I	114
	Class II	114
	Class III	114
	Class IV	115
APPENDIX 3	SURVEY ON THE REVISION OF WMO-NO. 258	116
	The WMO Survey	116
	Members' opinions	116
APPENDIX 4	GLOSSARY OF TERMS AND ABBREVIATIONS	118
	SELECTED BIBLIOGRAPHIC REFERENCES	122

FOREWORD

Availability of adequately trained human resources in any institution is most critical to its success; and education and training play a significant role in this connection. This is a fundamental view adhered to by the World Meteorological Organization (WMO). Indeed, one of the purposes of WMO, as stated in its Convention, is to encourage training in meteorology and in related fields and to assist in coordinating the international aspects of such training. Since its inception in 1950, WMO has been contributing significantly to the promotion of pertinent education and training activities.

The Education and Training Programme (ETRP) is one of WMO's major scientific and technical Programmes. Through this Programme, WMO activities have played a vital role in the development and strengthening of the National Meteorological and Hydrological Services (NMHSs), especially in the developing world. This has been accomplished through the education and training of personnel of these Services in relevant fields of meteorology, hydrology and other related areas; as well as through the provision of appropriate training support. The promotion of capacity building and human resources development have been key areas under the ETRP. This has contributed to bridging the gap between the level of services provided by NMHSs in the developed countries, on the one hand, and that provided in developing countries and countries with economies in transition, on the other hand.

Recent WMO activities in education and training include redefining its classification of meteorological and hydrological personnel, strengthening the role of WMO Regional Meteorological Training Centres, training of trainers, provision of technical support, organization of training events, implementation of the fellowship programme, and the preparation of training publications, such as this publication entitled *Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology*.

These activities are undertaken to respond to trends, developments and evolving needs brought about by changing socio-economic circumstances such as globalization and rapid technological advances, including information and communications technology. These also respond to the call for improved effectiveness and efficiency in the management of NMHSs and the delivery of relevant services.

Even now at the beginning of the twenty-first century, formidable additional challenges and opportunities are already on the horizon. Meeting those new challenges and availing of emerging opportunities will require better educated and skilled meteorological and hydrological personnel. To meet this evident need, considerable improvements in education and training methods, tools and attitudes are necessary. This will entail:

- Enhancing career-long continuing education and training, to maintain and enhance competency in a world of rapid scientific and technological advancements, and complex socio-economic challenges;
- Expanding the use of distance teaching and learning technology and increasing the opportunities for self-training, within the broader culture of lifelong learning;
- Re-directing more and more the professional instruction from formal training attestations or certificates to proven job-competency.

It is in this general context that the former edition of this publication (WMO-No. 258), which contained the traditional WMO classification of meteorological and hydrological personnel as well as the curricula for their education and training, has been substantively revised. This present edition, the fourth, aims at providing reference guidelines, which should be:

- Applicable in an international context, in particular in planning international training events and in assessing candidates for those events, including those funded under the WMO Programmes;
- Adaptable to a national context, in particular in National Meteorological and Hydrological Services from developing countries.

Accordingly, this new edition of the *Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology* provides an international framework for a common understanding of the basic qualifications required of individuals performing identified operational and related functions. It should also assist NMHSs in designing particular personnel categorization systems and training programmes applicable to their specific needs.

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 J.W. Zillman, for guiding the preparation of this publication. I would also like to thank presidents of Technical Commissions, who have offered their advice and proposed experts that have contributed samples of job-competency requirements in individual National Meteorological Services.

The Secretariat was assisted in the preparation of these Guidelines by Mr C. Billard (France), Prof. L.A. Ogallo (Kenya), Dr R.W. Riddaway (UK), and Prof. J.T. Snow (USA), to whom I express my thanks. I am also grateful to Prof. R.P. Pearce (UK) for reviewing an early version of the manuscript, and to Prof. Maria A.F. da Silva Dias (Brazil) for reviewing the final manuscript.

I would also like to take this occasion to recall with gratitude the contribution of the persons who have served in the EC Panel of Experts on Education and Training since its establishment in 1965. They have been led by chairpersons who have contributed much toward the progress we see presently. These include Prof. J. Van Mieghem (Belgium) who served as the first chairman. He was succeeded in 1971 by Dr Alf Nyberg (Sweden) who served in that capacity until 1979 when Dr R.L. Kintanar (Philippines) assumed the chairmanship. The high prestige accorded the Panel is demonstrated by the fact that Dr Nyberg and Dr Kintanar each served eight years as Presidents of WMO.

The successful work in education and training has been supported in a highly satisfactory manner in the WMO Secretariat. The work carried out by the Secretariat owes much to Dr H. Taba (Iran). He began and nurtured the initial small unit established in 1964, which dealt with all training matters under the supervision of the Secretary-General. This unit served as nucleus around which the Secretariat's efforts in all aspects of education and training were undertaken. There followed a rapid expansion of training activities and training became part of a reorganized Research, Education and Training Division. Subsequently, in 1976, it became necessary to establish a separate Education and Training Department within the WMO Secretariat. This is a matter of personal interest to me, having had the honour of serving as its Director from 1978 to 1983, prior to assuming the responsibilities of WMO Secretary-General.

Finally, the range of topics addressed in the "Guidelines" has profited much from the experiences of our Member countries, particularly their NMHSs, which they

have generously shared. I wish to pay special tribute to the Permanent Representatives of Members of WMO who have encouraged and contributed to the preparation of this publication. I hope that this publication will be of particular assistance to them, as well as to the wider meteorological and hydrological community.

(G.O.P. Obasi)
Secretary-General
World Meteorological Organization

PREFACE

Although the establishment of standards and guidelines for the education and training of scientific and technical staff to carry out the work of the National Meteorological and Hydrological Services (NMHSs) of both developing and developed countries has always been one of the highest priorities of the World Meteorological Organization (WMO), training is the only basic purpose of WMO set down in its Convention which has never been assigned for implementation by a special Technical Commission on which all WMO Members can be represented.

Accordingly, following a number of important preparatory initiatives through the 1950s and early 1960s, the then WMO Executive Committee (EC), in 1965, established an EC Panel of Experts on Education and Training chaired by the distinguished meteorological researcher and educator, Professor Jacques Van Mieghen of Belgium to provide overall guidance and coordination of the education and training activities of the Organization. In 1966, the EC requested the Panel to 'prepare a comprehensive guide containing syllabi for both basic and specialized fields of meteorological training'. In 1969, the first edition of what has now become widely known simply as WMO-No. 258 on *Guidelines for the Education and Training of Meteorological Personnel* was published by WMO, setting out a four-class (I-IV) system for the classification of meteorological personnel and syllabi for their education and training. In his Preface to the first edition (reproduced as Appendix 1 to this publication), Professor Van Mieghen explained the background to the development of the Guidelines and the philosophy that shaped their preparation.

Over the years since 1969 and following amendment of the WMO Convention in 1975 to include responsibility for operational hydrology, two further editions of WMO-No. 258 were issued, in 1977 and 1984, under the title *Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology*; and through the generous contribution of many distinguished authors, the WMO has sponsored the preparation of a series of vitally important training publications, the so-called *Blue Series*, to assist the teaching staff of the WMO Regional Meteorological Training Centres (RMTCs) and the training institutions of individual National Meteorological Services (NMSs), as well as the broader academic meteorological and hydrological communities; in the education and training of students to the standards required for the effective discharge of their responsibilities in support of the safety and efficiency of international shipping and aviation as well as the full range of users of meteorological and hydrological services at the national level. While respecting the prerogative of individual countries to set their own detailed standards and syllabi, and therefore not carrying the same legal status of a *Guide*, as defined by Resolution 18 of the Second World Meteorological Congress, the WMO-No. 258 has, under the auspices of the now Executive Council (EC) Panel, whose membership has included many distinguished experts in meteorological and hydrological education and training, provided the universally recognized framework for training activities in line with Article 2 (f) of the WMO Convention. It has, over several decades, played a profoundly important role in shaping the education and training of the staff of the NMHSs of the vast majority of the Member States and Territories of WMO.

Already by 1982, however, the EC had concluded 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 categorisation of meteorological personnel'. Extensive consultations were accordingly initiated, both directly with Members through their Permanent Representatives

with WMO and indirectly through the Technical Commissions on desirable amendments to the classification of meteorological personnel. But, since no clear consensus emerged on an overall new approach, and with a majority of Members inclined to maintain the four-class system for the time being, only minor amendments were introduced to the class definitions (see Supplement No. 1 to the third edition, February 1987) and a few additional topics were introduced into the meteorological telecommunications syllabus (Supplement No. 2, March 1987).

Proposals for more substantial revision of the classification of meteorological personnel emerged again at the Eleventh World Meteorological Congress in 1991 and the Twelfth Congress in 1995. Subsequently a worldwide gathering of meteorological educators and trainers participating in the WMO/Météo France Symposium on *Curriculum Needs Beyond 2000* in Toulouse in 1995 recommended a revision of the four-class system; a multidisciplinary approach to curriculum with more flexibility and receptivity to change; and phasing of education and training to sustain better career progression.

In response to these developments, the EC Panel of Experts on Education and Training, at its sixteenth session in Nanjing in April 1996 reviewed the full range of issues associated with the classification, education and training of meteorological and hydrological personnel in the light of the major changes taking place in international meteorology and hydrology, and developed initial proposals for the preparation of a new, fourth, edition of WMO-No. 258. The Panel recognized that the impacts of economic globalization on the operation of NMHSs, coupled with the greatly increased focus on natural disaster reduction, interdisciplinarity in the study of climate and environmental issues, and especially on the overall goals of sustainability, would require more broadly and expertly educated personnel with greater flexibility for development across the diverse areas of responsibility of NMHSs in the early decades of the twenty-first century. It also foresaw the need for more focused professional training of user-oriented NMHS personnel working in the major areas of application of meteorological, hydrological and related service provision. The Panel concluded that the classification system and curricula of WMO-No. 258 was in need of major revision. It requested the Education and Training Department of the WMO Secretariat to begin work on options for a new classification system and new approaches to development of education and training curricula.

Following extensive consultation with directors of RMTCs, directors, lecturers and instructors from a number of recognized NMS training institutions and universities as well as with the members of the Panel, the Secretariat developed proposals for a new classification system and curricula, which were canvassed with all Members of WMO during 1997. The consolidated proposal developed by the Secretariat on the basis of Members' responses was reviewed, revised and endorsed by the Panel at its seventeenth session in January 1998 and approved by the fiftieth session of the EC in June 1998. The proposal involved transition to a simplified two-tiered classification system common to both meteorology and operational hydrology, separate self-contained volumes of WMO-No. 258 for Meteorology (Volume I) and Hydrology (Volume II), and the establishment of Editorial Task Forces (ETF) to prepare the detailed curricula and oversight the preparation of the separate volumes.

At its eighteenth session in January 1999, the Panel reviewed the draft text of Volume I (Meteorology) prepared by the ETF and proposed a number of revisions. On the basis of further input from members of the Panel and in the light of views expressed by a number of delegations during the Thirteenth World Meteorological Congress in May 1999, a final draft text was submitted for review by an independent expert in early 2000 and further revised following his reactions and recommendations before being again considered by the Panel at its nineteenth session in April 2000. The Panel agreed that, in view of the major changes

envisaged to the overall structure of meteorological education and training and detailed curricula in line with the new classification system, it was important that there be the opportunity for final review by Members and the full range of interested experts including the directors of all RMTCs. Given that the new classification system approved by Thirteenth Congress came into effect on 1 January 2001, it was decided, therefore, to produce first a preliminary issue of the fourth edition as a Departmental publication. Copies of this preliminary issue were distributed (June-July 2000), to all potential readers, for information and possible comments. The manuscript was again revised by the ETF, in the light of comments and suggestions received by the Secretariat before 31 December 2000.

The main features of this fourth edition of WMO-No 258, which in principle should meet the agreement of a large majority of WMO Members, is being issued now as a formal WMO Programme Support publication, which may be summarized as follows:

- (a) It is written in terms of the new classification system, common to both meteorology and hydrology, which recognizes just two categories of personnel – graduate professionals and technicians – within each of which there are three career development levels (entry level, mid level and senior level);
- (b) The job-entry-level qualification of personnel assumes the successful completion of a Basic Instruction Package (BIP) specifically designed for Meteorologists (BIP-M), Hydrologists (BIP-H), for Meteorological Technicians (BIP-MT), and Hydrological Technicians (BIP-HT);
- (c) It will consist of two separate volumes: Volume I (Meteorology); and Volume II (Hydrology). Volume I is the present volume and Volume II is currently under preparation under the guidance of a separate ETF and with the involvement of other hydrology-related organizations in addition to WMO.

This Volume I (Meteorology) consists of two Parts, Part A covering chapters 1 to 5 and Part B covering chapters 6 and 7; and four appendices. Chapter 1 describes the origins and essential features of the new system for classification of meteorological and hydrological personnel and elaborates on the new approach for meteorological personnel. Chapter 2 introduces the basic disciplines involved in meteorology, the main fields of specialization and the broader field of earth system science; it also outlines the essential functions of an NMS and the main competencies involved in its operation. Chapters 3 and 4 describe the Basic Instruction Packages (BIP) for university-level graduate Meteorologists (BIP-M) and for non-graduate Meteorological Technicians (BIP-MT) respectively. Chapter 5 presents the essential concepts and strategy for continuing education and training in an NMS. Chapter 6 provides two samples of BIP-M and two samples of BIP-MT. Chapter 7 provides, in turn, a set of examples of job-competency requirements of each of the main branches of activities encountered in a typical NMS as a stimulus and aid to managers, and gives instructions in defining and elaborating the requirements for their own purposes. Appendix 1 reproduces the Preface to the first edition of WMO-No. 258 while Appendix 2 describes the former Class I-IV system for classification of meteorological personnel on the basis of extracts from the third edition. Appendix 3 summarizes Members' replies to the WMO Questionnaire of 26 March 1997 on the revision of the classification and curricula. Appendix 4 contains a short glossary of key education and training terms. It is followed by a selected bibliography.

I wish to express the appreciation of the EC Panel to all those who have contributed to the drafting of this volume; especially the six members of the Editorial Task Force, Mr C. Billard (France), Dr I. Drăghici (WMO Secretariat), Dr G.V. Necco (WMO Secretariat), Prof. L.A. Ogallo (Kenya), Dr R.W. Riddaway (UK) and Prof. J.T. Snow (USA), for their sustained efforts in the actual writing and

reviewing of the text. I also appreciate the valuable contribution of the two external reviewers, Prof. R.P. Pearce (UK) and Prof. Maria A.F. da Silva Dias (Brazil).

I also wish to take the opportunity to place on record my appreciation to all those present and past members of the Panel: Mr H. Abu-Taleb (Egypt), Mr J.P. Chalon (France), Dr M. Diarra (Niger), Dr C. Garcia-Legaz (Spain), Mr F. Gnoumou (Niger), Dr S. Khodkin (Russia), Mr A. Lagha (Algeria), Mr H. Pinheiro (Brazil), Prof. R. Quintana-Gomez (Venezuela), Dr R. Riddaway (UK), Mr D. Rousseau (France), Dr T. Spangler (US), Prof. Sun Zhaobo (China), and Prof. A. Van Der Beken (Belgium) whose experience and insight into the many facets of meteorological and hydrological education and training have enabled the WMO to address this complex, but vitally important, task so constructively and productively over the past six years.

(Dr J. W. Zillman)
Chairman of the Executive Council Panel
of Experts on Education and Training

PART A

GUIDANCE

WMO classification of personnel

The domain of meteorology

Basic Instruction Package for Meteorologists (BIP-M)

Basic Instruction Package for Meteorological Technicians (BIP-MT)

Continuing education and training (CET)

The scope and pace of changes in education in the past decade were unprecedented and, this pattern will most likely continue in the coming years. Within the global tendency toward an information society, the key word is 'restructuring', which touches on every aspect of education, including curriculum development and delivery, pedagogical methods, a lifelong learning culture, and Internet networking, etc.

There are no reasons to consider that meteorological (and hydrological) education and training escape these fundamental trends. On the contrary, as shown by the Secretary-General of WMO in his message in celebration of the World Meteorological Day 2000, the meteorological domain itself is rapidly changing and advancing vigorously, both as a science and profession; see also Obasi (1999).

This climate of continuing change demanded a large measure of 'focused flexibility' in the design of the present Guidelines, and this will require 'specific adaptation' by potential users who will gather that there are considerable changes from previous editions, even the overall aim remains essentially the same:

- (a) Assisting educators, particularly from developing countries, in designing professional education and specialized training programmes in meteorology;
- (b) Facilitating a common understanding and a degree of uniformity and stability in an international context, whilst fostering innovation and adaptation to national/local circumstances.

Part A provides recommendations for: personnel classification; main disciplines; competency requirements; mandatory instruction; and continuing professional development. It is assumed that educators and managers will adjust these human resources development recommendations according to the evolving priorities of their National Meteorological Service (NMS), as well as of other related organizations such as universities, research institutions, private companies, etc.

These Guidelines will be complemented by a WMO departmental publication containing detailed syllabus examples for each discipline under BIP-M and BIP-MT. A periodically updated version of this paper will be maintained on a specifically dedicated Web page on the WMO's Web site.

CHAPTER 1

WMO CLASSIFICATION OF PERSONNEL

Background information

Classification of personnel in meteorology and hydrology

Meteorological personnel

‘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.’

(WMO-No. 258, first edition, page 11)

Following the presentation of the new WMO classification of personnel in meteorology and operational hydrology, the second part of this chapter is devoted to meteorological personnel – their initial qualification requirements and subsequent career progression. Although the classification is focused on two main categories of personnel, the user may adapt it to his specific circumstances, for instance in line with national regulations for civil service classification.

- 1.1 **BACKGROUND INFORMATION** This section describes the new classification system and explains why it has been introduced.
- Need for change** It was considered necessary to revise the classification system and curricula used in the publication because there have been:
- (a) Important advances in meteorology, as an applied physical science, resulting from improved understanding of the coupled atmosphere-ocean-land system, improved prediction techniques and the ongoing revolution in Information and Communication Technology (ICT);
 - (b) New economic, social and political patterns evolving in many parts of the world, which, most probably, will not only give rise to new demands for meteorological and hydrological services, but will also bring major changes in many facets of the meteorological and hydrological professions;
 - (c) Significant changes in the philosophical and pedagogical approach to professional instruction and specialization, particularly as a result of the increasing importance attached to continuing education and training.
- Basic assumptions** A comprehensive questionnaire on the review and updating of the WMO classification of personnel and curricula for training was distributed to all WMO Members in 1997. The assessment of Members' replies to this questionnaire (see Appendix 3) and other related analyses led to the following consolidated conclusions:
- (a) WMO-No. 258 should provide reference guidelines generally applicable in an international context, and as far as possible, adaptable to a national context, in particular, for use by training units from developing National Meteorological Services (NMSs) or National Meteorological and Hydrological Services (NMHSs);
 - (b) The publication should aim for: a flexible classification system with two or three main categories of personnel; and a framework curricula allowing individual instructors to arrange specifically the syllabi according to the particular needs and possibilities of their NMSs or NMHSs;
 - (c) Graduation from a full-fledged university-level meteorology programme, or an equivalent qualification, should provide the basic criterion to differentiate graduate Meteorologists (formerly Class I personnel) from Meteorological Technicians (formerly Classes II, III and IV). Following the initial job-entry qualification, career-long continuing education and training would be required for subsequent professional development;
 - (d) Meteorologists and Meteorological Technicians should progress to higher grades in line with nationally determined career stages, for instance, according to national civil service career schemes. A meteorological technician could be recategorized as meteorologist, after completing a university-level meteorology programme or equivalent education;
 - (e) The new edition of WMO-No. 258 should have two separate volumes: Volume I: Meteorology and Volume II: Hydrology. Volume I should address those topics that are fundamental and relatively unchanging over time (which would constitute the core curricula for the initial instruction of meteorological personnel); and secondly, it would cover the main job-competency requirements, to provide the relevant knowledge and skills required in specific operational areas.
- Subsequent consultations** A preliminary issue of the present volume was distributed for an early appraisal, during June-July 2000, to all WMO Members, Regional Meteorological Training Centres (RMTCs), members of the Executive Council Panel of Experts on Education and Training, WMO Technical Commissions, various educational

institutions, specialized agencies, recognized professors, and specialists. The replies received were carefully assessed, and every effort was made to accommodate their various suggestions in this new version.

With respect to the new classification of personnel, most of the respondents appreciated its flexibility; some Members and RMTCs expressed their readiness to review their own classification of personnel, in order to be more in line with the new WMO system.

With respect to the new curricula, while most respondents welcomed the overall flexibility, there were few reservations about the level of detail and scope. It was suggested that:

- (a) There should be more detail in the various curricula, especially for the meteorological specializations;
- (b) The basic science requirements, particularly those for mathematics and computer science, should be strengthened;
- (c) There is a danger that having curricula that are too flexible might encourage a narrowing of the initial professional education of meteorologists.

To accommodate these concerns a detailed syllabus will be presented separately as a departmental publication, which will be made available to all WMO Members. It is assumed that interested trainers will extract and adjust from this publication those syllabus topics that are most suitable for their own training objectives.

1.2 CLASSIFICATION OF PERSONNEL IN METEOROLOGY AND HYDROLOGY

This section describes the WMO classification scheme approved by the WMO Executive Council at its fiftieth session (Geneva, 1998), and endorsed by the WMO Congress at its thirteenth session (Geneva, 1999). In contrast with the traditional WMO classification, this new scheme classifies personnel in meteorology and operational hydrology according to a single overarching scheme.

Purposes of the new classification

The purpose of the new WMO system for classification of personnel in meteorology and operational hydrology is to:

- (a) Provide an international framework for common understanding of the basic qualifications required of persons performing the meteorological and hydrological functions prescribed in the WMO Convention;
- (b) Facilitate the development of reference syllabi for the education and training of personnel in meteorology and operational hydrology performing these functions;
- (c) Assist the NMHSs of individual countries, particularly developing countries, in:
 - Elaborating personnel classification systems suited to their particular needs;
 - Developing training programmes applicable to their own classification structures and needs.

Categories of personnel

Two broad categories of personnel are identified as graduate professionals and technicians. For meteorological and hydrological personnel, these categories are designated as follows:

- (a) *Meteorological personnel*
 - **Meteorologist** – a person who holds a university-level degree or equivalent; has acquired an appropriate level of knowledge of mathematics, physics, chemistry and computer science, and has completed the Basic Instruction Package for Meteorologists (BIP-M);

- **Meteorological Technician** – a person who has completed the Basic Instruction Package for Meteorological Technicians (BIP-MT).

(b) *Hydrological personnel*

- **Hydrologist** – a person who holds a university-level degree or equivalent, and has completed the Basic Instruction Package for Hydrologists (BIP-H);
- **Hydrological Technician** – a person who has completed the Basic Instruction Package for Hydrological Technicians (BIP-HT).

Career progression Within both categories of personnel, depending on national circumstances, individuals will normally progress from positions of modest responsibility under close supervision, to positions with more responsibility and less supervision. Some individuals will advance to higher positions, with responsibilities for supervision and leadership. Any progression is based on increased experience, completion of appropriate continuing education and training and demonstrated competency.

The designations job-entry-level, mid-level, and senior-level will be used to denote three generic career progression levels within each main category of personnel.

Relation to the previous classification For general orientation purposes, a broad relationship between the previous classification and the new categorization system would be as follows:

(a) *Meteorological personnel*

The new category of Meteorologist is equivalent to the former Class I. The new Meteorological Technician sub-categories of senior-level, mid-level and job-entry-level, are broadly equivalent to the former Classes II, III and IV, respectively.

(b) *Hydrological personnel*

The new category of Hydrologist is equivalent to the former category of professional hydrologist. The new Hydrological Technician sub-categories of senior-level, mid-level and job-entry-level, are broadly equivalent to the former categories of senior technician, junior technician and hydrological observer, respectively.

It is not, however, envisaged that these qualitative associations should be used to establish any formal equivalence between the former classes and the current categories of personnel.

1.3 METEOROLOGICAL PERSONNEL

This section briefly elaborates the main thrust of the new classification scheme for the case of meteorological personnel.

Initial qualification of Meteorologists

The three qualification requirements for a Meteorologist can be met through completion of one of the following two programmes (see also Figure 1.1):

(a) *University-level degree in meteorology*

An adequate prerequisite knowledge in mathematics, physics and chemistry, at the level requisite for university admission into the corresponding faculties, is required before starting the BIP-M.

Normally, the BIP-M programme would require four academic years, but the actual period may vary between academic institutions. Typically, the first half of the programme will be focused on fundamental science education, while the second half will be dedicated essentially to the meteorological education, which may be specialized along three major streams: Weather, Climate and Environment.

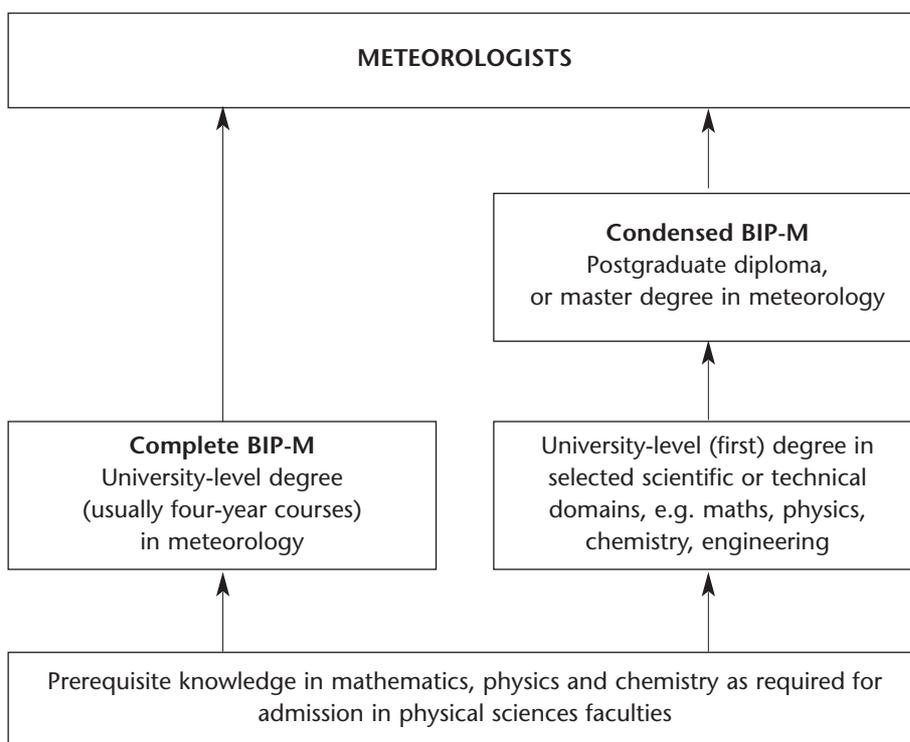
The main components of this complete BIP-M are:

- (i) Requisite topics in mathematics and physical sciences: mathematics and computational science, physics, and chemistry, at the level of 'Major' in

- physical science faculties. Required complementary topics: communication and presentational techniques and international communication languages;
- (ii) Compulsory topics in atmospheric sciences: physical meteorology, dynamic meteorology, synoptic meteorology (the main subject for the Weather stream), climatology (the main subject for the Climate stream), and atmospheric chemistry (the main subject for the Environment stream);
 - (iii) Elective fields of specialization in meteorology: aeronautical meteorology, agricultural meteorology, atmospheric chemistry, climate monitoring and prediction, mesoscale meteorology and weather forecasting, radar meteorology, satellite meteorology, tropical weather and climate, urban meteorology, and air pollution; additional fields are listed in section 3.4.

Besides the basic requirement to complete topics (i) and (ii), students wishing to obtain an early specialization may also deepen one optional subject from among items (iii). The final degree award may specify the acquired specialization.

Figure 1.1
Principal educational streams for
the initial qualification of
Meteorologists



(b) *Postgraduate diploma or master degree in meteorology*

A university-level degree in selected scientific or technical domains such as mathematics, physics, chemistry, electronic or geo-sciences engineering is required along with knowledge of mathematics, physics and chemistry at the level of the complete BIP-M.

The instruction components of this condensed BIP-M programme are essentially similar to those of the complete BIP-M, but the pace of their delivery may be considerably faster, particularly when students already possess the required standard in mathematics, physics and chemistry. Normally, a condensed BIP-M would require one or two academic years.

Initial qualification of
Meteorological Technicians

WMO Members have used various education and training approaches to qualify their Meteorological Technicians: from formal education in a technical school or college with specific training programmes in meteorology, to simple vocational and/or on-the-job training in meteorological observations and measurements.

To become a Meteorological Technician it is necessary to complete the Basic Instruction Package for Meteorological Technicians (BIP-MT). This requirement

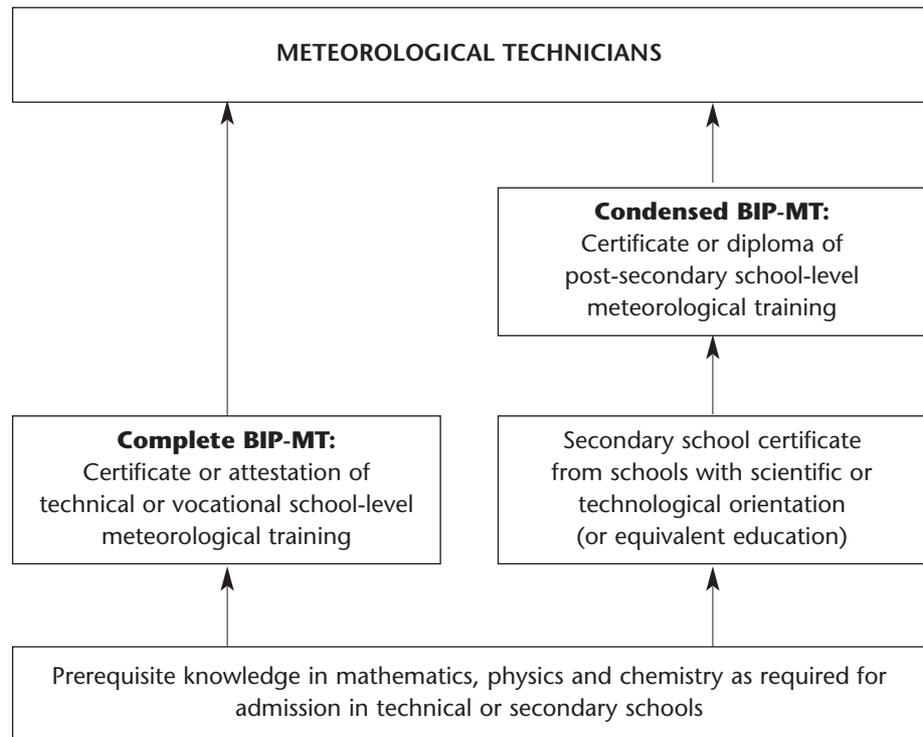
can be met through completion of one of the following two programmes (see also Figure 1.2):

- (a) *Certificate or attestation of technical/vocational meteorological training*
After completing education at the general, elementary or compulsory school, there is a requirement for continuing education in a technical or vocational school where the instruction programme includes at least one semester of training in meteorology. This instruction should be supplemented by an extensive period of practice in making meteorological observations and measurements, and in operating information and communication technology.

The main components of the complete BIP-MT programme are as follows:

- (i) Requisite topics in basic sciences: mathematics, physics, and chemistry at the level of secondary school education. Basic communication skills;
- (ii) Compulsory topics in general meteorology: introductory physical and dynamical meteorology, elements of synoptic meteorology and climatology, meteorological instruments and methods of observation;
- (iii) Elective topics in operational meteorology: synoptic observations and measurements, other specialized observations and measurements, remote sounding of the atmosphere, and aeronautical meteorology for technicians.

Figure 1.2
Principal educational streams for
the initial qualification of
Meteorological Technicians



- (b) *Post-secondary school-level meteorological training certificate or diploma*
In case there is pre-requisite knowledge in mathematics, physics, and chemistry at the level of secondary school education (minimum 12 years of schooling), it is sufficient to complete a condensed BIP-MT. The components of this programme are essentially the same as for the complete BIP-MT, but the pace of their delivery may be faster. Broadly, a condensed BIP-MT may take between a few months and one year, depending on the desired qualification.

Career levels for Meteorologists

Future meteorologists, upon completion of the BIP-M programme, enter the professional world and, after an orientation period and on-the-job training, they gradually assume operational duties in weather analysis and forecasting, climate monitoring and prediction, or other relevant applications. Some meteorologists will become involved in consulting, directing, decision-making and management;

others will undertake research and development or teaching activities, etc. Generic responsibilities for the three career levels may be summarized as follows:

- Entry-level* Job-entry-level meteorologists mainly carry out routine duties, to be performed under supervision and, most often, in collaboration with others. Individual autonomy within an established menu of responsibilities is expected.
- Mid-level* Mid-level meteorologists carry out a broad range of activities to be performed in a wide variety of contexts, some of which are complex and non-routine. Capacity to apply knowledge and skills in an integrated way, and an ability in problem-solving are required; important personal autonomy and responsibility, including for the control or guidance of others, may also be expected. Directing and managing local operational services; devising creative and imaginative solutions for technical and administrative problems.
- Senior-level* Senior-level meteorologists require competencies involving application of a significant range of fundamental principles and complex techniques across a wide and often unpredictable variety of contexts. Capacity to profitably transfer knowledge and skills in a new task and situation and substantial personal autonomy are required. Often, significant responsibility for the work of others – analysis and diagnosis, planning and execution, control and evaluation, training and retraining. Responsible for a service or branch; planning, coordinating, and managing the respective unit, also in collaboration with immediate associates.

Career levels for Meteorological Technicians

Meteorological Technicians duties include carrying out weather, climate and other environmental observations; assisting weather forecasters in the preparation and dissemination of analyses, forecasts, weather warnings, and related information, products and services. NMSs typically employ many other types of technicians, such as mechanical, electrical and electronic technicians to install and maintain equipment such as ground receivers for aerological observations, automatic weather stations, weather radar or telecommunication equipment. Generic responsibilities for the three career levels may be summarized as follows:

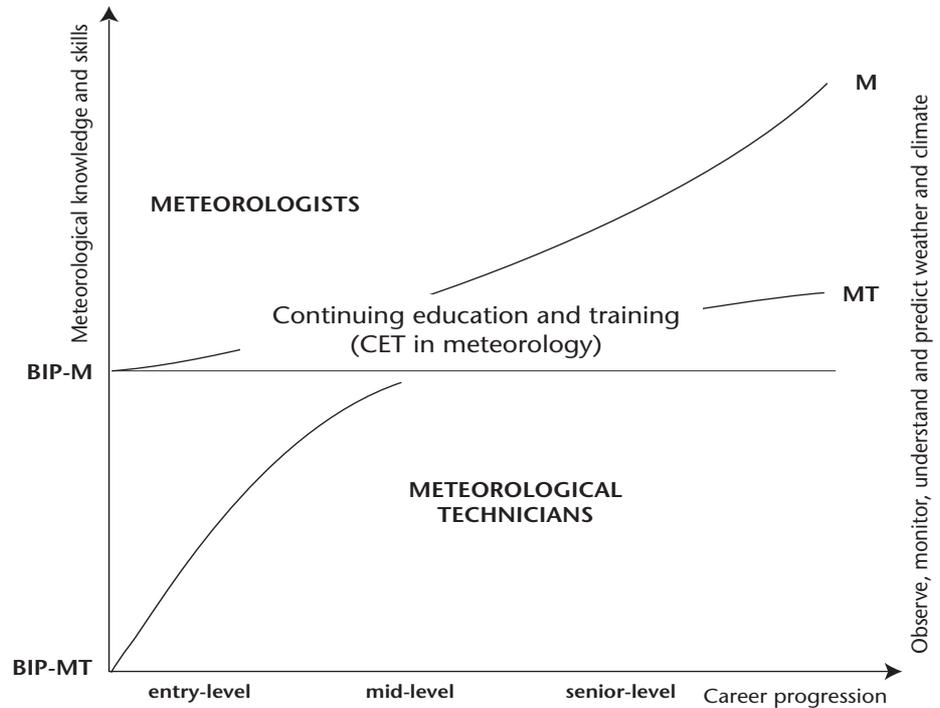
- Entry-level* Job-entry-level technicians mainly carry out routine and predictable duties, to be performed under supervision and, most often, in collaboration with others; they generally do not make decisions in the course of their work. Usually they specialize in a particular job (e.g. surface observations, upper-air soundings, radiation measurements, operational data processing, etc.).
- Mid-level* Mid-level technicians, besides performing standard duties, may also be required to carry out non-routine activities involving certain personal autonomy, in the context of explicit requirements and criteria. Responsibility for the guidance of others may also be assigned to some mid-level technicians. They generally work under the technical supervision of senior Meteorological Technicians or Meteorologists.
- Senior-level* Senior-level technicians require competencies in a wide range of complex technical-level and even professional-level work activities, to be performed in a variety of contexts and with a substantial degree of personal responsibility, including responsibility for the work of other Meteorological Technicians. They should be able to take technical decisions, and capable of solving all technical problems in their own specialized range of activity.

Collective abilities and transferable skills

The initial qualification and subsequent professional development of Meteorologists are essentially different from those of Meteorological Technicians. The two curves under Figure 1.3 show the likely career path for the two categories of personnel.

From the Chart it may be noted that just above the BIP-M level, the paths for the mid/senior-level technician and for the entry/mid-level meteorologist show an apparently similar level of knowledge and skill in meteorology. Indeed, in

Figure 1.3
Career progression of
Meteorologists and Meteorological
Technicians



practice, some mid/senior-level technicians may perform duties that are similar or overlap with duties of entry/mid-level meteorologists. However, for technicians the emphasis is on operational knowledge and practical skills, while for meteorologists the emphasis is on deeper knowledge and understanding.

The fact that the MT-path is ‘bounded’ relates mainly to limitations in the theoretical knowledge prescribed under the BIP-MT. However, Meteorological Technicians may become meteorologists by undertaking further education and training (i.e. by acquiring a university-level degree and the BIP-M standards). It is expected that both categories would undertake continuing education and training (including self-study), to update/upgrade their professional competency.

Most often, Meteorologists and Meteorological Technicians would act together as a team within their NMSs, where they not only need to be competent in their occupation, but they also need to be able to adapt to changing circumstances and develop their careers. They also need the breadth and depth of relevant knowledge, understanding and experience accompanied by an ability to be adaptable, flexible and independent when working.

Clearly, having the appropriate basic knowledge and technical skills are at the centre of being competent, but it is also necessary to be able to:

- Deal with physical constraints/hazards by following health and safety procedures;
- Communicate effectively and work effectively with others;
- Apply a problem-solving approach to non-routine tasks;
- Manage several tasks at any one time;
- Manage one’s own learning and performance;
- Acquire new skills, knowledge and understanding demanded by changes in products, technology and working practices; and
- Understand how one’s job contributes to meeting national and international commitments.

In this publication no attempt will be made to define these ‘collective abilities and transferable skills’, as they will depend crucially upon the type and level of the job, the specific requirements of the organization, and the extent to which individuals are responsible for their own performance and development.

CHAPTER 2

THE DOMAIN OF METEOROLOGY

Atmospheric sciences – breadth and depth

Meteorological profession – competency requirements

Academic specialities and job-specializations – the gap

The first section of this chapter gives a brief overview of the main meteorological disciplines, which are distinguished more to facilitate a structured approach to curricula design rather than to differentiate the subject matter itself. The second section describes the principal job-competency requirements in the main branches of activity of a typical National Meteorological Service (NMS). The presentation is meant to provide a first step in identifying the requirements in terms of knowledge and skills. The interested reader (e.g. instructor) may wish to refine the suggested job-competencies according to the more specific mission and functions of his NMS. The last section briefly touches on the gap that exists between the academic specialities and the fields of specialization required in meteorological professions.

The next step will be made in Chapters 3 and 4, where the framework curricula of the Basic Instruction Packages for Meteorologists and Meteorological Technicians (BIP-M/MT) will be oriented, to the extent possible, according to the knowledge and skills required for the job-entry level. Then, the examples from Chapter 7 will highlight additional job-competency requirements enabling the actual practice of individual jobs, at the current operations level.

2.1	<p style="text-align: center;">ATMOSPHERIC SCIENCES – BREADTH AND DEPTH</p>	<p>As a physical science, meteorology deals essentially with the physics, chemistry and dynamics of the atmosphere; it also deals with many direct effects of the atmosphere upon the Earth’s surface, the oceans, and life in general. Its ultimate goals are the best possible understanding and prediction of atmospheric phenomena, from local to planetary scale, and from a few seconds, minutes and hours to several days, weeks and seasons (even decades and centuries). For the purpose of these Guidelines, the terms atmospheric sciences and meteorology have the same meaning.</p>
	<p>Mathematics, physics and chemistry</p>	<p>A thorough knowledge of mathematics, physics and chemistry is required to enable students to understand the relationship between atmospheric phenomena and the nature of matter as expressed in the basic physical principles. Accordingly, when organising basic instruction programmes in meteorology, provisions should be made for co-requisite/refresher courses in mathematical physics, with emphasis on basic concepts and methods required in studies of fluid dynamics and thermodynamics.</p> <p>As with mathematics, there may be a need for co-requisite/refresher courses in physics and chemistry. There is, however, a significant distinction between the study of atmospheric sciences and the common study of physics or chemistry, where most often the focus is on individual processes in order to reveal the fundamental properties of the matter. In contrast, the study of atmospheric sciences concerns a large and complex system, which allows effects and interactions that may not be fully understood if considered separately from their environment. The ultimate goal is to understand, not only qualitatively but also quantitatively, the coherent functioning of the whole system. Consequently the co-requisite/refresher courses in physics and chemistry should provide the underpinning knowledge necessary for an understanding of atmospheric sciences.</p>
	<p>Basic meteorological disciplines</p>	<p>The basic meteorological disciplines – distinguished more in function of the state of the science rather than of the subject matter itself – may be designed as follows:</p> <ul style="list-style-type: none"> • Physical meteorology, including atmospheric chemistry and air quality; • Dynamic meteorology, including Numerical Weather Prediction (NWP); • Synoptic meteorology, including mesoscale meteorology and forecasting; • Climatology, including both the traditional statistical description and the modern dynamical study and interpretation of the climate, as well as climate prediction.
	<p><i>Physical meteorology</i></p>	<p>Physical meteorology deals with the scientific explanation of the atmospheric phenomena. A thorough knowledge and understanding of the basic physical principles of thermodynamics and of the theory of electromagnetic radiation is essential. This will provide the necessary background for the study of topics such as: the physical structure and chemical composition of the atmosphere, solar and terrestrial radiation, aerosol physics and chemistry, boundary-layer processes, microphysics of clouds and precipitation, atmospheric electricity, physical processes in small-scale dynamics (e.g. turbulence) and middle-upper atmosphere, and the basics of remote sensing technology.</p>
	<p><i>Dynamic meteorology</i></p>	<p>Dynamic meteorology is concerned with the study of atmospheric motions as solutions of the fundamental equations of hydrodynamics and thermodynamics or other systems of equations appropriate to special situations, as in statistical theory of turbulence. A solid background in higher mathematics and fluid dynamics is required since this provides the scientific basis for the understanding of the physical role of the atmospheric motions in determining the observed weather and climate at all scales – planetary, synoptic, mesoscale and microscale. Eventually, it is this understanding that enables the practical methodology for modern weather forecasting and climate prediction by dynamic methods.</p>
	<p><i>Synoptic meteorology</i></p>	<p>Synoptic meteorology was traditionally, concerned with the study and analysis of weather information taken concurrently to identify synoptic-scale weather</p>

systems, diagnose their structure, and qualitatively anticipate their future evolution. Today's synoptic meteorology deals with analysing and forecasting the weather from the mesoscale to planetary scale (e.g. 'weather regimes'); and its sophisticated technical basis includes operational databases, standardized sets of automatically plotted diagnostic meteorological maps and diagrams, NWP outputs, as well as other products and auxiliary material. The traditional interpretation of the synoptic situation was empowered by modern diagnostic tools (e.g. satellite and radar imagery) and new conceptual models (e.g. conveyor belt, potential vorticity thinking or Q-vectors analysis). The sharp distinction, which used to exist between synoptic forecasters and applied dynamic meteorologists, has become rather diffuse.

With the ever-increasing application of objective methods, particularly the continued development of remote sensing, sophisticated data assimilation techniques, and operational application of ensemble forecasting, the human forecasters' contribution is no longer dominant. And yet, experienced forecasters can still make some useful subjective interpretations to add value to the numerical objective products (e.g. utilize the ensemble forecasts' quantification of forecast uncertainty in conjunction with user-specific needs and constraints, including his risk-taking limitations). Good presentation and communication skills are required in the interaction with the users.

Climatology Climatology, according to the WMO *International Meteorological Vocabulary* (WMO-No. 182) is the 'study of the mean physical state of the atmosphere together with its statistical variations in both space and time as reflected in the weather behaviour over a period of many years'. Implicit in this definition is the limitation of the concept of climate to the atmospheric setting, a fact that genuinely reflects the emergence and historical development of climatology. However, during the past few decades atmospheric scientists have realized that the climate system must include not only the atmosphere, but also the relevant portions of the broader geophysical system which increasingly influence the atmosphere as the time period under consideration increases.

Today's climatologists, while focusing on meteorological processes, increasingly study the role of physical and chemical processes within the oceans and across the multitude of land surface regimes. Integration of data and knowledge from meteorology, oceanography and hydrology becomes essential. The climate is viewed as 'the long-term statistics that describe the coupled atmosphere-ocean-land weather system, averaged over an appropriate time period' (National Academy Press, 1998).

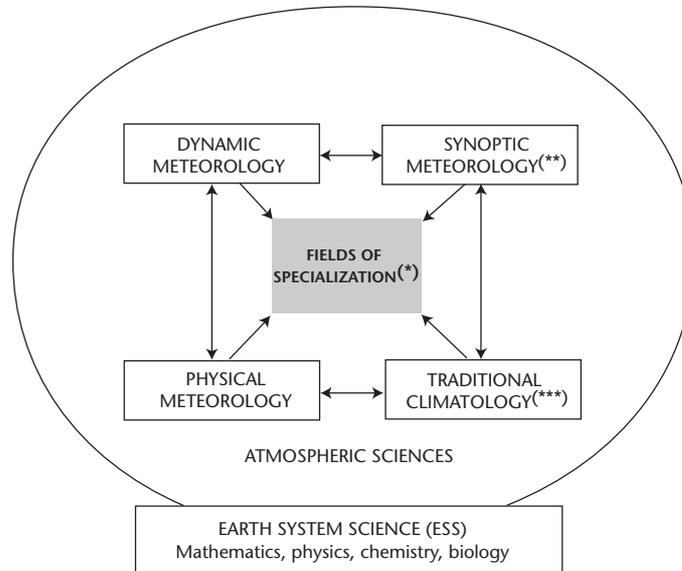
By dealing with the description of past, present and future state of the whole climate system, modern climatology has got a wider scope. Furthermore, it concerns not only the natural climate evolution, but also potential changes in the global and regional climate induced by the aggregate of human activities that change both the concentrations of greenhouse gases and aerosols in the atmosphere, and the pattern of vegetative land cover. The goal is to achieve the best possible understanding of the dynamic, physical and chemical basis of climate and climate evolution, in order to predict climate variability/change on seasonal to decadal and longer time scales.

Earth System Science Many sub-disciplines or specialities concerned with particular subjects of study and research, or specific applications co-exist and evolve within the above conventional disciplines. At the same time, the boundaries between various disciplines and sub-disciplines are gradually becoming less distinct, and the ensemble of atmospheric sciences is becoming less isolated from other geo-sciences (see also Figure 2.1).

The trend is towards an ensemble Earth System Science (ESS), which involves an integrated approach to the study of the Earth in order to explain Earth's

Figure 2.1
The main meteorological disciplines in the context of Earth System Science (ESS)

- (*) Common fields of specialization in meteorology are discussed under the next sections 3.3 and 3.4;
- (**) Synoptic meteorology would include mesoscale meteorology and weather forecasting;
- (***) The broadening scope of the climate science was acknowledged in the preceding discussion on climatology.



dynamics, evolution and global change. In this approach, the Earth is regarded as a unified system of interacting components, including:

- *Geosphere* – physical elements of the Earth’s surface, crust and interior; relevant processes include continental drift, volcanic eruptions, earthquakes, soil processes involving heat and water;
- *Hydrosphere* – water and ice on or near the surface of the Earth; also, water vapour in clouds, ice caps and glaciers; and water in the oceans, rivers, lakes, and aquifers; relevant processes include the flow of rivers, evaporation, rain, water pollution;
- *Atmosphere* – thin layer of gas or air that surrounds the Earth; relevant processes include winds, weather, the exchange of gases with living organisms, air pollution;
- *Biosphere* – the wealth and diversity of living organisms on the Earth; relevant processes include life and death, evolution and extinction, in particular, vegetation evolution and its role in the hydrological cycle and in the atmospheric gas composition.

ESS covers not only the natural processes with their complex three-phase nature, but also the effects of human-induced changes on the global environment. The aim is to obtain a scientific understanding of the entire earth system, how its component parts and their interactions have evolved, how they function, and especially how they may be expected to continue to evolve on all time scales. Noting the close connections between the ESS scope and contemporary climate studies, educators are encouraged to include in their BIP-M programmes introductory courses in ESS, which would enable students to look at the climate system from an even larger perspective.

2.2 METEOROLOGICAL PROFESSION – COMPETENCY REQUIREMENTS

Increasingly, training is being defined in terms of the output of the training process (what the trainee can do) rather than the input (what the trainee is taught). This approach leads to the concept of competency: the ability to perform the activities within an occupational area to the levels of performance expected in employment. Then, the outcome of the training process should be a person who has demonstrated the required competencies versus certain performance standards.

Training for job-competency

In principle, any job-performance standard should include information about:

- Duties to be performed (duty to be expressed in terms of specific tasks);
- Knowledge and understanding required; skills and experience requirements;
- Performance criteria for the successful completion of individual duties.

This section is focused on the duties to be performed under common meteorological jobs; the aim is to identify key competencies from which to derive the

underlying background for the required professional knowledge and understanding (to be described in Chapters 3 and 4). The skills and experience requirements, as well as the performance criteria, need to be defined in a way that takes account of the national situation – both in terms of the weather-climate conditions and employment practices. Such aspects, being too specific, will not be considered in any detail.

Generally, the mission of a typical NMS is to:

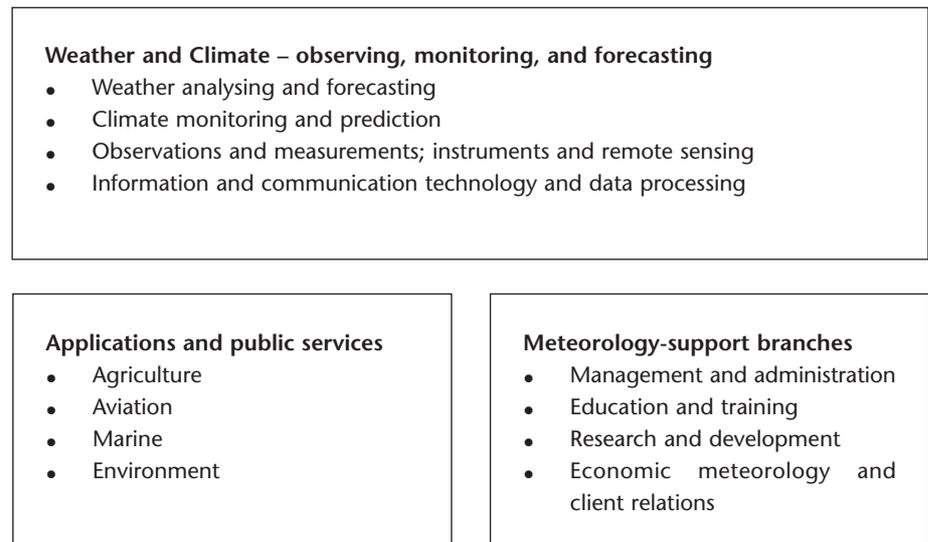
- Observe, monitor, and predict the weather and climate of its country;
- Provide meteorological and related services in support of national needs;
- Meet relevant international commitments under the WMO Convention.

(It should be noted that in several countries there is also a wide community outside the NMS that contributes to the achievement of these goals).

The practical implementation of this mission requires a wide range of activities, organized into a large number of jobs, which may be assembled into a smaller number of technically specific units that may be characterized as branches of activity. One simple model of these branches is shown in Figure 2.2.

Figure 2.2
Generic branches of activity in a typical NMS

Note: Given the diversity in the mission and structure of NMSs throughout the world, considerable variation in the grouping of activities and in the titles of various branches is inevitable. The aim is to illustrate the broad range of competencies required from the NMS' personnel as a whole.



Among these generic branches there are important differences with respect to the number of employed personnel and their job requirements. Underpinning these branches are also certain cross-cutting activities such as Numerical Weather Prediction (NWP) or radar- and satellite-sensing, not shown explicitly on this Figure; most NMHS will utilize output from these activities, but they may not have the technical/human resources to undertake them within their own Service.

Typical jobs and general competency requirements for the personnel employed in various activity branches will be described in the following three sub-sections. The presentation is not comprehensive, nor exclusive or prescriptive, in view of the fact that competencies have to be defined in such a way as to meet local needs. Thus, a large degree of flexibility is necessary when considering the competency requirements given below.

Weather and climate – observing, monitoring and forecasting

The operational duties and competency requirements for personnel employed in the professional branches dealing with weather and climate would be, normally, at the level of graduate Meteorologist and/or senior-level Meteorological Technician. In the technological branches for observations and measurements, instruments, information and communication technology and data processing, the work is more and more automated, and traditional staffing is decreasing. Both

Meteorologists and Meteorological Technicians should be familiar with basic observation methods and instruments and should be able to use computer text processors and common software.

Weather analysing and forecasting

The mission under this branch consists of constantly monitoring the weather over the assigned geographical area; elaborating and distributing general and specific weather forecasts, including weather warnings with particular emphasis on public safety and welfare. Typical individual jobs include operational (dependent, field, or main) weather forecaster; agricultural forecaster; aeronautical forecaster; marine forecaster; airquality or environmental forecaster. Operational duties and competency requirements include:

- *Atmospheric processes and phenomena.* Know and understand the main atmospheric processes and phenomena from a planetary to a local scale; know the region-specific weather phenomena and understand the major mesoscale-local scale particularities of the atmospheric dynamics over the assigned area;
- *Analysing and monitoring the weather.* Analyse and interpret synoptic charts, diagrams and graphics; integrate all available data to produce a consolidated diagnosis; perform real-time weather monitoring, especially utilising radar surveillance and satellite imagery; constantly monitor the actual weather evolution, particularly the severe weather aspects in the assigned area;
- *Weather forecasting.* Know and be able to apply weather forecasting principles, methods and techniques; understand the operation of NWP models, and their strength and weaknesses;
- *Post-processing of NWP output.* Perform selected post-processing of NWP outputs and add value to model or guidance forecasts where appropriate; identify processes that are significant on various scales and relevant for specific application areas. Generate predicted fields and interpret those fields in terms of the future state of appropriate weather elements; assess their relevance and accuracy versus the actual evolution of the weather;
- *User-specific forecasts.* Elaborate and distribute regional/local, and user-specific forecasts; verify the ongoing forecasts; identify errors and amend erroneous forecasts as appropriate; issue warnings; provide reliable emergency services;
- *Users' needs.* Understand users' needs and risk-taking limitations; assist and advise them in taking technical decisions which are dependent on weather.

While this list refers to a generic branch of weather analysis and forecasting, an example of actual competency requirements in such branch is given in section 7.1.

Climate monitoring and prediction

The mission under this branch consists of documenting, monitoring and assessing the climate characteristics over the assigned geographical area (in a global/regional context); preparing and distributing climate summaries and predictions, usually for seasonal time-scales; elaborating and distributing climate warnings. Typical individual jobs include operational climatologist; micro-climatologist; agrometeorologist; environmental meteorologist. Operational duties and competency requirements include:

- *Physical-dynamical principles.* Understand the physical-dynamical principles governing the functioning of the Earth's climate system, from global to national and local scales; know and be able to apply climate analysis and prognosis methods and techniques;
- *Region-specific weather phenomena and impacts.* Know and understand region-specific climate and weather phenomena and their detailed sub-regional patterns; understand the normal impact of climate on various economic sectors, particularly the vulnerability of human activities on climate-related severe events;
- *Monitoring climate data.* Monitor climate data; utilize satellite imagery to identify characteristic patterns in the atmospheric systems evolution; assemble climate records and perform other routine operations;

- *Processing climate data.* Execute appropriate processing (statistical and dynamical) of data to depict climate patterns and variability; interpret the climate data; assess the evolution of the patterns, anomalies and trends, and interpret them in terms of the future state of relevant climate elements; prepare and distribute user-specific forecasts, including warnings of severe climate events;
- *General Circulation Models (GCM).* Understand the operation of GCM; utilize, as available, current climate prediction products from large climate centres;
- *Climate change impact.* Use long-term integration of climate models for a range of emission scenarios, along with national climate records and regional adaptation techniques, to prepare advisories on possible impact of climate change.

An example of actual competency requirements in the branch is given in section 7.2.

Observations and measurements; instruments

The mission under this branch consists of producing observational data on an operational basis for the purposes of weather and climate services; operating and controlling the network; specifying and standardizing instruments and methods of observation; calibrating, maintaining and repairing instruments. Typical individual jobs include weather observer; radio-sounding technician; instruments technologist; AWS (Automatic Weather Station) technician. Operational duties and competency requirements include:

- *Surface observations.* Make surface observations: observe and record the parameters that make up a weather message; encode the observations in the standard format; transmit coded information;
- *Upper-air soundings.* Make upper-air sounding; perform radiation, and other meteorological measurements; encode the observations in the standard format; transmit coded information;
- *Weather watch.* Analyse observations in the local area and be in a position to identify probable significant changes in weather at the station; know and understand the region-specific weather phenomena; be aware of likely weather sequences that are expected to affect the station;
- *Weather alert.* Understand a basic weather briefing or forecast so as to be able to identify changes from the expected evolution at the station; alert the duty forecaster and external users to observed changes in the weather within the local area;
- *Product distribution.* Distribute data and information; disseminate messages to users; issue routine and non-routine reports in accordance with normal working practice; answer questions from users;
- *Equipment maintenance.* Carry out routine maintenance of observing/office equipment; operate and maintain automated weather stations, as appropriate.

An example of actual competency requirements is given in section 7.3.

Information and Communication Technology (ICT) and data processing

The mission under this branch consists of assembling and processing of incoming observational data; creating data sets for weather analysis and forecasting; archiving specific data sets; delivering products to users; maintaining ICT. Typical individual jobs include operational weather technician; meteorological data manager; software development engineer. Operational duties and competency requirements include:

- *Hardware and software.* Recognize basic hardware and software components; understand basic operating systems, particularly transmission and computing systems;
- *Data processing.* Apply standard methods and techniques for processing, quality control, and error analysis of the various input data sources, manual and automatic surface and upper-air observations, radar and satellite data;
- *Generation of meteorological data.* Know the general operations used to generate fields of meteorological variables, possibly including assimilation of data from various sensors and platforms;

- *Manipulation of meteorological data.* Manipulate and process meteorological data, including collecting, organising, managing and preserving information; capability to operate message switching system;
- *International telecommunication systems.* Know the purpose of the international meteorological telecommunication system, and the WMO regulations in organising this system;
- *Development of ICT systems.* Assist in the development and/or upgrading of information and communication technology systems.

An example of actual competency requirements is given in section 7.4.

Meteorological applications and public services

Generally, these branches foster meteorological studies and provide services aimed at increasing public safety and welfare and the productivity of the national economy with respect to weather and climate factors. Normally, these branches are not directly linked to the elaboration of operational weather forecasts or climate predictions, but may utilize relevant forecasts and predictions, and adapt them (add value) for very specific purposes. At the same time, a good part of the activities usually referred to as Public Weather Services are undertaken under the professional branches from the previous section; see also the *Guide to Public Weather Services* (WMO-No. 834).

Some of the operational duties and competency requirements described below are at Meteorologist level; others are at the level of Meteorological Technician.

Agricultural meteorology

The mission under this branch consists of defining and applying the knowledge of the interaction between meteorological, climatological and hydrological factors, and biological systems to practical use in agriculture, including horticulture, animal husbandry and forestry. Typical individual jobs include professional agricultural meteorologist; agricultural meteorology technician; agricultural engineer. Operational duties and competency requirements include:

- *Agricultural and biological sciences.* Know basic concepts in agricultural and biological sciences; understand the adaptation of plants and animals to climate;
- *Impact of weather and climatic factors.* Understand the relation of crop growth and development, and crop yields to the various climatic factors; understand the impact of extreme weather and climate events on agriculture and forestry; know the impact of weather and climatic conditions on insect pests and plant diseases;
- *Observations and data processing.* Carry out agricultural meteorology observations; perform routine data processing; determine net photosynthesis and water use of crops; determine irrigation demands;
- *Remote sensing and GIS.* Use satellite multi-spectral based, and other remote sensing products and Geographic Information System (GIS) tools to monitor surface parameters and solar radiation;
- *Crop models.* Know the principles of dynamic simulation models, their application and adaptation; calibrate and use crop-weather models and empirical statistical models for phenology and yield forecasting;
- *Agricultural advice and products.* Prepare specific agricultural meteorology outlooks; provide specialized agricultural meteorology products and tailored services; assist the agricultural industry to produce commodities economically and to reduce risk; maintain close contact with end users with a view to keeping them informed of services which meteorologists can provide;
- *Strategic planning.* Promote strategic applications to assist sustainable agricultural planning; carry out assessments of agricultural-climatic resources on various scales; identify strategies for adapting to (possible) climatic change.

An example of actual competency requirements is given in section 7.5.

Aeronautical meteorology

The mission under this branch consists of the study, analysis and forecasting of the influence of the atmosphere – particularly that of hazardous weather

phenomena – on the operation of aircraft. Effects considered include: low visibility and low cloud at aerodromes; wind shear; turbulence (including clear-air turbulence); icing; thunderstorms; tropical cyclones; upper winds and temperatures; jet streams and tropopause, and volcanic ash. Typical individual jobs include aeronautical meteorologist; aeronautical meteorological technician. Operational duties and competency requirements include:

- *Weather phenomena.* Understand the weather phenomena hazardous to aviation, and their analysis and forecasting; understand which meteorological parameters are crucial for the safety and regular operations of aviation user groups;
- *Meteorological codes.* Know all aeronautical meteorological codes, and all criteria applied for warnings and change groups in TAF and TREND forecasts; follow the standard regulations contained in WMO Technical Regulations; know the ICAO (International Civil Aviation Organization) cost recovery principles and guidance; cooperate operationally with Air Traffic Services (ATS) units;
- *International Organizations.* Understand the functioning and use of products from the World Area Forecast System (WAFS); understand the functioning of International Airways Volcano Watch (IAVW) and the advisory service provided by Volcanic Ash Advisory Centres (VAACs);
- *Weather monitoring.* Perform continuing monitoring of weather phenomena relevant to aviation, and understand the evolution of the weather phenomena observed at the aerodrome; carry out the required observations and measurements;
- *Weather forecasting.* Know and apply standard methods, techniques, and other numerical tools for forecasting low clouds, winds (including gusts), fog and reduced visibility, thunderstorms, heavy precipitation, hail and tropical cyclones; know and apply customary algorithms and methods of forecasting icing, mountain waves and turbulence (including clear-air turbulence);
- *Satellite and radar interpretation.* Know how to interpret satellite and radar imagery, including analysis of the evolution of convective systems, frontal systems and tropical cyclones, location of fog/stratus, active cumulonimbus-tops, gravity waves in cirrus cloud and jet streams; detection of icing potential in layer cloud, volcanic ash and wind-shear;
- *Local forecasters responsibilities.* Perform competently the 'local' forecaster's responsibilities, including the issuance of aerodrome warnings, SIGMET and AIRMET messages;
- *Special air-reports.* Be able to identify from special air-reports the relevant weather phenomena; assess those reports and, if appropriate, issue the corresponding SIGMET message.

Examples of actual competency requirements in the field of aeronautical meteorology are given in section 7.6.

Marine meteorology

The mission under this branch is to make available to marine users at sea or on the coast the marine meteorological and related oceanographic information they require, with the aim of maximizing the safety of marine operations and promoting the efficiency and economy of marine activities. To contribute towards the efficient exploration and optimize exploitation of coastal and marine resources (living and non-living) and protection of the marine environment. Concerned services may be specialized for the high seas, for the coastal and offshore areas and for ports and harbours. Typical individual jobs include marine observers on board ships, seafarers whilst at sea and in navigation schools, Port Meteorological Officers (PMO), and meteorological personnel who are engaged in observational, forecasting and climatological duties for marine purposes. Operational duties and competency requirements include:

- *Weather phenomena.* Understand the weather phenomena hazardous to marine operations; know the criteria for storm, and other warnings;

- *Observations.* Carry out surface meteorological observations and measurements; make upper-air measurements and sub-surface ocean measurements; know the relevant meteorological and oceanographic codes (e.g. SYNOP, SHIP, DRIBU, BATHY, TESAC); be aware of PMO activities, voluntary observing ships and ships of opportunity;
- *Remote sensing.* Know how to interpret remote sensing data from satellites and drifting and moored buoys; to derive characteristics of water masses, the behaviour of waves and ocean currents, and the state of the weather;
- *Marine climatology.* Prepare marine climatology summaries; provide climatic data required by the designers and operators of offshore exploration and exploitation facilities;
- *Forecasting.* Know meteorological forecasting techniques based on empirical, statistical, analogue and dynamical methods; know how and where to obtain marine products and forecast which are available from regional numerical models such as waves, sea-level topography, surface and sub-surface temperature, thermocline; issue warnings of strong winds, rough seas, poor visibility, heavy precipitation, ice accretion, storm surges, harbour tsunamis and abnormal seiches;
- *Provision of forecasting services and expert advice.* Provide services for high seas circumstances (e.g. search and rescue operations, weather routing, fishing industry); provide services for coastal and offshore areas; provide services for ports and harbours (e.g. cargo handling, industrial projects, commercial activities, litigation and insurance, icebreaking, waterborne recreational activities, operations to combat marine pollution). Be familiar with marine pollution dispersion models.

An example of actual competency requirements is given in section 7.7.

Environmental meteorology

The mission under this branch consists of the utilization of meteorological (weather, climate and air quality) information and related scientific findings, to environmental concerns such as air or water pollution, climate change, ozone depletion, or harmful solar radiation, in a manner intended to optimize the use of natural resources and strengthen human health and security. Environmental meteorology is also concerned with various processes in the atmosphere and the interrelation of the atmosphere with the solid and liquid phases of the Earth, with natural ecosystems and outer space. Typical individual jobs include environmental-, forensic-, urban- or bio-meteorologist. Operational duties and competency requirements include:

- *Weather and climate impacts.* Understand the impact, range, and potential of the weather and climate effects on life, society and environment in general; understand the effects of land use and other anthropogenic influences on weather and climate;
- *Methods and techniques.* Know and understand the principles, methods and techniques used in atmospheric physics and chemistry and their use in air-quality protection, urban design and construction; environmental problems in large cities; comprehend the general principles, methods and techniques used in other geo-sciences; have an inter-disciplinary approach to ‘assembling of knowledge’;
- *Satellite data.* Use satellite-based data to monitor the effect and distribution of flooding, fire location, smoke plumes, dust, ozone and volcanic ash clouds;
- *Policy and planning advice.* Assist in the development of policy planning and decisions on environmental issues; provide expert advice in policy- and decision-making on various operational problems in which users/customers attempt to optimally utilize (or limit) the influence of meteorological factors;
- *Forensic meteorology.* Provide meteorological information and advice for legal cases (e.g. determining the sequence of weather- and climate-affected events that is subject to litigation);
- *Environmental policies.* Be aware of the major environmental policies on scientific, technical and economic development; and on public health and

tourism; facilitate application of integrated approaches to sustainable development, management and rational use of environmental resources.

Job-competency requirements for environmental meteorologist are exemplified under section 7.8.

Meteorology-support branches

The personnel employed in the meteorology-support branches may not always be required to have a basic meteorological qualification (e.g. those working in branches for management or client relations), or may be required to possess much more than a basic meteorological qualification (e.g. those working in education or research branches). However, certain general meteorology knowledge would still be desirable even in the branches for management or client relations.

Management and administration

The mission under this branch consists of supervizing, guiding and directing in order to maximize the use of available human, technical and financial resources; representing one's NMS in national and international arenas. Typical individual jobs include operational manager and network inspector. Operational duties and competency requirements include:

- *Principles of management.* Know and understand the principles of management and administration as applied to a scientific and technical institution (e.g. NMS);
- *Managing performance.* Know the organization of the operational activities to be undertaken; set and prioritize objectives; monitor performance against planned activities; anticipate problems and develop contingency plans; make effective decisions, and consider alternative solutions;
- *Management of resources.* Manage human and financial resources effectively; manage change proactively; manage time; enable staff to develop expertise, plan careers and improve their performance continuously;
- *Team working.* Participate positively in team activities; develop collaborative relationships with both internal and external customers; understand their needs;
- *Leadership.* Provide leadership; choose appropriate communication methods and communicate effectively; be able to motivate others; show sensitivity to the needs of others and obtain their commitment; respond positively to innovation;
- *Weather and climate.* Be aware of region-specific weather phenomena and regional climatology.

The role of managers and administrators in planning and implementing continuing professional development programmes for NMS staff is essential, see sections 5.1 and 5.5.

Education and training

The mission under this branch consists of undertaking and facilitating training and development of personnel, to perform current and future jobs; educating users (general public included) in the use of meteorological products and services. Typical individual jobs include meteorological trainer; instructor; scientist; professor. Operational duties and competency requirements include:

- *Training requirements.* Identify organizational training and development requirements; identify learning requirements of individuals; plan and design training strategies for NMS;
- *Designing training.* Design training and development programmes, as well as teaching and learning materials;
- *Delivering training.* Manage the implementation of training and development programmes; understand and use new pedagogical approaches to education and training, including modern presentation tools; facilitate learning with individuals and groups;
- *Evaluating training.* Review the progress and effectiveness of training; assess achievement, including individual competency achievement;
- *Meteorological knowledge.* Know and understand the region-specific weather phenomena; continuously improve knowledge of ESS.

Note that Chapter 5 deal specifically with methods and strategies for continuing education and training in NMS.

Research and development

The mission under this branch consists of undertaking applied research and development to ensure continuing enhancement of the future operations and services; developing new ideas in meteorological science or technology. Typical individual jobs include meteorological researcher; applied scientist; system development meteorologist. Operational duties and competency requirements include:

- *Professional specialization.* Understand his/her own speciality at the in-depth level of a national expert or consultant; demonstrate skills in lifelong learning; application of scientific method; investigation; experimental inquiry; invention; and information searching; identification; and selection;
- *Computer knowledge.* Know, understand and use a range of software packages, basic skills in computer programming in different computer architectures;
- *Application of research and development.* Assimilate research results into the operational environment; possibly develop new products, procedures and techniques; also perform investigations into problems and applications relating to the atmosphere in the earth system context;
- *Creativity and problem solving.* Demonstrate critical and independent thinking; recognize and encourage creativity, innovative analysis and problem solving in others; demonstrate a high degree of innovation in the analysis of problems, and use science and technology intelligently to solve those problems;
- *Weather and climate.* Know and understand weather and climate, from locally-induced weather phenomena to global climate patterns;
- *Education, training and teaching.* Help, as appropriate in the implementation of continuing education and training programmes.

Economic meteorology and client relations

The mission under this branch consists of planning, promoting and selling of meteorological data, information and other products; tailoring services to support end-users' current activities and strategic planning decisions. Typical individual jobs include economic meteorologist; meteorological marketer; client services officer. Operational duties and competency requirements include:

- *Marketing.* Know and understand the basics of marketing methods, techniques and procedures; know a range of alternative promotional strategies; be familiar with standard market research software packages and databases in current use;
- *Economic benefits.* Understand how the weather market system works; understand the use of decision models; behavioural studies and the contingent valuation technique to estimate economic benefits;
- *Contractual regulations.* Understand the contractual regulations and procedures of NMSs; be aware of legal implications (for NMS) in case of failure to follow the process;
- *Innovation.* Demonstrate entrepreneurial outlook and innovation in the analysis of problems and use of techniques in solving them; apply marketing principles and utilize appropriate instruments;
- *Management of resources.* Develop and manage projects and execute financial and resource accounting;
- *Communications skills.* Demonstrate skills in personal relations, particularly in communication and presentation; ability to handle complaints;
- *Customer needs.* Understand a range of customer needs and constraints so as to relate and present their needs;
- *Weather phenomena.* Be aware of the general meteorology concepts and main region-specific weather phenomena.

2.3

ACADEMIC
SPECIALITIES AND
JOB-SPECIALIZATIONS –
THE GAP

In the context of scientific and technological advancements within and across atmospheric sciences there is a multitude of fields of specialization, which may be looked upon with a different focus; e.g. by putting more emphasis on the scientific development or on the practical application aspects.

Accordingly, a distinction may be made between the job-specialized personnel and the specialists – individuals, who, through study and experience, develop in-depth knowledge or skills in a given speciality. A specialist not only knows and understands a particular subject or a particular topic of a subject, but he also develops that subject or topic. This is not necessarily the case for the usual job-specialization, where personnel are required essentially to appropriately apply conventional knowledge from a given speciality. For example, a weather forecaster does not need to know NWP parameterizations at the specialist level, but he must know how to interpret and use moisture forecasts from operational models.

Furthermore, while some fields of specialization are ‘meteorological’ in their essence (e.g. NWP, or cloud and precipitation), other specialities may ‘borrow’ knowledge from non-meteorological disciplines. For instance, the syllabus for urban climatology may include not only meteorological subjects (e.g. atmospheric chemistry or boundary layer), but also topics on urban design, transport, building construction, architecture, etc.

The important issue is the gap that exists between academic specialities as described in conventional textbooks, and the job-specializations as required in meteorological practice. Accordingly, when designing job-specialized training, it is necessary to assemble specific packages of relevant topics taken from more than one conventional discipline. Then, the syllabi and the in-depth level of treatment of the various topics would have to be determined by the local instructor according to the job-competency requirements specifically targeted for his trainees.

Although no effective ‘external’ guidance can be provided on these specific matters, the interested reader may utilize the above-described operational duties and job-competencies as a background requirement when designing core curricula for the underlying knowledge and skills expected of meteorological personnel (see sections 3.3 and 3.4 of next chapter for further information).

CHAPTER 3

BASIC INSTRUCTION PACKAGE FOR METEOROLOGISTS (BIP-M)

Requisite topics in mathematics and physical sciences

Compulsory topics in atmospheric sciences

Elective fields of specialization in meteorology

Other fields of specialization

Beyond the BIP-M

Syllabus example for dynamic meteorology

This chapter describes the Basic Instruction Package for Meteorologists (BIP-M) in terms of a framework curriculum – a listing of major topics which as an ensemble provide the necessary foundation for entry into the profession, as well as the basis for future professional development. It is emphasized that this listing of topics (items *(a)*, *(b)*, *(c)*, etc. under each discipline) is neither a ‘curriculum’ nor a listing of ‘courses’. Rather, starting from the recommended BIP-M topics, a curriculum proper should be developed locally by faculty members with expertise in relevant disciplines, with due regard to the available resources and the interests of the stakeholders, e.g. the NMS. The actual curriculum would specify the effective subject matter to be taught for each core topic *(a)*, *(b)*, *(c)*, etc., of the relevant discipline.

As indicated in paragraph 1.1.3, detailed syllabus examples for each discipline are provided in a companion departmental publication; one such detailed syllabus, for the particular case of dynamic meteorology, is illustrated in the Annex to this chapter.

The in-depth level of instruction and the breadth of coverage of the BIP-M topics should be similar to that used in physical sciences, applied mathematics or engineering faculties. Several topics require not only classroom instruction, but also hands-on experience in dedicated laboratories and practical experience in the field.

- 3.1 **REQUISITE TOPICS IN MATHEMATICS AND PHYSICAL SCIENCES** The first three sub-sections concern pre-/co-requisite basic science topics that are essential for any in-depth study of meteorological subjects. The last sub-section concerns complementary topics in oral and written communication including possible use of a foreign language; it is noted, however that these topics are usually included in the general university requirements for completing a Bachelor's Degree.
- Mathematics (a) Linear algebra and vector calculus;
(b) Differential and integral calculus;
(c) Ordinary and partial differential equations;
(d) Probability theory and statistics;
(e) Information and communication technology;
(f) Numerical methods.
- Physics (a) Fundamentals of mechanics;
(b) Basic thermodynamics;
(c) Wave theory;
(d) Fluid motion;
(e) Turbulence in fluids;
(f) Basics of electromagnetic radiation; electromagnetism.
- Chemistry (a) Basic physical chemistry;
(b) Chemical thermodynamics;
(c) Aqueous solutions;
(d) Introductory photochemistry.
- Complementary requirements (a) Communication and presentation techniques;
(b) International communication languages (e.g. WMO official languages).
- 3.2 **COMPULSORY TOPICS IN ATMOSPHERIC SCIENCES** Completion of the physical meteorology and dynamic meteorology topics from this section is mandatory for any BIP-M programme, as these provide the meteorological foundation knowledge and understanding required for more specific developments under the three major degree-streams: Weather, Climate and Environment.
- For the required topics in synoptic meteorology, climatology and in atmospheric chemistry, certain flexibility may be considered, in function of the envisaged stream:
- Under the 'Weather' stream, more emphasis will be given to synoptic meteorology, particularly mesoscale weather forecasting and less emphasis on climatology;
 - Under the 'Climate' stream, more emphasis will be given to climatology, particularly seasonal forecasting, and less emphasis on synoptic meteorology;
 - Under the 'Environment' stream, more emphasis will be given to atmospheric chemistry, boundary layer processes and soil-vegetation-atmosphere interactions, and less emphasis on synoptic meteorology and climatology.
- It is recalled that the requirements for physical and dynamic meteorology under the 'Environment' stream remain essentially the same as for the 'Weather' and 'Climate' streams.
- Physical meteorology (a) Radiation in the atmosphere;
(b) Atmospheric acoustics, optics and electricity;
(c) The global energy balance;
(d) Cloud and precipitation; water cycle;
(e) Atmospheric thermodynamics;
(f) Boundary layer and turbulence; micrometeorology;
(g) Satellite systems;
(h) Weather radar;
(i) Introduction to atmospheric chemistry; urban pollution;
(j) Laboratory work and practical exercises.

- Dynamic meteorology
- (a) Basic fluid dynamics;
 - (b) The hydrostatic and geostrophic approximation;
 - (c) The vorticity and the thermodynamic energy equations;
 - (d) Quasi-geostrophic motion;
 - (e) Atmospheric waves; baroclinic and barotropic instability;
 - (f) General circulation energetics;
 - (g) Stratospheric dynamics; physics and chemistry;
 - (h) Numerical weather prediction;
 - (i) Laboratory work and practical exercises.
- Synoptic meteorology
- (a) Overview of meteorological observations and measurements;
 - (b) Relationships between wind, pressure, and temperature fields;
 - (c) Mid-latitude synoptic systems;
 - (d) Cyclogenesis and frontogenesis;
 - (e) Tropical weather systems;
 - (f) Mesoscale atmospheric circulations;
 - (g) Near real time monitoring of weather, nowcasting;
 - (h) Weather forecasting;
 - (i) Laboratory work and practical exercises.
- Climatology
- (a) Introduction to earth system science;
 - (b) Climatic data;
 - (c) Descriptive climatology; statistics and probability theory;
 - (d) Climate classification;
 - (e) The physics and chemistry of the climate system;
 - (f) Climate dynamics;
 - (g) Climate change;
 - (h) Climatology and seasons of the country;
 - (i) Laboratory work and practical exercises.

3.3 ELECTIVE FIELDS OF SPECIALIZATION IN METEOROLOGY

In principle, the items in the fields of specialization described in this section may be considered as going beyond the normal requirements for a complete BIP-M (i.e. B.Sc. programme in meteorology). Some senior undergraduate students may wish, however, to deepen their basic professional education by an early specialization, which would more readily prepare them for specific jobs. Under a condensed BIP-M (i.e. postgraduate Diploma or Master's degree programme in meteorology), the compulsory topics from the previous section would be covered in a much shorter time period than in the case of the complete BIP-M. In turn, the thorough study of a particular meteorological specialization is essential for students attending any condensed BIP-M.

Thus, the depth and breadth in studying any field of specialization may be different under the complete or the condensed BIP-M. In this sense, the presentations from this section are neither prescriptive nor comprehensive and the educational institutions have full freedom to adapt the suggested framework curricula to their own expressed needs so that they can for instance, be consistent with the mission and basic requirements of the supporting NMS, or according to specific job requirements. Furthermore, relevant educational institutions are encouraged to explore the actual world of work and to assess job prospects not only within NMS, but also in relation with broader meteorological, hydrological, oceanographic and many other environmental professions from the public and private sector. Accordingly, these institutions should provide suitable opportunities for early professional specialization in 'hot' subjects as required by the actual job market in meteorology and related environmental domains.

It should be stressed that completing the basic science and meteorological disciplines' topics mentioned in sections 3.1 and 3.2 constitute the essential prerequisite requirements for any field of specialization from this (and next) section.

- Aeronautical meteorology
- (a) Aircraft Icing;
 - (b) Turbulence;
 - (c) Other hazardous phenomena;
 - (d) Meteorological aspects of flight planning;
 - (e) Definitions;
 - (f) Procedures for meteorological services for international air navigation;
 - (g) Air traffic services;
 - (h) Aerodromes;
 - (i) Operation of aircraft;
 - (j) Aeronautical information services;
 - (k) Aeronautical telecommunications;
 - (l) WMO documentation;
 - (m) ICAO documentation.
- Agricultural meteorology
- (a) Plant physiology;
 - (b) Bio-meteorological interrelationships;
 - (c) Surface energy balance;
 - (d) Water balance;
 - (e) Observations and measurements; data processing;
 - (f) Operational forecasts;
 - (g) Assistance for planning;
 - (h) Preventing the impact of adverse weather conditions.
- Atmospheric chemistry
- (a) Evolution of the atmosphere; chemical composition and vertical structure;
 - (b) Attenuation of solar radiation by atmospheric gases and aerosols;
 - (c) Absorption and emission of long-wave terrestrial radiation;
 - (d) Chemicals in the troposphere;
 - (e) Atmospheric aerosols;
 - (f) Cloud and precipitation chemistry;
 - (g) Tropospheric chemical cycles;
 - (h) Stratospheric chemistry;
 - (i) Air quality and human health.
- Climate monitoring and prediction
- (a) The climate system;
 - (b) Climate monitoring; networks; principles;
 - (c) General circulation of the atmosphere;
 - (d) Air-sea interaction; hydrological cycle and the impact of land characteristics;
 - (e) Sources of climate predictability;
 - (f) Statistical forecasting methods;
 - (g) Dynamical forecasting methods;
 - (h) Climate change and human affairs;
 - (i) Uncertainties of the current climate projections;
 - (j) Seasonal forecasting.
- Mesoscale meteorology and weather forecasting
- (a) Overview of mesoscale and the role of forecaster;
 - (b) Mesoscale features of mid-latitude cyclones;
 - (c) 'Non-convective' mesoscale circulations and phenomena;
 - (d) Convective mesoscale circulations and phenomena;
 - (e) Cloud and precipitation in operational numerical models;
 - (f) Operational NWP suite;
 - (g) Weather monitoring; nowcasting;
 - (h) Forecasting specific weather phenomena; public weather services;
 - (i) Large-scale and medium range forecasts;
 - (j) Statement and verification of forecasts.
- Radar meteorology
- (a) The principles of weather radar;
 - (b) Weather signals;
 - (c) Doppler spectra of weather signals;
 - (d) Weather signal processing;

- (e) Weather observation;
 - (f) Precipitation measurements;
 - (g) Observation of winds, storms and related phenomena;
 - (h) Observation of fair weather;
 - (i) Applications; examples of displays and products.
- Satellite meteorology
- (a) Evolution of satellite meteorology;
 - (b) Nature of radiation;
 - (c) Absorption, emission, reflection and scattering;
 - (d) Radiation budget;
 - (e) The radiative transfer equation;
 - (f) Surface temperature;
 - (g) Detecting clouds;
 - (h) Techniques for determining atmospheric parameters;
 - (i) Techniques for determining atmospheric motions;
 - (j) Satellite orbits.
- Tropical weather and climate
- (a) Tropical weather overview;
 - (b) Large-scale circulation;
 - (c) Synoptic-scale circulations;
 - (d) Monsoon meteorology;
 - (e) The ENSO;
 - (f) Convection and mesoscale convective systems;
 - (g) Tropical cyclones.
- Urban meteorology and air pollution
- (a) Overview of urban atmosphere;
 - (b) Monitoring urban weather and climate;
 - (c) Thermal radiation;
 - (d) Atmospheric boundary layer; application of basic concepts;
 - (e) Buoyant plumes; dispersion of air pollutants;
 - (f) Application concepts in boundary layer meteorology;
 - (g) Urban pollution forecasts;
 - (h) Health effects of pollutants.
- 3.4 OTHER FIELDS OF SPECIALIZATION
- In addition to the above-mentioned truly ‘meteorological’ fields of specialization there are other meteorology-related fields such as biometeorology, hydrometeorology, marine meteorology, advanced remote sensing, as well as numerical methods for mathematical modelling in atmospheric sciences or economic meteorology and management. Framework curricula for these cross-disciplinary specializations, particularly for postgraduate Meteorologists, will be briefly presented in this section.
- Biometeorology and human health
- (a) Human bio-meteorology scope;
 - (b) Biophysical adaptation; the body-environment energy budget;
 - (c) Biophysical adaptation; clothing and housing;
 - (d) Epidemiology and environmental human physiology;
 - (e) Climatic comfort; windchill and heat discomfort;
 - (f) Monitoring bio-climatic resources.
- Boundary layer meteorology
- (a) Physics of the boundary layer;
 - (b) Atmospheric turbulence;
 - (c) Parameterizations of the planetary boundary layer;
 - (d) Bulk transport of pollutants;
 - (e) Transport modelling by primitive equations models.
- Clouds and precipitation; weather modification
- (a) Atmospheric aerosols;
 - (b) Formation of clouds;
 - (c) Precipitation process;
 - (d) Cumulonimbus convection;
 - (e) Hail suppression;

- (f) Fog-clearing; precipitation management;
 - (g) Technology of weather modification.
- Economic meteorology; marketing and management
- (a) Meteorological information; products and services;
 - (b) Users and beneficiaries of meteorological information;
 - (c) Introductory econometric statistics;
 - (d) Verification of forecasts; conceptual framework;
 - (e) Verification methods;
 - (f) Estimation of economic benefits using decision models;
 - (g) Basis of standard cost-loss models; the economic value of forecasts;
 - (h) Extension of the standard cost-loss model; applications of decision models;
 - (i) Techniques for the estimation of economic benefits;
 - (j) Marketing meteorological products and services.
- General hydrology and hydrometeorology
- (a) Development of hydrology;
 - (b) Precipitation;
 - (c) Evaporation and evapotranspiration;
 - (d) Ground water resources;
 - (e) Surface water resources;
 - (f) Water balance;
 - (g) The hydrological cycle; hydrometeorology.
- General oceanography and marine meteorology
- (a) Physical oceanography overview;
 - (b) Introduction to ocean dynamics;
 - (c) Wind-driven currents; turbulence transfer; thermohaline circulation;
 - (d) Surface waves; oscillations of air-sea interface;
 - (e) Tides;
 - (f) The heat budget of the ocean;
 - (g) Air-sea interaction;
 - (h) Measurement platforms and instruments;
 - (i) Meteorological applications.
- Middle-upper atmosphere
- (a) Upper atmosphere sub-regions;
 - (b) The Sun's radiation in the upper atmosphere; space 'weather';
 - (c) Chemistry of the upper atmosphere; stratospheric ozone;
 - (d) Radiative transfer;
 - (e) Atmospheric tides; geomagnetic phenomena; the ionosphere;
 - (f) The dynamics of the stratosphere and mesosphere.
- Numerical methods for mathematical modelling
- (a) Basic finite-difference methods;
 - (b) Systems of equations;
 - (c) Spectral and other methods;
 - (d) Semi-Lagrangian methods;
 - (e) Boundary conditions.

3.5 BEYOND THE BIP-M Completion of the BIP-M is only the first step in the professional development of individuals pursuing a career in meteorology. Routine updates and refresher training will subsequently be required in order to keep in touch with the continual development of the atmospheric sciences and the rapid advances in technology.

Career progression to mid- and senior-level positions requires demonstrated practical experience and additional specialized instruction that extends the scientific knowledge and understanding provided by the BIP-M. Some senior-level positions, for example in research and development normally require formal post-graduate study in meteorology or a related field. Other positions, especially those in mid- and senior-level management, may require advanced degrees in business, economics or marketing, complemented by a technical background in meteorology.

However, in addition to formal and informal education, career progression requires an individual to continually demonstrate increasing technical competency on the job, as well as show indications of leadership, willingness and ability to acquire skills outside of meteorology, evidence of managerial skills, and the desire to take on more responsibility.

ANNEX

EXAMPLE OF A SYLLABUS FOR DYNAMIC METEOROLOGY

<i>Basic fluid dynamics</i>	Scalar and vector fields; Gauss and Stokes theorems; kinematics of flow fields; material derivative; Eulerian and Lagrangean rates of change; conservation of mass, momentum and energy. Navier-Stokes equations. Rotating frames of reference; equations of motion in coordinate form: spherical coordinates; preliminary approximations to the equations in spherical coordinate form; Coriolis parameter; tangent-plane geometry; f - and β -plane approximations.
<i>The hydrostatic and geostrophic approximation</i>	Scale analysis for the mid-latitude large-scale weather systems. Rossby number; hydrostatic and geostrophic balance; inertial flow; cyclostrophic flow; gradient flow and the gradient-wind balance for a steady circular vortex. Vertical shear of the geostrophic wind; thermal wind; pressure coordinates and geopotential height.
<i>The vorticity and the thermodynamic energy equations</i>	Bjerknes' circulation theorem; stream function and velocity potential; Helmholtz theorem; trajectories and streamlines; natural coordinates. Vorticity and vorticity equation; relation between absolute vorticity and relative vorticity; principal mechanisms for vorticity generation and change. First law of thermodynamics, meteorological formulation; diabatic forcing in the lower and middle atmosphere; adiabatic motion: potential temperature conservation.
<i>Quasi-geostrophic motion</i>	Boussinesq approximation; Brunt-Väisälä (buoyancy) frequency; Taylor-Proudman theorem; quasi-geostrophic approximation. Geopotential tendency equation. Omega equation; vertical motion; cancellation between the forcing terms; alternative interpretation; Q-vectors diagnosis of vertical motion. Conservation of quasi-geostrophic potential vorticity for frictionless and adiabatic flow. General potential vorticity equation of Ertel-Rossby; anomalies of potential vorticity in the cyclogenesis process; role of diabatic heating as a source/sink of potential vorticity; non-linear interactions; initial value approach, invertibility principle; use of the gradient-wind equation as balance condition to find the wind and mass field from the potential vorticity distribution.
<i>Atmospheric waves; baroclinic and barotropic instability</i>	Quasi-linear behaviour of atmospheric motions; small perturbation theory; classical wave equation; dispersion relations; phase and group velocity. Simple wave types: acoustic and sound waves; shallow water gravity waves; internal gravity (buoyancy) waves; inertial gravity waves, inertial oscillations. Barotropic (Rossby) waves; westward propagation; beta effect; strong dispersion. Baroclinic instability; Eady and Charney models; stabilizing influence of the beta effect on the long waves and of the static stability on short waves. Barotropic instability; Rayleigh-Kuo criterion for a basic zonal current with horizontal meridional shear; stable and unstable distribution of the absolute vorticity field.
<i>General circulation energetics</i>	Kinetic, potential and internal energy; relationship between potential and internal energy in quasi-static flow; available potential energy; conservation theorems. Energy equations for an atmosphere confined to a zonal channel on an f -plane, with rigid lateral walls. Conversion of available potential energy to kinetic energy; generation of available potential energy. Treatment of the available potential energy and kinetic energy in their zonal and eddy forms, and their interaction. Momentum budget; dynamics of zonally symmetric circulations. Selective role of various scales of atmospheric motions; the generation, conversion and transfer of energy as a function of wave number. Introduction to weather and climate predictability; non-linearity, complexity, chaos, and strange attractors.
<i>Stratospheric dynamics; physics and chemistry</i>	Dynamic interactions between the stratosphere and troposphere, ultra-long quasi-stationary planetary scale waves; vertically propagating planetary waves.

Energetics of the lower stratosphere; sudden stratospheric warming; waves in the equatorial stratosphere; Kelvin waves and mixed Rossby-gravity waves; quasi-biennial oscillation; ozone layer; stratospheric heat balance. Transport of chemicals; Brewer-Dobson troposphere-stratosphere circulation (equator-poles), and the solstitial stratosphere-mesosphere circulation (summer-winter poles). Antarctic 'polar stratospheric clouds'; photolysis of man-made chlorofluorocarbons (CFCs) from ultra-violet radiation; blend of chemical, dynamic and transport processes leading to the stratospheric ozone hole(s).

*Numerical Weather Prediction
(NWP)*

Finite differences and truncation errors, accuracy, consistency, stability, convergence, time and space differencing. Numerical solution of Laplace, Poisson and Helmholtz equations by iterative methods; relaxation techniques. Introduction to spectral methods, spherical harmonics, transform method, semi-Lagrangian approach. Primitive equation models: model variables; inclusion of moisture and radiation effects; boundary and initial conditions. Objective analysis and data assimilation; optimum interpolation method, variational methods; dynamic initialization, non-linear normal mode initialization; 4-D data assimilation. Current operational models: global, regional, and local models; model equations; coordinate systems and numerical formulation; parameterization of physical processes. Ensemble forecasts; unpredictable internal variations. Application of model products to the prediction of routine parameters and specific events; shortcomings and sources of error in the models; role of the human forecaster.

*Suggestions for laboratory
work and practical exercises*

Physical demonstration of dynamical concepts: Bernoulli's theorem, vorticity, Reynolds, Rossby, Richardson and Burger numbers. Waves and turbulence. Density currents, convective thermals and plumes, cellular convection in a stable layer of fluid, spin-up of a rotating fluid, baroclinic waves in a heated rotating annulus, surface gravity waves and barotropic Rossby waves. Information and communication technology and data processing systems; computer architecture, visualization, and networking; programming techniques and languages. Numerical methods, round-off errors, finite difference formulas, trapezoidal rule for integration, tridiagonal linear systems; 1-D diffusion and 1-D advection equation. Quasi-geostrophic potential vorticity conservation, quasi-geostrophic omega equation, Q-vectors approach to vertical motion field, baroclinic instability and Eady model. Numerical solution of the barotropic vorticity equation. Eulerian, Lagrangean and spectral methods, vector and parallel processing; application in data assimilation, NWP; and other computer simulations.

CHAPTER 4

BASIC INSTRUCTION PACKAGE FOR METEOROLOGICAL TECHNICIANS (BIP-MT)

Requisite topics in basic sciences

Compulsory topics in general meteorology

Elective options in operational meteorology

Beyond the BIP-MT

Syllabus example for aeronautical meteorology – technician level

Meteorological Technicians may perform a wide variety of tasks, these include making and transmitting of weather and climate observations and measurements; performing routine maintenance of observing equipment; assisting a Meteorologist in preparing analyses and forecasts; responding to routine queries for information from customers, etc. Usually, NMSs also use ‘technologists’ to install, maintain and upgrade sophisticated observing systems as well as information and communication technology equipment; however, their initial qualifications would be different from that of a Meteorological Technician.

This chapter describes the Basic Instruction Package for Meteorological Technicians (BIP-MT). It lists the core topics (items *(a)*, *(b)*, *(c)*, under each discipline) required to acquire the knowledge and skills necessary for the job at an entry-level. Detailed syllabus examples for the core topics under each discipline are presented in a departmental publication accompanying this volume. An example of a detailed syllabus on aeronautical meteorology is reiterated in an Annex to this chapter.

The level of instruction and depth of coverage of the topics in the BIP-MT should be equivalent to that used in post-secondary or technical schools preparing individuals for careers such as electronic, mechanical or chemistry technicians. Many of the topics will require both classroom instruction and hands-on experience in the laboratory and/or practical experience in the field.

- 4.1 **REQUISITE TOPICS IN BASIC SCIENCES** An individual entering the BIP-MT programme should have completed general, elementary or compulsory school, and should possess a background in mathematics and physical sciences that includes elementary algebra, simple plane geometry and trigonometry, as well as introductory physics and chemistry. If the acquired education does not provide this background, the individual should undertake the necessary preparatory work prior to the beginning of the BIP-MT programme.
- This section outlines the requisite topics in mathematics, physical sciences and computer operation that are necessary to develop the general knowledge base and skills expected of any meteorological technician. Completion of those topics is also essential in enabling the proper acquisition of the meteorological instruction and on-the-job training envisaged under the BIP-MT proper.
- Mathematics (a) Review of elementary algebra, geometry and trigonometry;
(b) Introductory differential and integral calculus;
(c) Elementary statistics;
(d) Introduction to information technology.
- Physics (a) Basic mechanics;
(b) Nature of fluids; heat;
(c) Acoustics and optics;
(d) Electricity and magnetism.
- Chemistry (a) Basic chemical concepts;
(b) Elements of bio- and geo-chemistry.
- Communication skills (a) Expression and communication skills: Course work and practical activities to develop oral and written presentation and communication skills.
- 4.2 **COMPULSORY TOPICS IN GENERAL METEOROLOGY** The topics described under this section provide an overview of meteorology as a whole, together with an introduction to basic observation and measurement methods and instruments. These topics, mandatory for any BIP-MT programme, are aimed to enable trainees for satisfactory performance at the job-entry level.
- Introductory physical and dynamical meteorology (a) The Sun, Earth and electromagnetic radiation;
(b) Introductory atmospheric thermodynamics;
(c) Atmospheric moisture; condensation process;
(d) Atmospheric motion; geostrophic flow;
(e) Elements of atmospheric optics and electricity.
- Elements of synoptic meteorology and climatology (a) Observing the Earth's atmosphere and oceans;
(b) Information technology; operational data processing;
(c) Air-masses; cyclones and anticyclones;
(d) Introduction to synoptic analysis method;
(e) General climatology; routine applications;
(f) Climatological measurements;
(g) Organization of meteorology.
- Meteorological instruments and methods of observation (a) Overview of meteorological observation and instrumentation;
(b) Making an observation;
(c) Quality control, coding, and transmission of observations;
(d) Operating, and maintaining instruments;
(e) Automatic observing stations.
- 4.3 **ELECTIVE OPTIONS IN OPERATIONAL METEOROLOGY** The options listed below concern foundation knowledge for the job-entry-level specialization. Each trainee will elect one option, which then becomes mandatory for that trainee. It is understood that the class lectures will be accompanied/ followed by extensive laboratory/field practice supervised by instructors with expertise in relevant disciplines and with due regard to the trainee's future job requirements.

- Synoptic observations and measurements
- (a) Surface temperature; pressure; humidity; wind;
 - (b) Precipitation; evaporation; visibility; clouds; fog;
 - (c) Sunshine and radiation;
 - (d) Hydro-, litho-, photo-, electro-meteors; past and present weather;
 - (e) Upper-air observations.
- Other specialized observations and measurements
- (a) Marine observations and measurements;
 - (b) Agrometeorological and biological observations;
 - (c) Atmospheric chemistry measurements.
- Remote sounding of the atmosphere
- (a) Meteorological satellites;
 - (b) Weather radar;
 - (c) Lidar and sodar;
 - (d) Ozone spectrophotometer;
 - (e) Special soundings; meteorological rockets.
- Aeronautical meteorology for technicians
- (a) Observing techniques;
 - (b) Hazardous phenomena;
 - (c) Meteorological aspects of flight planning;
 - (d) Reporting, coding and dissemination of weather information;
 - (e) Definitions;
 - (f) Procedures for meteorological services for international aviation;
 - (g) Air traffic services;
 - (h) Operation of aircraft;
 - (i) Aeronautical telecommunications;
 - (j) WMO documents;
 - (k) ICAO documents.

4.4

BEYOND THE
BIP-MT

The BIP-MT provides the foundation necessary for entry into a technical career in meteorology. Individuals pursuing this career development will require periodic updates and refresher training and/or additional specialized formal instruction that builds on and extends the knowledge and understanding provided under the BIP-MT. This instruction could also concern complementary topics addressing general cultural knowledge, oral and written communication and presentation skills, including possibly communication by one of the commonly used international languages.

It is also envisaged that formal instruction for mid- and/or senior-level technicians may include topics from the fields of specialization already described in Chapter 3 for the BIP-M, but adapted to the technician-level knowledge and to the practical needs of employers (e.g. the NMSs). For instance, many subjects from the BIP-M syllabus in agricultural meteorology, biometeorology, marine meteorology, economic meteorology, urban meteorology and air pollution, weather modification, etc. may easily be adapted for technician-level training. Naturally, the treatment of those subjects will be focused mainly on the application rather than on theoretical aspects.

Finally, in addition to formal and informal instruction, career progression for senior level technicians requires the individual to demonstrate increasing technical competency on the job, and a desire to take on more responsibility (e.g. for the design, implementation or supervision of networks, observing systems and standards, and other relevant activities).

ANNEX

SYLLABUS EXAMPLE FOR AERONAUTICAL METEOROLOGY – TECHNICIAN LEVEL

(Based on an extract from WMO-No. 258, third edition, as revised by N. Gordon, President of the WMO Commission for Aeronautical Meteorology and T. Fox, Chief of Aeronautical Meteorology at ICAO)

Observations for aeronautical purposes are characteristically different from those for synoptic purposes. 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 runways. On a routine basis they are made more frequently than synoptic observations as well as being made on a non-routine basis to cover significant changes in the weather and to satisfy the requirements of pilots and air traffic services.

The syllabus below will supplement the Basic Instruction Package for Meteorological Technicians (BIP-MT) provided under sections 4.1 and 4.2 of Chapter 4. The first four items refer to meteorological knowledge; the next five items to aviation knowledge, and the last two items to basic regulatory documents and related publications by WMO and ICAO. Aeronautical meteorological technicians need to have a sound knowledge of:

- Observing techniques* Surface wind direction and speed, including changes and variations. Visibility and runway visual range, including spatial and temporal variations in RVR observations, by visual means or by use of automatic instruments such as the transmissometer and forward-scatter meter. Cloud amount, height and type and spatial and temporal variations; vertical visibility, observations using automatic instruments such as a ceilometer. Pressure measurements for the purpose of determining QFE and QNH.
- Hazardous phenomena* 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 jet streams. Wind shear. Volcanic ash.
- Meteorological aspects of flight planning* Meteorological basis for pressure-pattern flying; meteorological requirements for en-route winds and temperatures; weather and aerodrome forecasts. Interpretation of area, route and terminal forecasts and preparation of material for briefing of flight crews.
- Reporting, coding and dissemination of weather information* Complete knowledge of international meteorological codes related to observations, such as METAR, SPECI, SYNOP, PILOT, and TEMP, and aeronautical forecasts, such as TAF 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.
- Definitions* Meteorological report, observation. Visibility, runway visual ranges. Altitude, elevation, height, aerodrome elevation, flight-level, and transition level. Aerodrome meteorological

minima, instrument runway, landing area. Landing forecast, aerodrome forecast, forecast, GAMET area forecast, SIGMET and AIRMET (information), briefing, routine and special air-report. Operator, operator's local representative, pilot-in-command.

- Procedures for meteorological services for international aviation* Organization of the meteorological service and particularly the functions of the various types of meteorological offices. Aeronautical meteorological stations and their functions, local routine and special observations and reports, reports in METAR and SPECI code forms. 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.
- Air Traffic Services (ATS)* 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 displays in ATS units or by prompt data transmission originated by the meteorological office or station. Familiarity 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.
- 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, wind shear and volcanic ash 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.
- Aeronautical telecommunications* Elementary understanding of the general organization of aeronautical telecommunications, a good working knowledge of the operation of the aeronautical fixed service (particularly AFTN and ATN), and any special broadcasts and/or regional telecommunications networks applicable to the region concerned, e.g. AMBEX and ROBEX. Such knowledge should include: message headings, addressing of messages, priorities of messages and any appropriate regional procedures. Meteorological technicians should be acquainted with the ICAO abbreviations used in messages on the Aeronautical Fixed Services (AFS). The more frequently used abbreviations should be known by heart.
- WMO documents* *Technical Regulations*, (WMO-No. 49), Vol. II — Meteorological Service for International Air Navigation. *Manual on Codes* (WMO-No. 306). *Guide to Meteorological Instruments and Methods of Observation* (WMO-No. 8). *Weather Reporting* (WMO-No. 9).
- ICAO documents* Annex 3 — *Meteorological Service for International Air Navigation. Regional Supplementary Procedures* (Doc. 7030). *Procedures for Air Navigation Services — ICAO Abbreviations and Codes* (PANS-ABC, Doc 8400). *Location indicators* (Doc. 7910). *Manual of Aeronautical Meteorological Practice* (Doc. 8896). *Manual of Runway Visual Range Observing and Reporting Practices* (Doc 9328). *Manual on Coordination between Air Traffic Services, Aeronautical Information Service (AIS) and Aeronautical Meteorological Services* (Doc 9377) and *Relevant Air Navigation Plans* (ANPs and FASID;)

Note: Some civil aviation administrations in specific circumstances authorize ATS personnel to make meteorological observations at an aerodrome. As indicated in ICAO Annex 1— Personnel Licensing, the training syllabi of the relevant ATS personnel concerned should be supplemented by relevant parts of the Aeronautical meteorological technician syllabus given under items (a) to (d) above.

CHAPTER 5

CONTINUING EDUCATION AND TRAINING (CET)

Introduction

Basic concepts

Getting the most from CET

CET methods

Some CET trends

Final remarks

To understand the importance of CET, it is first necessary to consider how and why organizations change, and how this change can be managed. This leads to the concept of the 'learning organization'. Central to this concept is the empowerment of individuals and the need for them to seek learning opportunities. The associated change in culture is only possible if there is full commitment to such realignment throughout the organization.

It is increasingly likely that organizations will only be successful if they make full use of the creativity and learning potential of the people within the organization. To do this it is necessary to have a strategic approach to the identification of training and development needs. Also procedures and systems need to be in place to ensure that the organization has a clear commitment to training and development, makes appropriate training and development plans, takes action to implement the plans and evaluates the effectiveness of the activities.

In this chapter, concepts such as training, development and continuing professional development will be used to illustrate ways in which people within an organization, such as an NMS, can improve their performance and develop their careers. However, these concepts should be considered in the context of lifelong learning – the process by which individuals continue to participate in formal and informal learning activities throughout their working life.

5.1 INTRODUCTION Change is a natural process for all organizations. Indeed, without change it is unlikely that an organization could continue to be successful.

Factors affecting NMSs The changes affecting NMSs fall into three broad categories:

- Change associated with the evolution of technology which allows 'old things' to be done better (i.e. more efficiently and effectively) and 'new things' which can now be done but which were previously impractical;
- Change arising from improvements in our understanding of physical processes in the earth system, which underpins the development of new products and services;
- Change associated with the political, economic and legal environment in which NMSs operate.

The following are some specific examples of factors influencing the way NMSs operate:

- Increased use of technology to provide both ground-based and space-based observations; these observations are growing in quality and quantity;
- Improved understanding of the processes taking place in the atmosphere and oceans and a greater ability to use numerical models to forecast the weather out to about ten days and simulate the atmosphere-ocean climate system;
- Improved use of workstations to display and manipulate meteorological information;
- Increased application of new data, new models, new research and new forecasting techniques to provide meteorological services that are of benefit to the user;
- Increased pressure for commercialization and/or cost recovery by many governments;
- Growth of the provision of meteorological services by the private sector;
- Increased participation of regional services within a country (at state or province level, for example) in the observation network and in providing meteorological services to end-users; and
- Increased interdisciplinary cooperation amongst the Earth's sciences.

It should be noted that in the last few decades there has been an increase in the rate with which NMSs have needed to change as a result of rapid developments in information technology and telecommunications and globalization.

As change is natural and inevitable both for organizations and individuals, it is desirable that it should be planned and guided rather than simply be a response to a crisis. This requires a culture of learning and development within the organization. The result is a flexible and responsive workforce that can respond positively to change and also actively contribute to creating the change.

The learning organization There are strategic benefits in an organization being able to manage change so that it is always in harmony with changing technology and the environment in which it is operating. The need for an organization to change in this way has led to the concept of a 'learning organization'. Some of the features of a learning organization are as follows:

- Individuals seek learning opportunities;
- Training is learner-centred;
- Empowerment of individuals is the norm;
- Teamwork is fostered;
- Bureaucratic rules are eliminated;
- Feedback on performance is provided;
- Mistakes are tolerated in the interests of learning.

To become a learning organization often requires a complete change in culture. Indeed the whole structure and operation of the organization may need to be realigned. It needs to be recognized, however, that this cannot be done successfully without full commitment to the process throughout the organization.

There are many factors that need to be examined if an organization wants to move towards becoming a learning organization. These deal with issues such as strategy and vision; executive and managerial practice; job structure; and information flow. With regard to training and development the following questions could be asked:

- Is the organization proactive in identifying future skill requirements and providing education and training to meet these requirements?
- Does the organization encourage planned professional development activities?
- Is the identification of training and professional development needs integrated into the organization's appraisal process?

There seems little doubt in these changing and uncertain times, NMSs could benefit from answering 'yes' to these questions and moving towards becoming a learning organization.

Strategic approach to training and development

In 1993 the Royal Society of Arts in the UK produced a report called 'Tomorrow's Company'. In this report it was noted that:

- The centre of gravity in business success is already shifting from the exploitation of a company's physical assets to the realization of the creativity and learning potential of all the people with whom it has contact;
- Education and training are being seen less as an issue of cost, and more as a precondition for competitive success.

Further, it was noted that companies need to strive to develop and use the full potential of their employees by:

- Anticipating and responding to change in employment patterns and the expectations of individuals;
- Supporting and motivating individuals in developing their capabilities;
- Adapting its organizational structure to enable people's contribution to be used effectively.

If this analysis is correct, it is essential that a strategic approach be taken to the planning of CET. This is just as much applicable to an NMS as to a commercial company.

Good practice in the continuing education and training of employees could be achieved if the NMS:

- Has a clear commitment to the career development of its employees;
- Plans for employee development;
- Takes action to develop employees;
- Evaluates the development activities.

Table 5.1 gives an indication of how an organization can demonstrate that it is following good practice for the continuing education and training of its employees.

These considerations indicate that CET must be placed within an organizational context. However, for long-term success, there should be a partnership that fully takes into account the aims and aspirations of the individual, as well as the requirements of the organization. Continuing education and training for an individual requires direction, support and recognition from within the organization.

<i>Principle</i>	<i>Indicator</i>
<p>Commitment There is a commitment from the top to develop all employees to achieve organizational objectives.</p>	<ul style="list-style-type: none"> • The organization has considered what employees at all levels will contribute to the success of the organization; and • Has communicated this effectively to them.
<p>Planning Needs and plans for the training and development of all employees are regularly reviewed.</p>	<ul style="list-style-type: none"> • A written plan identifies resources that will be used to meet training and development needs; • Objectives are set for training and development actions at the organizational, individual and team level;
<p>Action Action is taken to develop and train individuals on recruitment and throughout their employment.</p>	<ul style="list-style-type: none"> • All new employees are introduced effectively to the organization and all employees new to a job are given the training and development they need to do the job; • All employees are encouraged to meet their job-related training and development needs;
<p>Evaluation Investment in training and development is evaluated to assess achievement and improve future effectiveness.</p>	<ul style="list-style-type: none"> • Top management understands the broad costs of developing and training employees; • Action takes place to implement improvements to training and development identified as a result of evaluation.

Table 5.1 — Indicators of whether an organization is following good practice for CET

5.2	BASIC CONCEPTS	In order to describe the role of CET it is important that the meaning of terms such as education, formal and non-formal education, training or competency is understood.
	Continuing Education and Training (CET)	The following definitions might prove useful, though they are not unique.
	<i>Education</i>	<p>The learning process in which the transfer of knowledge and the development of critical thinking are the principal aims. Increasingly the educational process is focusing on the process by which the learner comes to know, understand and be able to apply the accumulated knowledge and understanding in a particular field of study.</p> <p>Part of this learning is acquired in a non-structured and chaotic way, and depends upon the socio-cultural environment in which people live. This is sometimes referred to as 'informal education'. For children much of it takes place within the family environment, but there are also many outside influences. Informal education is a continuing process though it has the greatest influence on behaviour during childhood. It is independent of the work or profession of an individual.</p> <p>The education that forms part of a planned and systematic process can be divided into 'formal education' and 'non-formal education'.</p>
	<i>Formal education</i>	Education provided in a regular and highly structured system (e.g. in schools and academic institutions).
	<i>Non-formal education</i>	Education provided after an individual has left formal education and/or assumed adult responsibilities. Continuing education consists mainly of non-formal education, although sometimes formal education can play a role.
	<i>Continuing education</i>	Learning provided after an individual has left formal education and has entered employment and/or assumed adult responsibilities in which the transfer of knowledge is the principal aim.

Continuing education can be provided in a wide variety of ways (e.g. short courses, seminars, workshops, conferences) and is normally aimed at the specific needs of the individual and/or the organization in which that person works. Having defined various aspects of education, it is appropriate to define training.

Training A planned process of directed learning focused on achieving specific performance objectives associated with a job. Training can modify knowledge, skills and attitude. Training is often concentrated on imparting skills and technical abilities (i.e. the ability to carry out a stated task in a specified way). Knowledge beyond the essentials required to carry out the task are often of secondary considerations.

In reality it is often difficult to clearly differentiate between continuing education and training, so it is appropriate to consider them as two complementary aspects of the way in which improved performance in the workplace can be achieved through appropriate learning. Consequently the combination of the two will be referred to as CET.

CET is usually aimed at helping an individual acquire all the competency required in a particular job, or providing the individual with the competency needed to take on new responsibilities or to progress in his/her career.

Competency The ability to perform the activities within an occupational area to the levels of performance expected in employment.

Training and development The concept of 'development' is now becoming more widely used. It encompasses CET, but also includes the concept of individuals reaching their full potential.

Development The process which encourages or stimulates the growth and potential of an individual. This includes both professional development (changing knowledge and skills) and personal development (changing attitudes and traits). The characteristics of training and development are given in Table 5.2.

For a healthy and vibrant organization it is important that the role of training and development are recognized. Without the development of people an organization will not make most effective use of its most important component – the people that work in that organization.

Continuing Professional Development (CPD) is the process by which individuals develop their skills throughout their working lives.

<i>Training</i>	<i>Development</i>
Imparts specific knowledge, skills and ideas in order to enable an individual to perform better.	Encourages or stimulates the growth and potential of an individual.
One-off event or series of events with a specified end-point.	A continuous process with no fixed end-point.
Done mainly off-the-job (e.g. in a controlled learning environment at a specific time, place).	Achieved mostly on-the-job (e.g. through experience, coaching and practice).
Controlled and managed by the instructor.	Controlled and managed by the individual.
Usually linked to specific organization rather than individual needs.	Specific to the individual and his/her needs and abilities.
Often a group event.	Often a 'solo' event.

Table 5.2 —The characteristics of training and development

Continuing Professional Development (CPD) The planned acquisition of knowledge, experience and skills, and the development of personal qualities necessary for the execution of professional duties throughout the working life.

An important component of CPD is often the careful planned movement of people from position to position within the organization to develop different types of knowledge, understanding and skills through hands-on experiences. This process can be institutionalized in organizations by developing appropriate personnel policies.

Clearly CPD and CET are closely linked and there may be little value in trying to differentiate between them. There are two aspects to CPD which are of benefit to the individual and the organization:

- Individuals acquire up-to-date skills and knowledge that are of value in their existing job;
- Individuals acquire transferable skills that are of value for career development and mobility.

Lifelong learning is an extension of the concept of CPD.

Lifelong learning The process by which individuals continue to participate in formal and informal learning activities throughout their working life. An essential aspect of lifelong learning is that it recognizes the need for personal development as well as work-focused professional development. The overall aim is that each individual should strive towards meeting their full potential in both their personal and professional lives.

5.3

GETTING THE MOST FROM CET

CET is of importance to both organizations and the individuals within that organization.

Importance of CET

For an organization it may be worth investing in CET in order to:

- Fill a gap in basic skills when adequately skilled staff are not available;
- Lead to an improvement in efficiency/effectiveness;
- Allow new working practices or new technology to be introduced;
- Change the culture of the organization;
- Provide a mechanism for regularly updating staff skills;
- Induction of new employees into methods of work and organizational culture;
- Improve staff morale and job satisfaction;
- Allow staff to appreciate how their work fits into the broader business activities of the organization.

However, the organization needs to manage CET activities by ensuring that:

- CET activities fully take into account the training needs and business objectives of the organization; and
- The cost of CET is assessed, though it should be recognized that CET leads to benefits that are very difficult to express in financial terms (e.g. increased motivation).

For an individual, CET is important as it may:

- Bridge the gap between formal education and the acquisition of the competencies required in employment;
- Improve the level of competency; develop interpersonal and managerial skills;
- Allow greater contribution to the business;

- Increase earnings;
- Lead to self-improvement;
- Provide a new challenge and better job satisfaction;
- Broaden expertise beyond the existing job, allow a move into a different area of work, and improve employment prospects; and
- Provide professional accreditation.

Figure 5.1 illustrates the impact of CET on an individual's knowledge and skills. Without CET the knowledge and skills required to perform effectively in employment will decline and performance will suffer.

In general, CET leads to increased motivation of individuals. This can be of benefit to the organization either in terms of a direct increase in efficiency/effectiveness or raised morale, which can have indirect financial benefits to the organization. However, it is essential that the organization makes use of the increased skills acquired through CET activities. If this does not happen, frustration and low morale may result.

Making a success of CET activities

The success of CET activities depends upon:

- An individual's capacity for learning;
- The motivation of the individual which may depend upon personal commitment, incentives or external pressure;
- Choice of CET activities and supporting techniques;
- Support for CET activities within the organization;
- Clearly identifying the needs of the individual and the organization.

This indicates once again that CET activities should be considered within an organizational context.

There are a number of questions that should be asked by an individual under consideration for development through CET:

- Where have I been?
- Where am I now?
- Where do I want to be?
- Why do I want to go there?
- How shall I get there?
- What support do I require?
- How shall I know when I arrive?

The answers to these questions should determine how and when the CET activities are implemented.

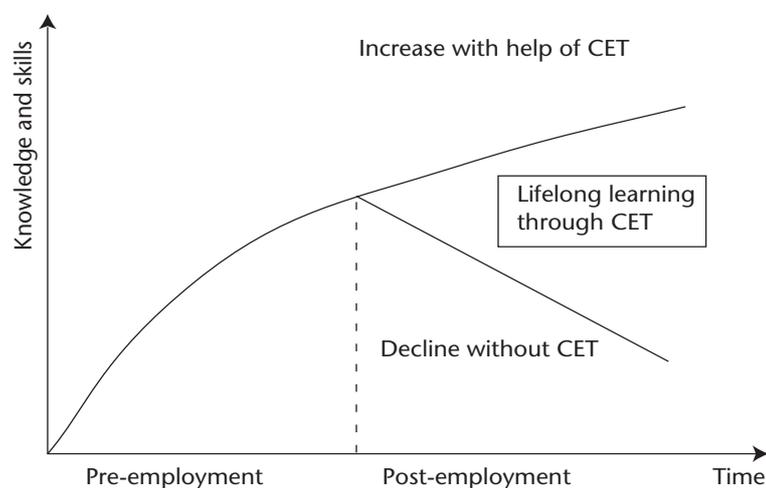


Figure 5.1
Impact of lifelong learning
through CET on knowledge and
skills required during employment

5.4 CET METHODS For CET to be most effective it is important that the method of delivery is appropriate for:

- The learning preferences of the individual;
- The learning objectives of the programme.

Satisfaction of these requirements should ensure that the learning objectives are achieved and the individual remains highly motivated.

General issues There are four background factors that need to be considered when agreeing a CET programme for an individual, these are:

- *Location*; it may be that the most appropriate CET activity is not available locally. This means that sometimes cost becomes a decisive factor in deciding how the CET should take place;
- *Monitoring*; a decision needs to be taken about the level of monitoring required by an individual as he/she is involved in CET activities. A decision will depend upon the kind of CET activity and the personal qualities and experience of the individual;
- *Educational technology*; for some CET activities a high level of educational technology is required. Therefore the availability of expensive resources and the level of expertise of the individual must be taken into account;
- *Accreditation*; some CET activities can lead to a formal accreditation or professional qualification. This may be very desirable, but considerable additional costs may be incurred. Therefore a decision needs to be made about whether the additional benefits that come from accreditation (which are usually difficult to quantify), can justify the additional cost.

Delivery of CET There is a wide range of methods that can be used to deliver continuing education and training. The methods available include the following (in alphabetical order):

- *Coaching*; the coach gives a pre-brief and post-brief associated with on-the-job activities;
- *Conference/seminar*; attendance at a conference, seminar or workshop to benefit from the knowledge of others;
- *Computer-aided learning*; interactive use of learning material available on a computer;
- *Courses*; training for a group led by an instructor;
- *Guided reading*; a guided programme of reading for an individual;
- *Observation*; observing a colleague carry out a particular task;
- *Secondment/temporary placement*; planned move to a job on a temporary basis;
- *Self-study material*; structured training provided from books or manuals;
- *Simulation*; an individual works through a hypothetical situation associated with his work; and
- *Video-based learning*; training provided by the use of videos.

The choice of method will depend upon:

- The desired outcome of the training;
- Strengths and weaknesses of the method;
- Availability of training resources;
- Preferred learning style of the individual; and
- Time available to complete the training.

Table 5.3 gives an indication of whether the methods of training are effective in changing attitude, knowledge or skill, and whether the training is delivered on-the-job or off-the-job; certainly, there are advantages and disadvantages associated with each method of delivering CET. These are outlined in Table 5.4.

<i>Method</i>	<i>Attitude</i>	<i>Knowledge</i>	<i>Skill</i>	<i>Delivery</i>
Coaching	Yes	Yes	Yes	On-the-job
Conference/seminar	No	Yes	No	Off-the-job
Computer-aided learning	No	Yes	No	Off-the-job
Courses	Yes	Yes	Yes	Off-the-job
Guided reading	Yes	Yes	No	Off-the-job
Observation	No	Yes	Yes	On-the-job
Secondment	Yes	Yes	Yes	On-the-job
Self-study material	No	Yes	No	Off-the-job
Simulation	Yes	No	Yes	Off-the-job
Video-based learning	No	Yes	No	Off-the-job

Table 5.3 — Impact of various CET methods on attitude, knowledge and skills, and the way they are usually delivered

5.5 SOME TRENDS IN CET Any CET programme developed within a NMS should take account of:

- The needs and culture of the organization;
- The gap between the competencies of individuals and those they require in the future;
- The availability and appropriateness of the various methods of delivering CET.

Consequently, it is not possible to define what a CET programme should be for all NMSs. It is possible, however, to identify some trends in the development of those programmes.

Training plans Increasingly CET programmes are being based upon an analysis of the training needs of the organization. Though this can be a difficult task to carry out, it has the benefit of ensuring that the CET programme has a firm foundation and is linked to the strategic aims of the NMS. The outcome of the analysis and the identification of appropriate CET activities are often contained in a Training Plan. For example, the Training Plan might indicate that the strategic aims of the NMS are to:

- Increase the ability of forecasters to act as meteorological consultants;
- Increase knowledge of mesoscale systems;
- Ensure that effective use is made of new satellite and radar systems;
- Make greater use of the Internet to deliver forecasting services; and
- Improve the accuracy of forecasting of severe weather.

The Training Plan would also define the strategy to be followed and specific actions associated with the implementation of the strategy. In addition there would usually be an assessment of the resources required. For example, the strategy may be to provide all forecasters with training about the new satellite and radar systems within the next two years. The associated action may be to develop computer-aided learning that will be used at the forecast offices. Alternatively the decision could be to have forecasters attend a short course on this subject either delivered centrally or at the forecast office.

Shorter courses In the past there has been a tendency to have long foundation courses in the expectation that this training will prepare employees for a wide range of posts within the NMS and that the knowledge and skills acquired will not be outdated quickly. Nowadays, however, the demands placed upon NMSs and the development of the science of meteorology are changing rapidly. Also the high costs of the foundation training are being scrutinized as financial pressures come to bear on the NMSs. One response to these pressures is to:

- Limit the foundation training to the acquisition of the competencies required for a particular job both now and in the near future;

<i>Method</i>	<i>Characteristics</i>
Coaching	<ul style="list-style-type: none"> • Good way to practice new skills on the job; • Success depends upon the effectiveness of briefing and de-briefing sessions before and after a task execution; • The support of the coach is required; • The individual must be prepared to discuss openly areas in which performance is not adequate;
Conference/seminar	<ul style="list-style-type: none"> • Of most value in complementing other CET activities; • Participants tend to be passive; • Can be stimulating and enriching experience;
Computer-aided learning	<ul style="list-style-type: none"> • May contain both instructional and illustrative information; • Learning can be done in the individual's own time and at his own pace; • Computers and software may be expensive; • Needs to be supported by other activities to develop skills in using the concepts learned; • Content may not reflect the organization's structure and needs;
Courses	<ul style="list-style-type: none"> • Useful when several people have the same training need; • Needs to take account of the time pressure and work commitments of all learners; • Needs to be scheduled in advance; • Will remove the individual from the workplace;
Guided reading	<ul style="list-style-type: none"> • Good for acquiring new knowledge; • Needs to be supported by other activities to develop skills in using the concepts learned; • Essentially a 'solo' activity so may not appeal to people who prefer to interact with others and learn in groups;
Observation	<ul style="list-style-type: none"> • Good way to study the practical work-based applications of theoretical concepts; • Useful when an individual wants to see how a new concept is put into practice before applying it in his/her own work; • Rapport between the individual and 'shadow' is essential; • The shadow must not feel threatened;
Secondment/ temporary placement	<ul style="list-style-type: none"> • Can provide a good broadening experience; • Objectives must be clearly defined; • Effective induction is necessary;
Self-study material	<ul style="list-style-type: none"> • Useful for acquiring knowledge; • To be effective the material needs to be well structured and take account of how people learn; • Support in using the material is often required;
Simulation	<ul style="list-style-type: none"> • Good way to give exposure to real work-based practices and problems; • Can be used for testing without the risks of real-life application of learning; • complex simulations take a long time to set up and run; • Require support from at least one other person;
Video-based learning	<ul style="list-style-type: none"> • Can be a quick way to learn; • Can be used by an individual or with a group; • Videos can be expensive and of variable quality.

Table 5.4 — Characteristics of various methods for delivering CET

- Institute a programme of CET that will allow employees to update and develop their competency when required. This programme usually consists of a set of short courses aimed at specific areas of competency; for example, interpretation of NWP products, use of satellite and radar imagery and provision of probability forecasts.

This approach to CET allows a very flexible response to the changing needs of the NMSs and their employees. However, the process has to be effectively managed to

ensure that all the staff that need to update their skills and knowledge participate in appropriate CET activities. Also it is necessary to be proactive in identifying newly emerging areas of activity so that timely CET programmes can be put in place.

Vocational qualification and accreditation

In recent years there has been a tendency to develop vocational qualifications which are accredited by an awarding body. Vocational qualifications are based on a clear definition of the competencies required in a particular area of employment – the occupational standard. Consequently the qualification is directly relevant to both the employer and employee. In the meteorological sector some vocational qualifications are being set up for observers and forecasters to meet a particular national need.

To obtain a vocational qualification, an individual usually has to demonstrate that he/she has acquired all competencies defined in the occupational standard. Ideally, the way in which these competencies are acquired should be considered as irrelevant – it does not matter if they result from courses, guided reading, coaching, etc. There are two main advantages of having a vocational qualification:

- For foundation training, the qualification sets a recognized standard that can be used by a variety of educational or training institutions;
- The occupational standard provides a framework for CET activities; for example, a short course could be offered that is aimed at maintaining or enhancing a particular set of competencies that form part of the occupational standard.

As well as vocational qualifications being developed, there is increasing interest in the setting up of accreditation schemes by professional bodies. In the meteorological sector, the professional body is usually a National Meteorological Society or a Professional Board at the National level, though in some cases it is the National Meteorological Service that takes on this role. The accreditation scheme defines the standard, both in terms of professional abilities and personal qualities that need to be satisfied. For some of these schemes there is a requirement to demonstrate a commitment to professional development by being actively involved in CET activities. This means that CET is a basic requirement rather than being something which is optional.

Recruitment and induction

A key aspect of having a well-motivated and competent workforce is to recruit the right people. As well as considering attainment, intelligence and aptitude, it is necessary to assess personality and motivation. National Meteorological Services need employees who are willing and able to acquire new skills in order to develop their career or adapt to changing requirements.

Consider the requirements of forecasters. At one time the main role of forecasters was to use their meteorological knowledge to forecast the weather. However, increasingly NWP models are producing the forecasts. This means that the forecaster's role is changing, there is now much more emphasis on presenting the information in the way required by the user of the services or acting as a meteorological consultant. Consequently it is becoming increasingly important to recruit forecasters that have:

- A good level of inter-personal and communication skills;
- The capability to work as a member of a team; and
- The ability to respond positively to change.

If forecasting recruits have these characteristics, it should be possible to have an effective CET programme for forecasters.

It should also be noted that proper induction is vital in developing the correct approach to professional development from the start of an individual's career with

the NMS. The induction should highlight the rights and responsibilities associated with professional development and give a clear indication of how to access the available opportunities for CET.

Training the instructor and supervisor

In order for CET programmes to be as effective as possible, it is important that people involved in the delivery of the programme are properly trained. For example, instructors require knowledge on:

- The subjects being covered by the CET activity;
- A systematic approach to training – identify training needs, plan training, design and deliver training, and evaluate training; and
- The way adults learn and are motivated.

There was a tendency for the training of instructors to concentrate on the first of these, but it is now recognized that the other two areas of knowledge are vital. This has influenced the way instructors are trained.

It is not just the professional instructor that requires appropriate skills. Increasingly the supervisor is playing a key role in guiding and supporting CET activities. Therefore, supervisors need to have appropriate training. Without this there is the danger that the benefits of CET will not have a significant impact on performance.

5.6 FINAL REMARKS

CET should be viewed within the context of how and why an organization changes. Also for continuing education and training to be of real value to the individual and organization there needs to be:

- Commitment from throughout the organization for the training and development of individuals;
- A clear understanding of the purpose and needs of the organization and the role of the individual in that organization;
- Effective planning of training and development so that the needs of the individual and the organization are both taken into account;
- Information about how training and development activities can be accessed;
- Action taken to implement an individual's training plan;
- A clear understanding of what an individual expects to gain from a training and development activity; and
- Evaluation of the effectiveness of a training and development activity.

These may be difficult to achieve but moving towards these goals should provide benefits to both the individual and the organization.

PART B

EXAMPLES

Examples of Basic Instruction Packages

Examples of actual job-competency requirements

The spirit of ‘focused flexibility’ and ‘specific adaptation’ followed under Part A is somehow reversed under the present Part B, where real-life examples are ‘specifically focused’, but these may still be ‘flexibly adapted’ to local priorities.

The four examples from Chapter 6 illustrate Basic Instruction Packages (BIP) for qualifying job-entry-level Meteorologists and Meteorological Technicians. Heads of relevant educational institutions, teachers and instructors may inspire themselves from these examples when designing and implementing their own educational programmes for the initial formation of meteorological personnel.

The nine examples from Chapter 7 highlight the job-competency requirements at the current operational level in some NMSs. It is recalled that defining the job competencies is only the first step in identifying the requirements in terms of knowledge and skills. Once these requirements are known, appropriate programmes and curricula for specialized training beyond the BIP-M and BIP-MT standards can be designed. It is expected that the resulting training activities, while being focused on the actual needs of the NMS, would also take into account the possible limitations in financial and human resources, as well as the availability of training opportunities and facilities.

CHAPTER 6

EXAMPLES OF BASIC INSTRUCTION PACKAGES

Examples of:

A Complete BIP-M Programme:

Bachelor's Degree in Atmospheric Sciences

A Condensed BIP-M Programme:

Postgraduate Diploma in Meteorology

A Complete BIP-MT Programme:

Higher Meteorological Technician Diploma

A Condensed BIP-MT Programme:

Meteorological Observer Certificate

The BIP-M and BIP-MT descriptions in Chapters 3 and 4 only present a framework curricula for the initial qualification of meteorological personnel, the actual BIP examples from this chapter could facilitate a more complete picture of the effective organization of relevant teaching programmes.

The first example describes the minimum curricular composition and career options for a four-year degree programme in atmospheric sciences. The second example describes a 12-month postgraduate diploma course in meteorology for graduate students with a degree in selected domains (e.g. mathematics, physics or chemistry). The third example illustrates a complete two-year course for qualifying higher Meteorological Technicians, and the fourth example describes a five-month programme for qualifying junior Meteorological Technicians (e.g. weather observers).

These examples may inspire instructors and managers to develop their own programmes for basic education in meteorology; they may also be helpful to prospective students who are exploring educational alternatives in atmospheric sciences. Depending on the actual circumstances, particularly on the prerequisite basic knowledge of the trainees, the length of such programmes may be slightly different from the above-indicated duration. For instance, a condensed BIP-M programme may take up to two academic years, in the case of a Master degree, while a complete BIP-MT programme might be implemented in one academic year, in the case of trainees with good background in mathematics and physics.

6.1 EXAMPLE OF A COMPLETE BIP-M PROGRAMME

Adapted by J. T. Snow from Bachelor's Degree in Atmospheric Science; Policy Statement by the American Meteorological Society (AMS), 1999; USA.

Introduction This statement describes the minimum curricular composition, faculty size and facility availability recommended by the American Meteorological Society for an undergraduate degree programme in atmospheric science. For the purposes of this statement, the terms 'atmospheric science' and 'meteorology' are taken to be equivalent. It is based on the American model wherein the initial education and training of individuals aspiring to be professional meteorologists is accomplished in a university setting, usually over a period of four years (eight 15-week semesters). Graduates of such programmes who enter government service normally complete additional specialized training in a federal training centre and serve a lengthy internship. Graduates, who obtain employment in the private sector or the media, receive typically no additional training at initial job-entry. Finally, many graduates pursue a Master's degree (typically requiring two years of additional study in a speciality area and completion of a research thesis) before seeking initial employment; others return to university later in their careers to obtain a Master's degree to enhance their career progression. Accordingly, the programme described in the AMS statement is structured to prepare students for entry onto these various career paths.

The primary purpose of this statement is to provide advice to university faculty and administrators who are seeking to establish and maintain undergraduate programmes in atmospheric science. It also provides information that may be helpful to prospective students who are exploring educational alternatives in atmospheric science.

A contemporary academic programme in atmospheric science must provide students with a fundamental background in basic atmospheric science and related sciences and mathematics. It must also provide flexibility and breadth so those students can prepare to pursue a variety of professional career paths.

The programme attributes listed in the next section below are those common to any career in atmospheric science. Additional coursework may be helpful for gaining entry to some specific career paths; suggestions are given in the last section for a few selected careers.

While many similarities exist, the curricular programme described for Bachelor's degree differs somewhat from that required for employment as a meteorologist by the federal government. Although federal requirements provide excellent guidelines for preparation for a career in operational weather forecasting, university academic requirements are designed to support a spectrum of career options.

Attributes of Bachelor's degree programmes The objectives of a Bachelor's degree programme in atmospheric science should include one or more of the following:

- In-depth study of meteorology to serve as the culmination to a science or liberal arts education;
- Preparation for graduate education;
- Preparation for professional employment in meteorology or a closely related field.

Course offerings A curriculum leading to a Bachelor of Science degree (or a Bachelor of Arts degree) in atmospheric science should contain:

- (i) At least 24 semester hours of credit in atmospheric science that includes:
 - Twelve semester hours of lecture and laboratory courses, with calculus as a prerequisite or co-requisite, in atmospheric thermodynamics and dynamic,

- synoptic, and mesoscale meteorology that provide a broad treatment of atmospheric processes at all scales;
- Three semester hours of atmospheric physics with emphasis on cloud/precipitation physics and solar and terrestrial radiation;
 - Three semester hours of atmospheric measurements, instrumentation, or remote sensing, including both lecture and laboratory components, and
 - Three total semester hours in one or more of the following: a course in some aspect of applied meteorology such as air pollution meteorology, aviation meteorology, agricultural meteorology, hydrology or hydrometeorology, weather forecasting techniques, or applied climatology; an internship focused on a career in atmospheric science or a closely related field; an undergraduate research project.
 - An additional three semesters hours in atmospheric science electives.
- (ii) Mathematics, including calculus and ordinary differential equations, in courses designed for majors in either mathematics, physical science or engineering;
- (iii) A one-year sequence in physics lecture and laboratory courses, with calculus as a prerequisite or co-requisite;
- (iv) A course in chemistry appropriate for physical science majors;
- (v) A course in computer science appropriate for physical science majors;
- (vi) A course in statistics appropriate for physical science majors;
- (vii) A course in technical, scientific or professional writing;
- (viii) A course with a primary focus of developing students' oral communications skills.

Course requirements should include components that utilize modern departmental and/or institutional computer facilities.

As in any science curriculum, students should have the opportunity and be encouraged to supplement minimum requirements with additional course work in the major and supporting areas. This supplemental course work may include courses designed to broaden the student's perspective on the earth, and the environmental sciences (e.g., hydrology, oceanography and solid earth sciences) and science administration and policy making, as well as additional courses in the basic sciences, mathematics and engineering. Also, students should be strongly urged to give considerable attention to additional course work or other activities designed to develop effective communications skills, both written and oral.

Faculty There should be a minimum of three full-time regular faculty with sufficiently broad expertise to address the subject areas identified in item (i) above. The faculty role should extend beyond teaching and research to include counselling and mentoring of students with diverse educational and cultural backgrounds.

Facilities There should be coherent space for the atmospheric science programme and its students. Contained within this space should be facilities where real-time and archived meteorological data can be accessed through computer-based data acquisition and display systems, and indoor and outdoor facilities suitable for teaching modern atmospheric observation and measurement techniques.

To support the courses in (i)–(viii) above, the atmospheric science programme should provide students modern computer facilities with applications software suitable for the diagnosis of dynamical and physical processes in the atmosphere. Alternatively, students should have ready access to institutional facilities that provide these capabilities.

Student recruitment and retention Institutions should provide academic programmes with resources and the flexibility necessary to recruit and retain students with diverse educational and cultural backgrounds.

Preparation for selected careers in atmospheric science This section provides advice about additional courses that could be useful for those students who wish to pursue a specific career path in atmospheric science.

The careers listed are judged to provide particularly good opportunities at the entry-level at present, however, they cover only a small fraction of the professional employment opportunities in meteorology. Since this statement is concerned with the Bachelor's degree and students already have many course requirements, only a few additional courses are listed per career. It is not intended to be an exhaustive list of all courses that could be useful for a particular career.

Students should keep in mind that many of the suggested courses may have prerequisites which are not listed here and which may vary from institution to institution.

As a general rule, performing an internship in the area of interest and/or completion of an undergraduate research project on a topic in the area are excellent complements to the additional courses listed here.

Weather forecasting careers Students intending to enter this career field should seriously consider including the following coursework or types of experiences in their programme of study:

- (i) Three courses in synoptic and mesoscale meteorology, to include an introduction to NWP (these courses would include any taken as part of the courses recommended in basic requirements under item (i) of sub-section on Course offerings);
- (ii) A course in operational weather analysis and forecasting techniques which includes a laboratory component;
- (iii) A remote sensing course, which includes a laboratory component (such a course would also meet the basic requirements under item (i) of sub-section on Course offerings).

Air pollution careers Students intending to enter this career field should seriously consider including the following coursework or types of experiences in their programme of study:

- (i) An additional chemistry course (in most schools this course would be a continuation of the course used to meet the requirement for a chemistry course, item (iv) of sub-section on Course offerings);
- (ii) A course in atmospheric or environmental chemistry;
- (iii) A course in atmospheric turbulence, micrometeorology, or boundary layer meteorology;
- (iv) An air pollution meteorology course with courses such as (ii) and (iii) above as prerequisites;
- (v) A course involving dispersion analysis and the use of air quality models.

Business-related careers Students intending to pursue a career in private sector or commercial meteorology may wish to gain some knowledge of the business world. The following courses may be helpful:

- (i) A course in marketing;
- (ii) A course in management principles;
- (iii) A course in management information systems; and
- (iv) Either a course in organizational behaviour or one in entrepreneurship or small business management.

6.2 EXAMPLE OF A CONDENSED BIP-M PROGRAMME

Adapted by L. A. Ogallo from the curriculum for Postgraduate Diploma in Meteorology, University of Nairobi, 1999; Kenya

Introduction The department offers the course Postgraduate Diploma in Meteorology, which caters for those students who have a university degree in areas other than

meteorology but wish to take up the subject of meteorology as a profession. Students admitted to this programme should have a B.Sc. degree in any of the following combinations:

- Mathematics and physics;
- Mathematics with physics taken in first year;
- Mathematics and chemistry with physics taken in the first year; and
- Physics with chemistry.

The courses offered in this programme are the same as those covered in the B.Sc. undergraduate degree programme in meteorology. In many cases, postgraduate students may share the same classes with the undergraduate students in the second, third and fourth year. The total number of units for this course is 15, split into equal parts for each of the two university semesters. The duration of the course is one calendar year (12 months). The last three months are devoted to project work.

- Examinations scheme
- (a) For all the courses other than the project work, the continuous assessment marks will constitute 30 per cent of the total marks while the written examinations will take the remaining 70 per cent. Students will undertake research projects in specific fields of meteorology or meteorological applications under the supervision of an academic member(s) of staff. The project work is presented orally before a panel of examiners including an external examiner. Final oral presentations constitute 50 per cent of the total marks. Students should submit typewritten project reports duly signed by their respective supervisor(s). These reports shall be examined by at least two internal examiners from which the student will get the remaining 50 per cent;
 - (b) Pass mark for each unit course is 50 per cent;
 - (c) To be eligible for the award of the Postgraduate Diploma in Meteorology, the candidate must pass in at least 13 of the 15 units with an average grade greater or equal to 50 per cent;
 - (d) A candidate who fails between 7 – 12 units with an average of 50 per cent will be allowed to sit supplementary examinations in the failed units;
 - (e) A candidate who fails to meet the above requirements may be allowed to repeat the year provided he has passed in at least 6 units;
 - (f) The Diploma will be classified based on the average of all the 15 units as follows:
 - 50 – 59 per cent – pass;
 - 60 – 69 per cent – pass with credit;
 - ≥ 70 per cent – pass with distinction.

Core courses To obtain a Postgraduate Diploma in Meteorology the core courses offered are as follows:

SMR 201: Meteorological instruments and methods of observation
 SMR 202: Atmospheric radiation and optics
 SMR 301: Dynamic meteorology I
 SMR 302: Tropical meteorology I
 SMR 303: General circulation and climatology
 SMR 304: Synoptic meteorology and weather analysis
 SMR 305: Applications of statistical methods in meteorology I
 SMR 307: Thermodynamics and cloud physics
 SMR 308: Hydrometeorology I
 SMR 309: Agrometeorology I
 SMR 401: Dynamic meteorology II
 SMR 402: Tropical meteorology II
 SMR 403: Project work
 SMR 405: Applications of statistical methods in meteorology II
 SMR 407: Micrometeorology and atmospheric pollution

Note: Each course amounts to 1 unit credit.

- Meteorological instruments and methods of observations* The need for the surveillance of the atmosphere. The standard meteorological instruments; their uses, accuracy and sources of errors in meteorological observations. Characteristics and uses of special observational platforms: satellite, constant level balloons, automatic buoys and rockets. Synoptic weather observations taken from surface and space platforms. Uses of satellite imagery. Meteorological codes. *In situ* and optimal interpolation techniques in data processing, especially with SST. Implementation of World Weather Watch (WWW). Optimum and minimum network designs for meteorological observations.
- Atmospheric radiation and optics* Features of the Sun and Sun-Earth system, motion and duration of the Sun, sunspot activity, Earth-Moon system, eclipse, tides etc. Solar radiation measurement techniques; absorption, emission and scattering of radiation. Depletion of solar radiation (direct/diffused) under cloudless and cloudy conditions, mean depletion, reflection at the Earth's surface and oceans. Heat balance of the earth-atmosphere system and the role of carbon dioxide, water vapour and ozone on radiation quality and quantity; radiation charts. Introduction to atmospheric optics with application to rainbow, halo and other phenomena; transparency of the atmosphere and visual range.
- Dynamic meteorology I* Real and apparent forces affecting atmospheric motions. Equation of motion in inertial and rotating coordinate systems. Relative equation of motion and its components in different coordinate systems (cartesian, pressure, natural and spherical coordinates). Scale analysis of the relative equation of motion. Geostrophic and hydrostatic approximations. Horizontal frictionless flow of balanced motions: geostrophic flow, inertial flow, cyclostrophic flow and gradient flow. Thermal wind, barotropic and baroclinic atmosphere. Divergence and vorticity theorems, their scale analyses.
- Tropical meteorology I* Differences between the tropics and extra-tropics. Tropical general circulation: observed mean fields; temperature, zonal wind, mean meridional motions, humidity, sea-level pressure. Angular momentum balance and maintenance of temperature field; water balance in the atmosphere. ITCZ, vertical and seasonal characteristics. Weather in the neighbourhood of the ITCZ, double equatorial trough. Monsoons and associated weather with particular reference to Africa and South-East Asia. Tropical jet streams and their relationship to thermal wind: subtropical, tropical easterly, West African and East African low-level jets, easterly waves, major African anti-cyclones, tropical cyclones, West African squall lines. Seasonal location, intensity and structure of the systems that control weather over Africa with reference to eastern Africa.
- General circulation and climatology* Main features of the atmospheric general circulation: Jet streams, global circulation cells, dynamics of the monsoon circulation and fluctuations of the general circulation systems. Angular momentum: meridional and vertical transports of angular momentum, heat and water vapour. Maintenance of mean circulation, zonal wind and temperature. Introduction to atmospheric energetics: kinetic energy, potential energy, total potential energy and available potential energy. Climate classification: use of vegetation, water budget, energy balance, Budyko as radiation index of dryness; satellite data and other methods. Limitations of instrumental observation in meteorology. Estimation of missing data: grid point and areal records. Climate change, potential impacts and adaptation strategies. General climatology of Africa; regional climatology of eastern Africa. Climate processes; factors controlling the global climate system. Global climate processes: past, present and future climate fluctuations of the global and regional climate. Climatological statistics; use of paleo-climatological and instrumental records. Causes of climatic variability and change: Natural and anthropogenic causes, random variations. Land-sea-ocean interactions and the global climate. History and applications of the climate models. Microclimates. Climate change: soils, vegetation, animals, agriculture, hydrology, man, building, economy, transport industry, communication, etc. Spatial and temporal distributions of the major climatic parameters: radiation, temperature, pressure, wind, hydrometeors,

precipitation, cloudiness, snow, evaporation, humidity, fog and thunderstorms. Climate change: climate, drought and desertification. Factors controlling climate, past, present and future climatic fluctuations.

Synoptic meteorology and weather analysis

Different types of charts used in a forecasting office. Different scales of motion identifiable in the daily synoptic charts. Analysis and identification of the middle and high latitude disturbances: waves in the westerlies, zonal index, long (Rossby) and short waves, pressure-wind relationship, quasi-geostrophy, streamline-isotach analysis, air-masses and fronts. Airmass transformations. Frontal slope, weather associated with airmasses, extratropical cyclones and anticyclones, blocking systems, structure of jetstreams. Analysis and identification of the space-time characteristics of tropical synoptic weather systems in Africa and East Africa. Vertical tilt of the synoptic scale systems. Forecasting for aviators: take-off, climb cruise, descent and landing phases. METAR and TAF codes, visibility, aircraft icing, clear air turbulence, meteorological factors in supersonic flights. Forecasting for mariners, agriculturalists, hydrologists and other users. Satellite application in synoptic meteorology. Synoptic meteorology as applied to modern forecasting techniques: development, interpretation of numerical forecasts and computer simulations. Three-dimensional analysis of atmospheric systems, cross-sections and time-sections of upper-air charts. Contour and streamline analysis: pattern continuity. Confluence and diffluence: computation of vorticity and divergence. Analysis, identification and forecasting of synoptic and mesoscale systems: ITCZ and ITD, Monsoons, jet streams, anticyclones, easterly/westerly waves, Geostrophic wind, Gradient wind, thunderstorms, maximum wind gusts, marine systems, like state of the sea, ocean waves, swells, cyclones and other synoptic/meso/microscale systems. Use of climatology in forecasting. Daily, monthly and seasonal dominant synoptic and regional systems.

Applications of statistical methods in meteorology I

Methods of presentation and analysis of meteorological data. Frequency analysis, probability density and cumulative functions. Probability distributions and parameters as descriptors of the characteristics of the distributions. Application of probability density functions in meteorology. Normal, Lognormal, Chi-square, Students' t-Test, Fisher and Gamma distributions. Parameter estimation methods. The central limit theorem. Normality, goodness of fit tests, hypothesis testing and confidence intervals. Correlation and regression analysis. Estimation of missing meteorological records. Data quality control: homogeneity, area averages, Thiessen polygons and isohyetal method. Deterministic and probabilistic characteristics of natural phenomena. Joint, marginal and conditional probability. Binomial and Poisson distributions. Univariate time series analysis, ARMA and ARIMA models.

Thermodynamics and cloud physics

The equation of state for perfect gases and their mixtures applied to dry air and water vapour. Different concepts for specification of water vapour content. Laws of thermodynamics and irreversible processes, the concept of entropy. Change of phase in thermodynamics: relationship of T , T_e , e , etc., lifting condensation level and saturation point. Thermodynamic diagrams and their uses. Hydrostatic equation and its importance in meteorology: geopotential, altimetry, hydrostatics of special atmospheres, standard atmosphere. Dry and saturated adiabatic lapse rates, static stability. Stability criteria for dry and moist air; parcel and slice methods, entrainment and buoyancy in cumulus clouds, top mixing. Diurnal variation of stability. Radiative cooling, subsidence, formation of fog.

Hydrometeorology I

The hydrological cycle, the history of hydrology, hydrological applications. Concept of the water balance. Intensity depth-area duration analysis. Areal distribution of precipitation, extreme rainfall analysis and estimation. The physical process of evaporation, evaporation from free water surfaces, actual and potential evapotranspiration, methods of estimating evapo-transpiration. Hydrometry and hydrometeorological gauge network, hydrographs, hydrograph analysis, hydrograph synthesis; theory and applications of the unit hydrograph floods and low flows. Flood related design: reservoir yield/capacity.

- Agrometeorology I* Scope of agrometeorology and agro-forestry. Agrometeorological measurements. Phenological observations. Near-surface climate: temperature, wind, carbon dioxide, radiation and humidity profiles within the fully adjusted layer of plant communities. Light and radiation intercepts in sole crop, inter-crops and agro-forestry systems in relation to yields. Modification of microclimate: wind breaks and shelter belts, irrigation, tillage, mulching, agroforestry systems, etc. Soil profile description, physical characteristics of soils, soil water and methods of measurement, soil temperature and fertility. Determination of wilting fields capacity and bulk density. Soil degradation; erosion, land-use, salinization, etc. Plant growth and development; vegetation monitoring. Climate, weather and agricultural production, irrigation requirements, diseases, pests, etc.
- Dynamic meteorology II* Kinematics: resolution of a linear horizontal wind field into translation, rotational, divergence and deformation fields. Stream lines, trajectories and streaklines. Helmholtz theorem for resolving horizontal wind field into rotational and irrotational components, stream function and velocity-potential. Vorticity and divergence equations in different coordinate systems. Continuity equation. Pressure tendency equation. Barotropic and baroclinic fluids. Circulation theorems: illustrations of thermally-driven circulations; land-sea breezes, mountain and valley winds, monsoons, etc., direct and indirect circulations. Generalized wave theory, harmonic motion and Fourier decomposition of periodic functions. Free, forced and damped oscillatory motions; examples from atmospheric oscillations. Atmospheric waves including Rossby waves, sound waves, gravity waves and Kelvin waves. Filtering processes. Introduction to Numerical Weather Prediction (NWP): finite differencing, initialization, Lateral boundary conditions, etc. Problems of NWP in the tropics. Dynamic instability: baroclinic, barotropic and inertial instability.
- Tropical meteorology II* The tropical boundary layer processes. Tropical convection, CISK, CISK and wave-CISK. Tropical cyclones, their causes and observational aspects, numerical modelling and prediction: survey of tropical wave disturbances, cloud clusters, squall lines, scale interactions between tropical weather systems; forcing mechanisms for tropical disturbances. Observed temporal variability in the tropics: the diurnal cycle, annual and semi-annual cycles, inter-seasonal and Intra-seasonal oscillations. The tropical stratosphere and mesosphere; Quasi-biennial oscillation, quasi-stationary waves, zonal asymmetric features of the tropics; interactions between land-atmosphere-ocean, East-West circulations; El-Niño-Southern Oscillation (ENSO). Modelling and prediction of the tropical atmosphere, long-term variations and tropical weather anomalies.
- Project work* Students will undertake research projects in specific fields of meteorology or meteorological applications under supervision of an academic member(s) of staff. Students are required to consult with the relevant supervisor(s) at least once every two weeks for guidance. Students will be guided on how to prepare a project proposal in their areas of choice. Project work is presented orally before a panel of examiners including the External Examiner. Final Oral presentations constitute 50 per cent of the total marks. Students should submit typewritten project reports dully signed by their respective supervisor(s). These reports shall be examined by internal examiners, from which the student will get the remaining 50 per cent. Before the student undertakes to carry out his/her designated research work, he/she is required to write a project proposal, which is presented in a seminar form to a panel of supervisors for evaluation.
- Applications of statistical methods in meteorology II* Sampling theory. Analysis of variance. Multivariate correlation and regression analysis. Design of experiments, Randomized design and randomized block design. Analysis of covariance. Statistical and probability prediction in meteorology. Skill tests: Evaluation of meteorological forecasts. Bivariate expectations. Introduction to non-parametric statistics and extreme value analysis. Multivariate time-series analysis, empirical orthogonal functions. Risk zoning. Discriminate analysis. Smoothing and filtering in meteorology. ARIMA and transfer function models.

Micrometeorology and atmospheric pollution

Laminar and turbulent flow, Reynolds number, shearing stress, molecular motion in laminar sub-layer. Newtonian analysis of viscosity, mean free path, equation of motion of viscous fluids, inertia and viscous effects, transition zone between laminar and turbulent layers. Turbulent layer, friction, eddy stresses and momentum fluxes, vertical structure of the wind in the surface layer. Mass, heat and momentum transfer in the turbulent layer, exchange coefficient in the turbulent layer, mixing length theory, smooth and rough surfaces, wind power law, logarithmic wind profile. The relationship between turbulence and temperature profiles. Richardson number, diabatic wind profiles. The energy balance of the Earth's surface, daily and annual temperature cycles. Transition zone between turbulent and geostrophic layer. The vertical variation of wind in the spiral layer, spiral winds, Ekman spiral. Nature and sources of air pollution. Partial differential equations of turbulent diffusion for instantaneous point sources, continuous point and line sources. Statistical theory of turbulent diffusion. Gaussian diffusion formula, nature and sources of air pollution. Methods of estimation of air pollution concentration levels. Chemical and photochemical reaction of air pollutants. Dry and wet deposition, acidification of rain, ozone layer, greenhouse effect. Effects of air pollution, its control and management. Nuclear effects in the atmosphere. Air pollution and urban climate. Noise pollution.

6.3 EXAMPLE OF A COMPLETE BIP-MT PROGRAMME

Adapted by C. Billard from the curriculum for Higher Meteorological Technician Diploma, Météo-France, 1998, France

Aims and organization of the programme	This programme is aimed at training the students to enable them to perform observation and meteorological measurements, meteorological information processing activities, climatological studies and to assist in weather forecasting tasks. In addition, by the end of the programme, the students have to be able to adapt themselves as appropriate in their future activities as Meteorological Technicians.
Description of courses	The programme duration is two academic years, and it includes: <ul style="list-style-type: none"> • Theoretical and practical courses in turn, at the École Nationale de la Météorologie in Toulouse; • A short spell in a local operational meteorological unit; • A personal project, aimed at assessing the ability of the student to apply previously acquired knowledge and competencies.
<i>Mathematics</i>	Twenty hours (over 10 weeks): Complementary notions so as to enable the students to correctly benefit from meteorological lessons. Functions, limits and derived functions; integral calculus; partial derivatives and differentials; vector calculus; vector analysis and related operators (gradient, divergence, curl).
<i>Physics</i>	Twenty hours (over 10 weeks): Complementary notions so as to enable the students to correctly benefit from meteorological lessons. General thermodynamics: first and second basic principles; Fundamentals of elementary mechanics, statics and dynamics of a particle; deriving speeds and accelerations.
<i>General meteorology</i>	One hundred hours (over 25 weeks): Key course in the meteorological technician programme, determining the layout of the other courses; this includes two main topics, namely atmospheric thermodynamics and dynamics. Overview to the atmosphere and the terrestrial system: description of the atmospheric environment; recalling basics about electromagnetic radiation; solar and terrestrial radiation. Thermodynamics of the 'dry' and 'wet' atmosphere. Depiction of the vertical structure of the atmosphere on dedicated documents (tephigram); vertical equilibrium and hydrostatic approximation; equation of the horizontal motion

(wind); general circulation (surface and altitude); air masses and frontal boundaries; formation and developments of disturbances; local phenomena (föhn effect).

Dynamic meteorology Fifteen hours (over 5 weeks): Complementary course in General Meteorology, as well as a brief introduction to numerical weather prediction. Introduction to dynamic meteorology – basic equations describing atmospheric evolution in time; numerical modelling tools; overview and interest.

Oceanography Twenty hours (over 7 weeks): General course with the specific objective of giving a description of atmosphere-ocean coupling. The oceanic environment; currents in the sea and oceanic motions; air-sea interactions; marine waves and swells.

Meteorological observation One hundred hours (over 25 weeks): Qualitative approach, measuring and coding meteorological parameters, upper atmosphere observations, automated methods. General organization of the atmospheric monitoring activities (*ad hoc* networks, WMO scheme); description of clouds and meteors; coding of meteorological data collected for transmission; main processes of building for precipitation and various meteors; general survey of the sky and current local weather.

Measurements and meteorological sensors One hundred hours (over 35 weeks): This course deals with the physical principles underlying the measurement of different parameters in meteorology, both at the surface and at upper levels: radiation, pressure, temperature, humidity, wind, precipitation. Operational running of the equipment and its maintenance; automatic stations or systems; monitoring the quality of the measurements; related developments.

Weather analysis and forecasting One hundred and twenty hours (over 40 weeks): Course including lessons and practical activities aimed at delivering basic knowledge and skill to students about weather analysis and forecasting. Basic principles of weather forecasting; importance of the analysis step; extrapolation, persistence and analogue schemes; methods to be used for forecasts of different range; numerical model output and forecast guidance to prepare forecasts. Global data processing scheme in meteorology; adaptation of general forecasts to lower scale prediction; preparation of bulletins and other forecast products; specialized forecasts for aviation, marine activities, agriculture, air-quality; weathercasting; some features of the forecasting activities in tropical regions.

Interpretation of satellite imagery Fifteen hours (over 5 weeks): This course is orientated toward the efficient use of satellite imagery and other remote-sensing information in weather analysis and prediction. Orbits; different kinds of satellites; characteristics of meteorological satellites; interpretation of satellite images and data.

Météotel and synergie stations Fifteen hours (over 4 weeks): Presenting dedicated operational stations and techniques for professional forecasters and users. Presentation of these tools and trials by the students.

Statistics Fifty-two hours (over 17 weeks): Course about a fundamental tool for meteorology with some examples coming from this field of application; links with climatology. Probability laws; basic assumptions for the statistical approach; sample studies; case studies in meteorology.

Computer science Seventy hours (over 25 weeks): Computer tools are essential for processing the huge amount of data collected in meteorology. Programming languages; algorithms and methods used in computer sciences; software development.

Using PC and related software Twenty hours (over 10 weeks): Enabling students to use standard office software.

Meteorological telecommunications Twelve hours (over 3 weeks): The global telecommunications system of WMO; national meteorological telecommunication networks; different techniques used for telecommunications in meteorology.

<i>Geography</i>	Eighteen hours (over 9 weeks): Map marking; climatology and geography of climates: definition and classification; climatic areas; basics about numerical geographical information systems.
<i>Tropical meteorology</i>	Fourteen hours (over 4 weeks): Energy budget of the Earth; recalling salient facts about general circulation; meteorological equator; tropical disturbances and hurricanes.
<i>Meteorological services and products</i>	Ninety-one hours (over 25 weeks): These topics are presented according to the needs of various kinds of users and different economics sectors concerned.
<i>Administrative law</i>	Twenty hours (over 10 weeks): Origins of law; national and European political institutions; administrative organization at central and territorial levels; specific rules for finance management in a public body; human resources management and regulations.
<i>Foreign languages, especially English</i>	One hundred hours (over 40 weeks): General and specific 'meteorological' foreign language; standard evaluation systems, e.g. TOEFL; presenting meteorological bulletins in foreign language.
<i>Sport</i>	Two hours per week (over 30 weeks).
<i>Workshop sessions</i>	(Over 25 weeks): Two sessions in the second part of the programme in order to practice and to be trained in near-real conditions (almost the same as in an operational unit): <ul style="list-style-type: none"> • Eight weeks workshop covering: analysis (2 weeks); observation (2 weeks); computer techniques (2 weeks); oral communication (1/2 week); commercial methods (1/2 week); • Nine weeks workshop covering: analysis/forecasting (3 weeks); observation/local climatology (3 weeks); climatology/computer techniques (3 weeks).
<i>Training periods</i>	Two training periods are foreseen during the programme: <ul style="list-style-type: none"> • A one-week coaching period at an early stage in a professional team, enabling the trainee to discover the professional standards required within an NMS; • A two-week coaching period at a later stage in a professional team very similar to that which the trainee will finally join after the training programme; the objectives of this stay are to enable the trainee to complete, in an operational environment, his knowledge and skills in observation, weather analysis and forecasting, climatology, environmental and applied meteorology, and all other tasks to be performed by a Meteorological Technician.
<i>Personal project</i>	This is the final activity in the programme in six weeks spent in an external team. The student has to work with some autonomy and in an inventive spirit dealing with a concrete and well-defined subject of interest in meteorology. This venture, together with the results, are reported in a written document and presented by the student before an examining board.

6.4 EXAMPLE OF A CONDENSED BIP-MT PROGRAMME

Adapted by G. V. Necco from the Argentinean Air Force Training Institute Ezeiza; Training Course for Meteorological Observers; February 2001

Meteorology	Total number of hours: 90
<i>Objectives</i>	<ul style="list-style-type: none"> • To understand the fundamental concepts of meteorology. • To understand the objectives of the duties entrusted to the surface observer.

*Subjects, contents and hours of theory and practice**Meteorology* (Theory 2 hrs):

- Definition of meteorology.
- Relation of meteorology with different human activities.

The atmosphere (Theory 3 hrs):

- Composition of the atmosphere. Composition of the air. Constant and variable components. Atmospheric ozone. Water vapour in the atmosphere.
- The layers of the atmosphere. Layers of the atmosphere. Importance of the troposphere.
- Heat interchanges in the atmosphere. Solar radiation. Terrestrial radiation. Other processes of heat interchange. Energy balance of the atmosphere. Effect of the radiation in the surface of the globe. Temperature difference between continents and seas.

Parameters of the atmosphere (Theory 20 hrs):

- Temperature of the air. Kelvin scale of temperature. Diurnal variation of the surface air temperature. Variation of the temperature in altitude.
- Atmospheric pressure. Nature of the atmospheric pressure. Units of atmospheric pressure. Variation of pressure with altitude. Semi-diurnal variation of pressure. Gradient of pressure.
- Humid air. Humidity of the air. The three states of water. Vapour pressure. Process of condensation. Adiabatic process. Isobaric process. Process of solidification (or freezing). Latent heat. Indicators of the water vapour content in the air. Relative humidity. Principles of the humid thermometer. Density of the humid air.
- Wind. Forces that act on the air in movement. Geostrophic wind. Gradient wind. Law of Buys-Ballot. Wind in the boundary layer. Horizontal convergence and divergence. Air advection.
- Local winds. Sea breeze. Land breeze. Mountain breeze (katabatic wind). Valley breeze (anabatic wind). Foehn wind. Zonda wind.

Clouds (Theory 10 hrs):

- Formation and dissipation of clouds. Condensation, freezing and sublimation. General causes of cloud formation. Convection. Orographic ascents. Clouds associated to frontal zones. Dissipation of clouds.
- Precipitation processes. Size of cloud drops. Growth of cloud drops. Mechanism of coalescence. Ice crystal formation. Process of Bergeron. Growth of ice crystals by collision. Different types of precipitation.

Vertical stability of the atmosphere (Theory 7 hrs):

- Adiabatic processes in the atmosphere. Vertical gradient of temperature. Stability. Parcel method. Vertical motions of non-saturated air. Conditional instability. Indices of instability. Atmospheric turbulence. Different types.
- Temperature inversions. Frontal inversions.

Visibility (Theory 2 hrs):

- Factors that influence visibility. Effect of precipitation.
- Fog and mist. Degree of importance for different activities.

Air masses and fronts (Theory 8 hrs):

- Meteorological importance of the scale. Definition of air masses. Classification of local air masses. Symbols used. Evolution of the air masses.
- Definition of front. Phenomena associated to the different types of fronts. Cold front model. Associated phenomena. Warm front models. Associated phenomena.
- Extratropical cyclones. Disturbances in the polar front. Occluded fronts. Phenomena associated to occluded fronts.

Air masses and fronts. Severe phenomena (Theory 4 hrs):

- Storms. Formation and evolution of storm cells. Types of storms. Storm detection. Tornadoes.

Synoptic analysis (Theory 10 hrs):

- Synoptic maps at sea level. Anticyclones and ridges. Depressions and troughs. Other isobaric configurations. Frontal systems in the sea level map. Relations between synoptic configurations and weather.

General circulation (Theory 3 hrs):

- The average circulation in the troposphere. Definition of jet stream. Subtropical and polar jet stream. Models of general circulation.

Methodology to apply Exhibition, demonstration, dialogue and interrogation; oral and written evaluation.

Bibliography for the professor *Compendium of Lecture Notes for Training Class IV Meteorological Personnel*; Volume II Meteorology, WMO–No. 266.

Instruments and methods of observation
Total number of hours for the module: 214 hours

Objectives

- To use the instruments and methods for observation of the different meteorological parameters.
- To understand the operation of a meteorological station and its functions.
- To participate with a positive outlook in the teamwork of station personnel.
- To carry out the primary maintenance of instruments.
- To prepare the documentation for recording and reporting the observations.
- To know new techniques for obtaining information by means of radar and meteorological satellites.
- To value the necessity to provide only the information that corresponds to his role.

*Subjects, contents and hours of theory and practice**Operation and administration of a meteorological station* (Theory 10 hrs):

- Principles of administrative operation of a meteorological station. Meteorology. Work plans. Tasks and functions. Planning and management of available means.
- Attention to users. Documentation. Coordination with other dependencies of flight protection.

The meteorological observation (Theory 4 hrs, Practice 3 hrs):

- Scope of observations, Difference between measurement and estimation. Classification of the meteorological stations.
- Elements that are measured and/or estimated. Hours of observation. Observations of routine and aeronautical use. Time zones.
- Observation register. Recording observations.

Meteors (Theory 4 hrs, Practice 4 hrs)

- Hydrometeors, photometeors, lithometeors and electrometeors: definitions and symbols. Relation between types of clouds and meteors.
- Information on present and past weather. Intensity of the phenomena. Norms of annotation and information. Code tables. Definition of terms of current use, referred to present (WW) and past weather (W_1 W_2).

Clouds (Theory 6 hrs, Practice 20 hrs)

- Clouds classification. Cloud genera, species and varieties. Annotation in the meteorological notebook.
- Measurement of cloud height. Balloons for ceiling, nepho-altimeter. The aeronautical ceilings and minima. Information in real time: FVR, IFR, VMC.
- Codification of clouds. The evolution of the cloudy states of the sky. Priorities in coding clouds co-existing in a same layer.

Measurement of atmospheric pressure (Theory 4 hrs, Practice 12 hrs).

- Units of measurement of the atmospheric pressure. Conversion and passage of units. Measurement instruments. Barometers of adjustable (Fortin) and fix (Kew) cistern. The barographs. The vernier.

- Corrections to carry out to the barometric reading. Levels of comparison. Tables of d2 and d4. The standard atmosphere. Calculation and codification of QFE, QFF and QNH. Calculation and coding of appp.

Measurement of air temperature (Theory 3 hrs, Practice 10 hrs):

- Units of measurement of temperature. Passage of units. Thermometers. Different types of thermometers. The meteorological shelter.
- Reading and recording temperature. Actual temperature. Daily maximum and minimum temperature. Temperature of the soil. Geothermometer.
- Calibration of thermometers.
- Coding of the temperature in different messages. The thermograph. Reading and recording.

Measurement of air humidity (Theory 3 hrs, Practice 12 hrs):

- Measurement of vapour pressure, relative humidity and dew point. Definitions and units of measurement.
- The instruments of measurement of air humidity. The psychrometer and the hygrograph. Different types.
- Reading and recording. Calculation of different parameters from humidity measurement. The psychrometric tables.
- Coding and reporting dew point temperature.

Measurement of precipitation (Theory 2 hrs, Practice 6 hrs):

- Liquid and solid precipitation. Instruments for its measurement. Rain gauges. Pluviographs. Snow gauges.
- Reading times. Recording in the pluviometric registry and the notebook of observations. Coding of the information.

Wind measurement (Theory 3 hrs, Practice 12 hrs):

- Measurement of the direction. Vanes. Units of measurement of the wind direction. The wind rose. Measurement of the wind speed. Units of measurement of the speed. Equivalence. Passage of units.
- Reading, reporting and recording of the wind. Coding in the diverse messages.
- Definition and registering of gust, its reporting.

Measurement of visibility (Theory 4 hrs, Practice 10 hrs):

- Definition of horizontal visibility. Factors affecting it. Reference charts. Relation between the states of the sky, meteors and the visibility.
- Recording in the notebook. Reporting in real time. Diffusion to direct users. The runway visual range. Definition of RVR. Reporting for aeronautical use.
- The transmissometer: VFR, IFR, VMC.

Integrated measurement of different parameters (Practice 56 hrs):

Climatic message (Practical 12 hrs):

- Statistical messages. Norms for preparation. Additional CLIMAT message. Preparation of CLIMAT messages. Monthly record of extreme values.

Instruments maintenance (Practical 15 hrs):

- Primary maintenance of instruments.
- Electromechanical systems. Clockwork systems.
- Electronic systems.

Meteorological radars (Theory 6 hrs):

- Electromagnetic waves. Principles of radar operation. General concepts of the measurements. Identification of hydrometeors.
- Applications of radar information in the short-term forecasting.

Satellite information (Theory 8 hrs):

- Brief history of the space era. Orbits of the satellites. Laws of Kepler. Sub-satellite points and trajectories. Basic concepts for calculation of orbits.
- Visible and infrared sensors. General concepts on image interpretation.

Methodology to apply

Exhibition, demonstration, dialogue, integration; oral and written evaluations. Hand-on practice on the institute premises and in meteorological observing stations.

Coding of surface observations

Total number of hours of unit: 210 hrs

Objectives

- To understand the operation of the different systems of meteorological information employed in the services of flight protection.
- To codify and to decodify the different types of meteorological messages.
- To value the importance of a suitable coding for the transmission of meteorological information.

*Subjects, contents and hours of theory and practice**Meteorology and flight protection* (Theory 10 hrs):

- The National Meteorological Service.
- The WMO's Global Observation System. The Global Telecommunications System. The Global Data Processing System. Coordination of ATS-MET.
- The meteorological statistics.

Meteorological messages (Theory 180 hrs, Practice 20 hrs):

- Messages SYNOP. Symbols and code tables. Coding and decoding.
- Messages METAR and SPECI. Symbols and code tables. Coding and decoding.
- Messages PILOT. Symbols and code tables. Coding and decoding.
- Messages RADOB. Symbols and code tables. Coding and decoding.
- Messages SATOB and SATEM.

Methodology to apply

Practices of the different codes will be carried out on the premises of the institute.

CHAPTER 7

EXAMPLES OF ACTUAL JOB-COMPETENCY REQUIREMENTS

Weather analysis and forecasting
Climate monitoring and prediction
Observations and measurements; instruments
Information technology and data processing
Agrometeorology
Aeronautical meteorology
Marine meteorology
Environmental meteorology
Satellite meteorology

This chapter illustrates the job-competency and relevant knowledge and skills required of meteorological personnel assigned to the branches of activity identified in Chapter 2. Experts from individual NMS or other relevant institutions, provided 'real-life' examples in response to specific requests from WMO. Except for some general editing, the structure of the original inputs was essentially maintained. Consequently, there are slight differences in the level of detail and a degree of overlapping in the subject coverage of some examples.

The nine examples may inspire educators and managers to identify the requirements of their NMS for specialized knowledge and skills, and then to translate those requirements in terms of training outcomes. The user may have to adapt those examples to his specific priorities. Accordingly, various topics may receive more or less emphasis than suggested here. It could be that some examples might not even apply to a given NMS (e.g. a landlocked country may not be interested in marine meteorology).

Obviously, no one individual would be requested to possess all the competencies illustrated throughout this chapter. However, it would be expected that managers and instructors would make all efforts to ensure that the expertise needed in their NMS is well covered by appropriately trained personnel as a whole.

7.1 WEATHER ANALYSIS AND FORECASTING

by R. W. Riddaway, U.K. Met. Office

Producing a generic forecast To produce a generic forecast, the forecaster is required to:

Adopt an appropriate methodical approach at the start of the shift to assimilate quickly all the relevant data. For this, the forecaster describes the following in the first 15 minutes of arrival:

- The general situation;
- The main points in the guidance;
- What the weather is doing now;
- The key weather factors for the next 24 hours;
- Any forecast techniques that are relevant for today;

Interpret guidance correctly in terms of the local weather, and ensure that forecasts are consistent with it, i.e.:

- Know when and where to obtain the latest guidance;
- Read the latest guidance;
- Identify which parts of the guidance relate to the local area;
- Use the guidance to describe the weather for any given place;
- Identify when the weather locally is different from that expected in the guidance;
- Justify the occasions when his own local forecast does not agree with the guidance;

Interpret NWP forecast products correctly in terms of the local weather conditions inferred for the area of responsibility, taking due note of relevant comments in guidance bulletins, i.e.:

- Know when and where to obtain the latest NWP guidance;
- Keep up to date with the latest NWP guidance;
- Identify which parts of the guidance relate to the local area;
- Use NWP guidance to describe the weather for any given place;
- Identify when the weather locally is different from that expected in NWP guidance;
- Be able to justify the occasions when own local forecast does not agree with NWP guidance;
- Identify any comments on the NWP performance given in written or verbal guidance especially when it affects the local forecast output.

Interpret standard model output correctly with an appreciation for their strengths and weaknesses, i.e.:

- Show an awareness of which model run is currently valid;
- Describe weather in the model atmosphere by translating symbols and fields on the model charts;
- Translate weather in the model to the real atmosphere taking account of strengths and weaknesses;
- Describe the significance of any changes between each model run;

Identify, and pay particular attention to, those sources of data likely to provide an indication of any deviation from the expected weather conditions, i.e.:

- Know where to find the latest available satellite, radar and observational data;
- Select the appropriate data for each forecast for any weather situation;
- Interpret any data selected and compare with current guidance and forecast;
- React appropriately to the effects of the latest data on the current forecasts;

Apply correctly the appropriate local forecasting techniques for wind, temperature, visibility, fog, cloud, precipitation, and aviation hazards i.e.:

- Use effectively the appropriate forecasting methods taken from the Forecaster's Reference Book;

- Use the tephigram to do the following:
 - Forecast maximum temperature;
 - Forecast cloud bases, cloud tops and cloud structure;
 - Find the fog point;
 - Deduce changes in stability.

Use the guidance, NWP and local forecasting techniques to develop a forecast which can be adapted to fit local requirements, i.e.:

- Give a broad overview of weather expected in the local area for the next 36 hours within 15 minutes of coming on duty;
- State factors in the forecast that may be uncertain and point the way to possible errors in the stated forecast;
- Express the level of confidence in the current forecast:
 - Be aware of, and make appropriate use of, the main features available on the workstation, i.e.;
 - Use the workstation to determine the following:
 - Normands point;
 - Fog point;
 - Maximum temperature using Model Output Statistics (MOS);
 - Minimum temperature using MOS and McKenzie method;
 - Likelihood of mountain waves using the Casswell method;
 - Atmospheric refractivity;
 - Cloud top temperatures from IR imagery;
 - Use the workstation to find and apply the overlay facilities.

Producing forecasts for the user To produce forecasts for the user it is essential that the forecaster:

Can state typical criteria and appropriate wording for the issue of warnings, i.e.:

- State which warnings are issued at the forecast office either from memory or by immediate access to the warnings' book;
- Identify any criteria for a given warning;
- Produce warnings for issue that contain no ambiguities and are clear and easy to read.

Is familiar with laid down amendment criteria and procedures for the main forecast products, i.e.:

- Identify any amendment criteria for any forecast when asked;
- State the amendment procedure for any forecast;
- Use the correct amendment procedure.

Can use PC software to prepare forecast products, i.e.:

- Call up any forecast available on the workstation;
- Use MS-Office software package in order to produce forecasts;
- Use any other PC system necessary to do the job.

Can make correct use of TAF and TREND codes when producing aerodrome forecasts, i.e.:

- Use all parts of TAF and TREND appropriately;
- Appreciate the differences in change criteria between the two codes;
- Appreciate the differences between military and civil codes;

Follows rules agreed with the customer for producing forecasts, i.e.:

- State or readily obtain the agreed rules for all forecasts;
- Produce forecasts that follow the agreed rules.

Writes scripted forecasts in a style appropriate to the customer, i.e.:

- Appreciate the various styles preferred by customers;
- Make correct use of tense and punctuation in sentences;
- Produce scripts which are free from spelling mistakes;
- Produce scripts which are easy to read at the first attempt;
- Produce scripts free from ambiguity.

Presents verbal forecasts to an acceptable standard, i.e.:

- Have a clear and confident vocal delivery;
- Sound natural while reading a script;
- Respond well to questions;
- Maintain good eye/camera contact when briefing/broadcasting;
- Keep to the subject;
- Avoid ambiguity.

Providing any specialist or support work

To provide specialist or support work, the forecaster must be:

Proficient in the use of office IT systems so as to be able to undertake routine user maintenance and trouble shooting of such systems, i.e.:

- Recover any IT systems to working order, as laid down in local staff instructions;
- Understand and carry out any communications tasks, as laid down under local staff instructions;
- Change paper and ribbons in printers and photocopiers and carry out any other routine maintenance, as laid down in local staff instructions.

Able to make, code, and transmit accurate weather observations, i.e.:

- Accurately observe all parameters needed for input into SAMOS;
- Ensure timeliness of observation;
- Use SAMOS quickly and efficiently;
- Observations without error.

Able to operate any specialist equipment which the forecaster is required to use as part of normal duties, i.e.:

- Use radio studio equipment;
- Use overhead projector or any other equipment required for the main briefing;
- Use any answer phone equipment.

In possession of any other skills necessary, as defined locally, in order to be able to work at that office without direct supervision, i.e.:

- Know any local pricing policy;
- Know where to find the local pricing policy;
- Seek, and take due note of, guidance from colleagues when appropriate;
- Seek guidance from colleagues to clarify anything they do not understand;
- Seek advice from colleagues on ways to improve forecasting techniques;
- Try out new methods and techniques suggested by colleagues;
- Keep to stories agreed locally with colleagues when producing forecasts;
- Seek to improve future forecasts by hindcasting and analysing forecasts already issued.

Aware of, and make appropriate use of, all the relevant features available on the forecaster's data display workstations, i.e.:

- Know where to find, switch on and log in to any forecaster workstation;
- Be able to personalize the system;
- Select and manage chart areas;
- Obtain print-outs of any data;
- Set up print schedules.

Familiar with, and appreciate the importance of, any forecast verification schemes in operational use, i.e.:

- Be aware of any local verification schemes and their impact on future forecast services, as well as the own and colleagues' performance related pay;
- Fill in any details required by local verification schemes;
- Use verification schemes to determine any optimistic or pessimistic bias in the own forecasts.

Managing the working environment

To manage the working environment, the forecaster:

Works through a duty schedule effectively, i.e.:

- Be aware of the schedule of the shift currently being worked;
- Plan to ensure that deadlines are met;
- Put public safety as the top priority;
- Be aware of the relative importance/sensitivity of one forecast in relation to another forecast.

Ensures consistency with colleagues during forecasting duties, i.e.:

- Conduct regular and effective dialogue on the meteorological situation with colleagues;
- Be able to agree a 'story' with colleagues.

Relates well with colleagues and works as a member of a team, i.e.:

- Work with colleagues in an open friendly manner;
- Pay due regard to equal opportunities;
- Show an awareness of colleagues who are experiencing difficulties and respond appropriately;
- Share the workload at unusually busy times.

Deals with customers in an appropriate and professional way, i.e.:

- Answer the telephone in a clear and friendly manner;
- Deal with face-to-face enquiries in an open and friendly manner;
- Ask questions to clarify customer requirements;
- Do not show annoyance even if provoked and respond to criticism or complaints in a constructive way;
- Know the complaints procedure and implement it if necessary.

7.2 CLIMATE MONITORING AND PREDICTION

By Y. Kimura, Japan Meteorological Agency

Climate monitoring and prediction services

The climatologist must:

- Be aware of the impacts of climate (weather) fluctuations on society;
- Understand the value of climate monitoring and prediction information;
- Be aware of how climate monitoring and prediction information is used;
- Be aware of the needs of society for climate monitoring and prediction services.

Climate in the area of responsibility

The climatologist must:

- Have knowledge of the geography of the area of responsibility;
- Know the spatial representativeness of climatic data from each observing station within the area of responsibility;
- Know the characteristics of climate in the area of responsibility:
 - Normal and variability (standard deviation) of climatic elements;
 - Seasonal changes and inter-annual changes of climatic elements;
 - Seasonal changes of dominant weather patterns;
 - Know the influence of urbanization on climate in the area of responsibility.

Relationship between large-scale climate and climate in the area of responsibility

The climatologist must:

- Have knowledge of the normal conditions of large-scale climate:
 - Surface pressure patterns and circulation patterns which appear frequently;
 - Balances between various physical parameters;
 - Seasonal variations of the above two;
- Have knowledge of the relationship between large-scale climate and climate in the area of responsibility:

- Normal state;
- Anomalous climate years in the past;
- Results of former studies on the relationship between large-scale climate variations and climate variations in the area of responsibility;
- Results of former studies on the relationship between large-scale lower boundary conditions of the atmosphere, such as sea-surface temperature and snow-covered areas and climate in the area of responsibility.

Prediction of climate *The climatologist must:*

- Understand the predictability of climate and what can be predicted;
- Understand deterministic forecast and probabilistic forecast.

Methods used in climate monitoring and prediction *The climatologist must:*

- Have knowledge of methods used in climate analysis:
 - Time-series analysis (running mean, spectral analysis, trend analysis, etc);
 - Empirical Orthogonal Function (EOF) analysis;
 - Correlation analysis, Canonical Correlation Analysis (CCA);
 - Singular Value Decomposition (SVD) analysis, etc.;
- Have knowledge of methods used in climate prediction:
 - Statistical-empirical methods: persistency, analogue method, analogue/anti-analogue method, periodicity, multiple linear regression, CCA, discriminant analysis, Optimal Climate Normal (OCN), etc.;
 - Dynamical methods: atmospheric general circulation model, coupled ocean-atmosphere general circulation model, hybrid model, ensemble prediction;
 - Objective forecasts: Model Output Statistics (MOS), Perfect Prognosis Method (PPM), etc.

Verification of forecast (prediction) *The climatologist must:*

- Be aware of the purposes of forecast verification;
- Have knowledge of methods used in forecast verification:
 - Deterministic categorical forecast: contingency table, bias, hit rate, Heidke skill score, etc.;
 - Probabilistic forecasts: reliability diagram, Ranked Probability (RP) score, Brier score, Relative Operating Characteristic (ROC), etc.;
 - Forecasts of continuous variables: bias, anomaly correlation, root-mean squared error, etc.

Data used in climate monitoring and prediction *The climatologist must:*

- Be aware of the characteristics of data used:
 - Surface meteorological observation data, aerological observation data;
 - Oceanographic observation data;
 - Satellite observation data;
 - Objectively analysed data, re-analysis data, data from assimilation systems.

Climate monitoring operations *The climatologist should:*

- Become familiar with the working procedures for climate monitoring;
- Be aware of the ways of interpreting observed and analysed data correctly with an understanding of the characteristics and space-time resolution of these data and of the analysis methods used;
- Bear in mind the importance of monitoring not only climate in the area of responsibility, but also large-scale climate and the whole climatic system;
- Bear in mind the importance of investigating the causes of anomalous climate and accumulating the results for future reference.

Climate prediction operations *The climatologist should:*

- Become familiar with the working procedures for climate prediction;
- Be aware of the ways of interpreting forecast data correctly with an understanding of the strengths and weaknesses of these data, the skills (verification

results) of forecast methods used and space-time scales which the methods represent;

- Bear in mind the importance of accumulating verification results of forecast data and issued forecasts.

Provision and explanation of climate information

The climatologist must:

- Make appropriate use of terms, such as climatic normal, unusual climate, etc.;
- In explaining the climate monitoring and prediction information to users, consider the major impact which climate (weather) has or is expected to have on society;
- Explain the climate monitoring and prediction information to users plainly and unambiguously;
- Apply appropriate knowledge of meteorology and climatology when explaining the climate monitoring and prediction information to users.

7.3 OBSERVATIONS AND MEASUREMENTS; INSTRUMENTS

By R. A. Pannett, Meteorological Service of New Zealand Limited

Introduction

Meteorological datasets may be employed in a variety of applications in weather forecasting, climatology, meteorological research and many agricultural, industrial and commercial applications. To secure the particular quality of data as cheaply as possible for diverse applications places high demands on the design of modern data acquisition systems and the data sampling regime.

Since data acquisition costs comprise a high proportion of the total budget of an NMS, there is continuing pressure to ensure maximum effective utilization of resources; and to seek ways of reducing costs while maintaining required performance.

As data acquisition processes become increasingly automated to improve data quality and reduce costs, there is a movement in the Observations and Measurements (O&M) Branch of the skill base necessary to operate and maintain the observing networks. The emphasis moves from the earlier concentration on manual, visual methods and individual 'mechanical' instruments to automatic, remote-sensing systems employing electronic components with microprocessor- and software-controlled data sampling and processing, and with delivery to the user over various kinds of telecommunications bearer.

In the specialist staffing of the O&M Branch there is a tendency to reduce overall staff numbers while 'up-skilling' existing staff to be competent in newer technologies. Staff may, as well, be 'multi-skilled' so that they are competent over a broader range of tasks and may be more flexibly deployed to meet emerging needs. This practice also leads to improved job satisfaction.

The list of competencies below is given in terms of functional responsibilities or 'key result areas'. In some cases these will be the domains of one specialist, but often competencies will be distributed through the branch and several individuals or a functional team will offer complementary skills.

The following basic and advanced skills, and adequate attitudes and practices for occupational safety and health, will be common to the O&M Branch:

Basic skills

- Basic meteorology;
- Basic measurement science;
- Quality systems;
- Safety and hazard awareness; basic first aid practice;
- Use of personal computer software applications: word processing, spreadsheets, engineering drawing, flowcharts, electronic mail and Internet use; other productivity tools.

- Advanced skills*
- Resource planning;
 - Project management;
 - Electronic design;
 - System design;
 - Software engineering;
 - Communications engineering;
 - Calibration engineering.

- Occupational safety and health*
- Proper use of safety clothing and protective equipment;
 - Poisonous gases and vapours (solvents, mercury);
 - Corrosive chemicals (caustic chemicals);
 - Electrical shock hazards;
 - Falling weights;
 - Occupational overuse syndrome;
 - First aid training for injury (certified training).

- Branch management
Tasks
- Establish and manage contracts for basic data, including: upper-air observatories; voluntary observers; voluntary ships; climate data; METARs, and AMDAR;
 - Establish service level agreements with other divisions of the NMS for supply of quality data and maintenance services;
 - Provide for new and enhanced data acquisition systems to meet cost-effectively the ongoing needs of the NMS and its clients;
 - Maintain optimum quality and reliability of meteorological data collection by an effective programme of regular calibration and preventive maintenance;
 - Arrange for operational fault monitoring and response and timely repair of equipment;
 - Arrange participation in international cooperative programmes, e.g. the drifting buoy programme;
 - Arrange for the provision of appropriate guidance material and training on data collection procedures for staff and contractors and for monitoring of adherence to procedures;
 - Act as an expert spokesperson on overall data acquisition network matters;
 - Provide for participation in the WMO Commission for Instruments and Methods of Observation (CIMO);
 - Implement quality systems conforming to ISO 9000 requirements;
 - Provide financial and material resources (prepare and monitor budgets);
 - Report on the quality and performance of the overall data acquisition system as required;
 - Maintain, upgrade and optimally manage assets;
 - Recruit personnel with required skills;
 - Provide for staff technical training;
 - Conduct staff personal appraisals.

- Competencies*
- Staff leadership and personnel management;
 - Strong focus on meeting customer requirements;
 - Excellent oral and written communication skills;
 - Broad knowledge of all NMS processes depending on meteorological data;
 - Setting budgets and controlling expenditure;
 - Managing assets to maintain economic performance;
 - Strategic planning;
 - Negotiation skills;
 - Familiarity with WMO programmes, particularly the WWW;
 - Job scheduling to meet operational targets;
 - Working under pressure to meet deadlines.

- Network management
Tasks
- Manage the surface and upper-air observing programmes to provide optimum, representative and cost-effective networks;
 - Manage the marine observing programme (ships and drifting buoys) to provide an optimum network;

	<ul style="list-style-type: none"> • Contribute to network planning; • Site inspections; • Recruit and train contractors, voluntary observers and observing ships; • Contract for buoy deployment and buoy data processing; • Supply operating instructions and standard procedures to contractors and observers; • Ensure supply of station consumables; • Manage delivery of data from observing stations to Head Office to required quality including timeliness; • Maintain station records; • Negotiate with contractors operating observing programmes.
<i>Competencies</i>	<ul style="list-style-type: none"> • Understanding of forecasting and climatological data requirements; • Detailed practical knowledge and experience of all observing standards and techniques; • Problem solving ability; • Diplomacy; good liaison ability with other agencies and members of the public; • Negotiation skills.
Observing standards <i>Tasks</i>	<ul style="list-style-type: none"> • Ensure data quality (including timeliness and representativeness) complies with forecaster and climatologist requirements, and WMO standards for international exchange; • Develop and maintain ISO 9000 quality procedures for data collection; • Maintain a programme of inspections and quality audits for contractors and stations; • Coordinate the introduction of new data collection systems, techniques and codes, and arrange appropriate training for contractors and observers; • Survey and select observing sites; • Monitor network and contractor performance; maintain and analyse statistics.
<i>Competencies</i>	<ul style="list-style-type: none"> • Understanding of forecasting and climatological data requirements; • Detailed practical knowledge and experience of all observing standards and techniques related to the field context; • Conversant with WMO Regulations, WMO code practices, and the recommendations of WMO-No. 8, <i>Guide to Instruments and Methods of Observation</i>; • A well-developed quality culture; • Good analytical ability in statistical methods; capacity for problem solving.
Systems engineering <i>Tasks</i>	<ul style="list-style-type: none"> • Advise on new technical opportunities in meteorological data acquisition for new data sources, improved performance and reduced operating costs; • Introduce new data acquisition systems into operational use, and enhance existing systems; • Manage system development projects; • Develop in consultation with users, requirement briefs and system technical specifications; • Evaluate system options to meet user needs; • Estimate costs for projects and manage project budget; • Document projects with specifications, engineering drawings, tender and contract documents; • Arrange and manage technical procurement and liaison with suppliers; • Upgrade/develop information technology hardware and software as required; • Design for installation; arrange for sub-contractors to provide utilities; • Provide for data communications from remote sites; • Coordinate system communications, data formats and codes with NMS Information Technology Division; • Commission and test new systems to user specifications; • Provide for adequate technical manuals for operation and maintenance;

- Provide 'technology transfer' training for calibration, maintenance and operation.
- Competencies*
- Excellent understanding of users' data needs;
 - High level of technical knowledge on modern data acquisition systems;
 - Thorough knowledge of measurement science and error analysis;
 - Advanced skills in electronic design; software engineering and system integration;
 - Excellent technical oral and written communications skills (including engineering documentation);
 - Able to synthesize appropriate solutions; excellent problem solving skills;
 - Able to manage projects to tight time and cost targets.
- Provisioning and stores
Tasks
- Ensure reliable, cost-effective supply of meteorological consumables to contract and voluntary stations and ships;
 - Maintain an efficient, secure, and safe store of consumable items and spare parts for maintenance;
 - Monitor consumption of stores and purchasing lead times, and maintain inventories of stock-listed supplies, to facilitate the operation of an effective and reliable 'just-in-time' purchasing policy;
 - Maintain a database of preferred suppliers and purchase specifications;
 - Negotiate with potential suppliers for the best possible terms on inventory items;
 - Produce monthly stock balances and six-monthly stock audits as required by the Finance Division of the NMS.
- Competencies*
- Familiarity with the role of equipment and consumables in meteorological observing practices;
 - Ability to establish and manage good systems for stock control, purchasing and timely supply to users;
 - Thorough knowledge of commercial practices for tendering and contracts for supply of goods, terms of payment, international exchange rates, insurance, freight, customs clearance, invoicing, valuation and depreciation, and audit;
 - Negotiation skills to achieve supplies on favourable terms;
 - Computing skills to operate and maintain databases for stock inventories, order and payment status, and issue to users.
- Project management and
planning
Tasks
- Manage projects involving significant diverse resources for the establishment of major NMS data acquisition facilities, e.g. upper-air, radar and satellite receiving stations;
 - Apply for resource and planning consents; building permits from local authorities, and land leases;
 - Establish contracts for the supply of utilities and other services;
 - Liase with utility providers and works contractors;
 - Liase and negotiate with land owners, other agencies and local authorities;
 - Liase with lawyers and planning consultants.
- Competencies*
- Excellent technical appreciation of NMS data acquisition operations;
 - Well practiced in the use of appropriate computer-based project planning and scheduling tools;
 - Competent in writing specifications, producing engineering drawings and project reports;
 - Able to estimate financial and labour resources, and manage project budgets and resources to meet defined goals;
 - Practical knowledge of specification and safe installation of utilities: water supply, drainage, gas, electric power, telecommunications (both line and radio);
 - Good familiarity with national resource management law, contract law, and building and other government regulations;
 - Good problem solving and negotiation skills.

Measurement standards;
instrument calibration; quality
assurance
Tasks

- Manage and maintain NMS standards and their adherence to national and international standards, according to the ISO 9000 quality system;
- Manage instrument calibrations to an agreed schedule to maintain quality and meet operational demands;
- Document calibration procedures and maintain a calibration register;
- Provide specialist advice and evaluate meteorological sensors;
- Train technical staff in calibration procedures;
- Quality assurance;
 - Maintain an ISO 9000 quality system model or similar;
 - Maintain statistics and records of inspections and quality audits;
 - Analyse and review quality performance.

Competencies

- Intimate technical knowledge of the meteorological sensors, measurement systems and standards employed in the NMS data acquisition programme and the needs of data users;
- Conversant with WMO *Technical Regulations* (WMO-No. 49) and the *Guide to Instruments and Methods of Observation* (WMO-No. 8);
- Sound knowledge of national and international standards of physical measurement which are relevant to meteorology;
- Commitment to the selected quality system and competent in its application to instrument calibration;
- Good practical understanding of measurement physics, the treatment of errors and the derivation of appropriate statistics;
- Excellent manual skills in setting up and adjusting calibration equipment (including those with computer control) and the sensors under calibration;
- Competent with computer database systems for maintaining calibration records and able to maintain meticulous records of calibrations and instrument histories.

Field installation and
maintenance engineering
Tasks

- Prepare site works (concrete plinths, mountings, cable trenches, equipment shelters); liaise with sub-contractors;
- Do workshop fabrication and field installation of instruments and systems;
- Carry out commissioning tests;
- Plan for routine maintenance;
- Act on fault call-outs within agreed response times and priorities;
- Operate a help desk to respond effectively to fault reports and customer problems;
- Perform workshop and field maintenance of electro-mechanical, electronic and optical meteorological equipment, including corrosion prevention and refurbishing;
- Prepare site plans and equipment drawings;
- Prepare operating and maintenance instructions, including amendments;
- Maintain records of equipment installations, modification, calibration and repair;
- Maintain safe field and workshop practices.

Competencies

- Good understanding of how meteorological data is applied in the processes of the NMS;
- Sound technical knowledge of electronic and electro-mechanical meteorological instrumentation and systems;
- Familiarity with properties and processing of engineering materials: concrete, timber, ferrous and non-ferrous metals and protective coatings;
- Demonstrated practical skills and expertise in electronic and/or electro-mechanical maintenance in both the field and in the workshop;
- Good diagnostic and analytical skills, particularly when with limited support;
- Able to work effectively either as a team member or leader with other technical specialists;
- Well organized with good planning skills and attention to details.

7.4 INFORMATION TECHNOLOGY AND DATA PROCESSING

By H. J. Koppert, Deutscher Wetterdienst, Germany

The tasks performed in the Information Technology (IT) Department of NMSs differs little today from those at any scientific research institution. Significant differences can be found in the area of international telecommunication and in software engineering, where the software that has to be implemented and maintained is very specific to meteorology.

The principal job-competencies in an IT Department require skills and knowledge in certain areas (see the six sub-sections below). For all of those areas, a basic set of IT skills is necessary, these include:

- Recognize basic hardware and software components;
- Understand basic operating system functions like files and directories, menus and desktops, and networks;
- Experience with word processing/editing applications; and
- Use of e-mail and the Internet.

The detailed specifications of knowledge and experience in this paper reflects today's IT world (as of August 1999). The knowledge base described below may be not at the command of a single person, but an appropriate subset must be available within the NMS team.

Information systems operating Typically NMSs rely on mainframe/server computers. NWP models are run on vector or massively parallel supercomputers. Post-processing is done on powerful servers. Some NMSs operate Limited Area Models (LAMs) on powerful workstations.

An information systems operator has to:

- Monitor the information technology system's performance;
- Monitor the status of the jobs running on these systems;
- Use system management software to monitor all the servers and clients in NMS information technology system;
- Investigate anything that seems unusual;
- Take appropriate action in case of failures;
- Start, restart or kill applications;
- Start-up and shut down the computers.

The operator does this with:

- Experience with the System Operator utilities;
- Knowledge of system maintenance tools;
- Proficiency in specific batch job scheduling systems (e.g. SMS from the European Center of Medium Range Weather Forecasts);
- Proficiency in UNIX/Windows NT operating system;
- System commands, tools and applications;
- Shell programming (UNIX).

Database administration and programming NMSs have to store large amounts of observational, processed and gridded data. These data are stored in commercial relational-databases.

An associate database administrator:

- Is responsible for the storage and retrieval of NMS data;
- Develops and implements user interfaces to the database;
- Manages database backup and recoveries;
- Is able to configure, install, tune, and run SQL-databases;
- Is able to develop and implement data models together with internal and external users.

The administrator does this with:

- Profound knowledge of all database administration issues in order to be able to:
 - Establish mechanisms for backup and recovery using the database suppliers tool-set;
 - Tune, optimize for performance (especially for NWP data) and monitor the database;
 - Validate users;
 - Implement table spaces and indices;
- Knowledge of meteorological data codes (WMO GRIB and BUFR codes, sometimes GTS-reports, if the original GTS-reports are stored);
- Experience with relational and/or object orientated OO data modelling of station related, imagery, or numerical data using commercial tools like the entity relationship modeller;
- Experience with programming user interfaces with SQL, PLSQL, JAVA (Web-interfaces), embedded SQL, C, C++, and FORTRAN (interfacing with legacy code).

Networking NMS strongly depend on the flow of data and information in their network. Today's client-server architectures separate data from the client application.

A network specialist has to:

- Analyse the requirements of NMS network needs to make sure that it fulfils the needs of timely and secure data transmission;
- Set up NMS Local Area Network (LAN) and Wide Area Network (WAN) according to his or her assessment of NMS needs;
- Connect IT systems (e.g. supercomputers, workstation, X-terminals, PCs, printers, etc.) using cables, fibre optics, routers, hubs and modems;
- Apply and assess the available technology like Fast and Gigabit Ethernet, FDDI, HIPPI, ATM, DSL;
- Protect the network against unwanted access by installing firewalls and proxies;
- Monitor the performance of the network with the appropriate network management tools;
- Troubleshoot network problems.

The network specialist has to have:

- Profound knowledge of:
 - Line protocols like X.25, PPP, HDLC, Frame Relay and ATM;
 - The network protocol TCP/IP and of applications based on TCP/IP;
 - Routing protocols like OSPF, BGP, RIP, EIGRP;
- The ability to configure and install hubs, switches and routers (configuration is mostly centralized);
- Proficiency in configuring firewalls and in implementing NMS security policy on firewalls;
- Knowledge of SNMP-based Network Management Systems;
- Experience with performing proactive performance analyses e.g. with Ramon probes systems and network analysers;
- Experience with optimising LAN-performance by layer2/layer3 switching.

International meteorological telecommunication Advanced NMSs operate as part of International Meteorological Telecommunications specially equipped information technology systems (clustered, hot standby or fault tolerant). A message switching software is run on these systems.

Staff responsible for NMS international telecommunications or for Regional Telecommunication Hub (RTH) should have:

- Comprehensive knowledge of the Message Switching System (MSS) application software in use, especially:
 - For installing and updating the MSS application software;
 - To configure and give the parameters of the operated international connections;

- To configure the in-house connections from and to the computer centre;
- To install and to keep up to date the message distribution lists;
- To define the extent of logging and monitoring operations;
- Knowledge of the hardware configuration in use, including the operating system (e.g. UNIX):
 - Installation procedures;
 - Monitoring the operation of components to eliminate faults;
 - Checking that the state of the system is appropriate for the tasks it is to perform;
 - Back-up operations;
 - Upgrades;
- Knowledge of:
 - Network and communication protocols in use, e.g. X.25 and TCP/IP;
 - Data exchange via the Internet;
 - The parameters to be set for each of the connections in coordination with the remote installation;
- Knowledge of:
 - The codes used for meteorological information in messages;
 - Common practices in operating the international data exchange;
 - WMO regulations organizing the international meteorological message exchange;
 - The overall structure of the GTS.

Operating/application systems design and maintenance

NMHSs have to implement and maintain a variety of information technology hardware and software including supercomputers running the UNIX operating system, high performance servers and meteorological workstations also running UNIX and PCs running Windows system.

An analyst/operating systems programmer has to:

- Evaluate, implement and update the operating systems software and all the related software, such as compilers and libraries;
- Integrate all the computer systems hardware, such as CPUs, graphics cards, memory, disks and peripheral devices;
- Test and implement application software, such as editors, visualization packages, mathematical and physical libraries, image manipulation programmes, word processors, spreadsheets;
- Distribute software throughout the NMS network;
- Provide customer and technical support;
- Run system management software.

The information systems operator must have:

- Profound knowledge of the UNIX and/or Windows NT operating system, especially in the areas of:
 - Setting up and configuring workstations and/or PCs in a networked environment;
 - User administration/user accounting;
 - Management of file systems (e.g. create file systems, partition disks, create and manage logical disk volumes, manage swap space, monitor file system performance and usage);
- Experience in managing distributed computing environments together with Network Specialists. He or she should be able to configure clients/servers for NIS, DNS, NFS or DCE/DFS;
- Proficiency in utilizing the appropriate tools of software and hardware vendors;
- Experience with setting up printers, terminals and other peripheral devices;
- Proficiency in shell (UNIX) and Pearl programming;
- Experience in installing and updating application software;
- Experience in tailoring and implementing system management software like Tivoli, HP OpenView or CA Unicenter;

- Experience in integrating NT and UNIX, e.g. by employing:
 - Samba for file service;
 - Terminal servers;
- Experience with system troubleshooting.

Software engineering Most meteorological application software is very specific. A software engineer therefore has to have some profound knowledge of meteorology and meteorological codes.

A software engineer does the followings:

- Elaborates the software specification together with the users;
- Determines the computer platform, programming language, network resources and all the necessary application programming interfaces to be used;
- Codes, compiles and tests the software;
- Codes/decodes meteorological datasets (GRIB, BUFR, GTS-reports);
- Maintains software at programme level.

The following IT-capabilities are indispensable:

- Knowledge of software life cycle development;
- Experience in structured and/or Object Oriented (OO) analysis and design depending on strategy of the NMS;
- Proficiency in FORTRAN 90, C++ and JAVA programming for new software projects;
- Knowledge of FORTRAN 77 and C for the maintenance of legacy code;
- Proficiency in graphics programming with X, OpenGL, Direct X and JAVA foundation classes;
- Knowledge in building user interfaces with Motif, Tcl/TK, VISUAL C++ and JAVA;
- Experience in middleware (Corba, DCOM) for complex multi-platform and multi-programming languages projects;
- Experience in HTML, CGI, JavaScript programming to create and maintain Web pages;
- Proficiency in UNIX/Windows NT depending on the targeted platform;
- Knowledge (for certain applications) of:
 - NWP data (structure of model grids and parameters);
 - GTS-reports like FM12, FM13, FM15, FM16, FM 18, FM 32, FM33, FM 35, FM36, FM41 and FM 42;
- Knowledge of WMO BUFR and GRIB codes.

7.5 AGROMETEOROLOGY

By H. P. Das, India Meteorological Department

Developing weather forecasts for agriculture; products for the customer
Competency requirements

- Developing suitable techniques for accurate predictions of weather elements, which affect farm planning and operations;
- Developing special agricultural weather forecasts to serve weather related agricultural problems associated with the crop for specific locations;
- Interpreting actual and forecast data correctly and identifying the most relevant data for any given situation;
- Creating products consistent with guidance and relevant data.

Skills and knowledge; tasks

Know what guidance products are available and where to find them, i.e.:

- Obtain relevant agrometeorological data such as maximum and minimum temperature, wind, humidity, soil temperature, soil moisture and any other element, if required;
- Collect detailed information on types of crops, crop phenology, the date of occurrences of the main crop development phases, cultivation practices, soil types and other related information;

- Collect weather and climatological data to determine strategy, tactics and logistics in programme to monitor and control plant diseases and noxious insects;
- Obtain cardinal points (maximum and minimum limits) and optimum range of relevant agrometeorological parameters for potential growth and development of seasonal crops;
- Obtain normals of weather elements and data on probability of rainfall including conditional probabilities;
- Collect biometeorological observations on the health and diseases of live-stock.

Be aware of and make appropriate use of the available relevant information in preparation of user product. Know how to do the following:

- Develop techniques for predicting maximum and minimum temperatures, wind, humidity, dew and sky cover including cloud and sunshine percentage;
- Calculate a suitable drought index to assess prolonged and abnormal soil moisture deficiencies leading to delineation of potential disaster areas;
- Develop accurate methods for the prognosis of soil temperature and soil moisture;
- Calculate Potential Evapotranspiration (PET) by modified Penman's method;
- Calculate water requirements of crops from PET and crop coefficient values;
- Calculate a suitable crop moisture index to measure the status of dryness or wetness effecting warm season crops;
- Determine the weather conditions favourable for crop curing;
- determine growing degree-days to find the linear relationship between plant growth and temperature;
- Identify the weather factors responsible for the development of pests and diseases of crops and animals.

Be proficient in preparing special agricultural weather/phenological forecasts; be able to:

- Predict sowing dates, plant development stages and crop yield;
- Prepare phenological forecasts of onset of flowering of fruit trees; dates of ripening of fruit;
- Forecast soil temperature during the sowing period to avoid sowing or planting under adverse soil conditions which would have otherwise hindered proper seed germination/emergence;
- Predict conditions favourable for harvest operations of most crops and post-harvest operations such as curing;
- Determine the minimum soil temperature at the depth of the tilling node and critical temperature of plant freezing to predict crop freezing;
- Predict soil freezing and thawing dates;
- Forecast the most likely thermal conditions during the growing season of heat-loving plants;
- Develop methods of forecasting over-wintering conditions and estimate the extent of frost damage areas;
- Predict leaf wetness duration, as most plant diseases develop and spread in conditions of wet vegetation;
- Assess the current locust situation, provide forecasts up to six weeks in advance on their migration and breeding; issue warning on an *ad hoc* basis;
- Prepare forecast of maximum and minimum temperature for transport of agricultural produce along the transport route;
- Assess summer and winter growing conditions for cattle;
- Evaluate suitability of weather conditions for grazing, shearing and reproduction of sheep;
- Forecast adverse weather conditions and hazards relative to grazing of live-stock breeds;
- Forecast favourable weather conditions for poultry production;
- Assess how the health, development and quality of fish is affected by water pollution;

- Predict forest fire danger on the basis of moisture control of forest fuels, particularly during logging operations;
- Determine low level wind drift and stability factors for agricultural aircraft operation.

Be proficient in preparing weather bulletins for farmers, i.e.:

- Prepare crop-weather calendars comprising various weather warning requirements of the agriculturists and the life history and mean dates of important epochs of crop growth;
- Collect district-wide forecasts of weather during the next 48 hours with any special weather warnings along with the outlook for the subsequent two days;
- Based on the above, prepare and issue a weather bulletin for farmers indicating the onset and cessation of rain, probable rainfall intensity and duration and occurrence of adverse weather phenomena.

Determine priorities in situations when the distribution of special advisory information is proposed, i.e.:

- Be able to determine priorities of output material;
- Be able to work under stress with minimum disruption to normal routine work;
- Seek appropriate advice from colleagues with expertise in the specialized field;
- Get feedback from the users on improvement of the bulletins.

Acquire necessary skills to work independently, i.e.:

- Seek and take guidance from colleagues when appropriate;
- Solicit advice from colleagues towards improving forecasting technique;
- Be willing to try out new techniques suggested by colleagues.

Be proficient in the use of IT and operate any other special device not required as a routine, i.e.:

- Be able to set right minor faults in office IT system, as per local staff instruction;
- Be aware of the correct procedure to report faults in IT equipment to superiors, and inform when such equipment should not be touched;
- Be able to use IT equipment.

Developing an
Agrometeorological
Advisory Service (AAS)
Competency requirements

- Developing operationally useful forecasts of meteorological parameters important for current farming operations;
- Utilizing information on the state and stage of the crop and weather requirements for healthy growth;
- Giving objective interpretation of prevailing weather and its forecast in terms of its effect on crop growth and agricultural operations;
- Arranging regular consultation between weather forecasters and agricultural scientists;
- Applying a standard procedure for the evaluation of the effectiveness of the advisories issued;
- Framing the AAS bulletins consistent with the guidance and relevant information mentioned above.

Skills and knowledge; tasks

Know what guidance materials are available and where to find them.

- Collect promptly relevant meteorological data such as maximum and minimum temperatures, wind, humidity, average cloud cover and, if required, other relevant elements;
- Collect from relevant authorities routine information on types of crops, their strains and phytophases for the area under consideration;
- Collect detailed information on soil type, topography, climate, cultivation practices, etc.;

- Collect latest information on agriculturally vulnerable areas such as flood prone/drought prone areas;
- Determine the dates of occurrence of the main crop development phases, each of which has different climatic requirements;
- Collect cardinal and optimum temperatures for the major phenological phases of the crop;
- Identify the environmental parameters most likely to provide an early indication of any significant deviation related to the occurrence of pest and diseases;
- Determine the agrometeorological conditions favourable for the development of insects and parasites transmitting diseases to animals;
- Be able to get any further specific guidance material needed immediately but not required as a routine.

Be proficient in developing/issuing the required forecast products for AAS bulletins; know how to do the following:

- Be able to issue short-range weather forecast for rainfall, wind speed, maximum and minimum temperature, humidity, cloud cover and dew;
- Be able to develop and issue medium range forecasts (3 to 10 days) of rainfall that can be used in scheduling farm work;
- Be able to use the long-range weather forecast to advise potential users of the tentative nature of the monthly and seasonal outlook;
- Develop suitable crop yield forecasting models for a specific crop and area;
- Be able to indicate by means of a probability analysis the percentage risk of adverse weather;
- Be able to issue meteorological alerts about frost occurrence, conditions that favour the danger of forest fires or any phenomenon that could affect the agricultural activities of a region (e.g. strong wind, heavy rain, heat/cold waves, etc.);
- Be able to develop appropriate models to forewarn the onset, spread and severity of pests and diseases, which mostly depend on weather.

Be aware and make appropriate use of the available relevant information in preparing advisory bulletins. Interpret the forecast product judiciously, i.e.:

- Incorporate inputs of short, medium and long-range weather forecasts in the AAS bulletins;
- Demonstrate a capability to appreciate and apply forecasting models of agricultural yield and production;
- Compute the aridity index to monitor drought conditions;
- Compute soil moisture balance to find water deficit and water surplus periods during the growing period and plan for irrigation scheduling;
- Evaluate the optimal period for sowing which will have a decisive impact on the quantity and quality of yield;
- Be aware of how sowing and tillage are greatly influenced by the ground as well as soil moisture and soil temperature;
- Determine the optimum date for harvesting;
- Ensure that forecast products and agricultural information will be used jointly by agricultural scientists and agrometeorologists to prepare explicit interpretative guidance for users;
- Ensure that fertilisers and plant protection products (like pesticides and insecticides) are not used during periods of rain, high wind and high temperature;
- Determine the threshold values of temperature, precipitation, and speed of the wind for application of agricultural chemicals;
- Be aware of the effect of low temperature on the crop i.e. cold injury, hardness, frost damage and frost resistance;
- Be able to monitor the development of pests and diseases which is often closely related to the beginning of certain phenological phases of plants;
- Be aware of the fact that animal pests are resilient to desiccation, so temperature variables are often more important than wetness variables;

- Be aware that the key factors for the effective utilization of agrometeorological services are accessibility, presentation and relevance.

Analyse plotted charts with particular reference to presentation when used for briefing and for end-users, i.e.:

- Be able to analyse in detail all plotted charts needed in framing AAS Bulletins;
- Be able to give convincing reasons for the analysed features;
- Maintain the continuity and standard of the charts analysed.

Ensure the timely dissemination of advisories to farmers, i.e.:

- Be able to disseminate advisories quickly and efficiently using techniques like videotext, fax and teletext or by using conventional methods such as the postal service, press, radio, telephone, etc.;
- Be able to develop mechanisms that permit training of end-users, identify requirements of users and coordinate diffusion of information;
- Be able to evolve appropriate means to get feedback from proactive farmers, extension workers and grass-root level agricultural administration.

Evaluate the socio-economic aspects of the advisory service, i.e.:

- Be able to prepare an economic evaluation of agrometeorological advice to farmers for the country as a whole, including different agro-economic and agroclimatic zones;
- Be able to inform administrators about likely production/shortfalls and advice on policy matters like import/export;
- Be able to critically assess the shortcomings and successes of the activity carried out and identify areas where additional information is required.

Respond quickly while assimilating data and framing advisories, i.e.:

- Discusses with the group possible questions while formulating bulletins;
- Be able to identify inconsistencies/inaccuracies before dissemination;
- Know where to get the latest data, if needed;
- Be able to provide advisories at short notice.

Computer-based information system for operational application
Competency requirements

- Standardizing data collection and information delivery system for user requirements by incorporating new technological innovations;
- Using the agrometeorological data base judiciously for advisories and other operational decisions.

Skills and knowledge; tasks

Be proficient in operational application of agrometeorological data, i.e.:

- Be able to provide documentation in a user-friendly format available in microcomputer versions;
- Acquire the required expertise to sift through the data to formulate the best management decision rather than settling for the average expectation;
- Be able to disseminate in good time the recommended decisions to farm community centres using all available channels ranging from telephones to personal computers through to an agricultural network;
- Introduce new electronic technology in the form of 'bulletin boards' which offer a new means of transferring relevant data and information;
- Be able to present data clearly and simply so that the user can understand the meaning of the information which should be relevant and appropriate to the user's particular requirements.

Acquire skill for quality control checks of meteorological, phenological and agricultural data for operational purposes, i.e.:

- Evaluate the frequency of erroneous or missing data and correct these values following standard guidelines;
- Determine the extreme value thresholds based on climatological expectations and critically check values falling outside the determined thresholds;
- Prepare the format of data for operational use;

- Adopt an internationally recognized standard to establish a suitable code for specific crop types in all countries, as the data types often vary from region to region.

Incorporate remotely-sensed satellite data/imagery into an agrometeorological database for operational use. For this, the agrometeorologist must:

- Be aware of the advantages and limitations of using satellite information and imageries for operational purpose;
- Be able to make a fair estimation of rainfall, soil moisture, crop area, vegetation conditions, water supplies and desert locust migration, as well as land use analysis from satellite and aerial data;
- Be able to compute Normalized Difference Vegetation Index (NDVI) and other related vegetation indices for assessing crop phenology over large areas;
- Be able to develop Geographic Information System (GIS) allowing graphic product displays which are easy to interpret.

7.6 AERONAUTICAL METEOROLOGY

PART A: Principal job competencies required for the aeronautical forecasting

By T. C. Spangler and D. Wesley, USA: Cooperative Programme for Operational Meteorology, Education and Training (COMET)

The principal job competencies for aeronautical forecasters vary to some degree, but generally require skills and knowledge in three primary categories. The forecaster must have a clear knowledge of the:

- Meteorological hazards;
- Tools used to develop forecasts of aviation hazards;
- Procedures and formats of forecast products.

The aeronautical forecaster is typically responsible for terminal and route forecasts for various aircraft flights or missions. These include forecasts of both surface conditions at terminals and conditions aloft between terminals. The forecasts must include the potential occurrence of meteorological phenomena that are aircraft hazards.

Major hazards to aviation The major hazards to aviation, both near the ground and aloft are:

- Low cloud ceilings;
- Restricted visibility (both horizontal and vertical);
- Turbulence;
- Icing;
- Thunderstorms;
- Strong winds;
- Wind shear (both horizontal and vertical);
- Volcanic ash; and
- Extreme temperatures (both cold and hot).

In order to maintain and improve aviation safety, the aeronautical forecaster is responsible for forecasts of all of the hazards listed above, and in many cases for the global airspace. Typical time periods covered by these forecasts range from one hour to several days. For a particular hazard, competency requirements exist for the climatology of the hazard at various horizontal scales (hemispheric, regional and local) as well as the diagnosis and prognosis at the appropriate scale of the forecast area.

Forecasting skills for the particular hazards of aircraft icing and fog are described in the COMET/NWS Professional Development Series (PDS): Forecasting

Low-altitude Clouds and Fog for Aviation Operations; Forecasting Aviation Icing. The next two sub-sections highlight those skills.

Forecasting skills for aviation icing

Here is a list of procedures and skills required for forecasting aviation icing, as defined in the PDS, in no particular order of importance:

Climatology

- Recognize favoured geographical areas for occurrence of in-flight and ground icing related to snowfall during specific weather regimes and/or season of the year;
- Apply climatological data to the icing forecast process at all scales of motion (i.e., synoptic/mesoscale/microscale 'regimes' associated with in-flight and ground icing).

Large scale

- Recognize the hemispheric wave patterns that favour widespread over-running precipitation events;
- In order to assess the potential for an icing episode predict the response, within the area of responsibility, created by geography and regional topography, to hemispheric features;
- Identify the current and anticipate future hemispheric flow and moisture patterns to assess areas of precipitation and cloud movement, development and dissipation (trough/ridge locations, moisture patterns, jet stream location, orientation, and strength);
- Assess hemispheric vertical and horizontal temperature patterns to determine where the temperature structure is conducive to icing (e.g., warm vs. cold advection, subfreezing layers, etc.);
- Integrate remote sensing data, observational data, and numerical model output to identify areas where juxtaposition of parameters favourable for icing are occurring and are anticipated;
- Using knowledge of synoptic weather patterns related to icing, perform an analysis of initial synoptic-scale data to evaluate the potential for icing in the area of responsibility;
- Diagnose the current state of the atmosphere by analysing observational data in order to assess prominent features such as:
 - Surface and upper-air observations (temperature and moisture profiles, precipitation type, fronts, cloud height). Utilize vertical cross sections;
 - Pilot reports (PIREPs);
 - Radar mosaics (areas of precipitation);
 - Satellite data and derived products (basic weather patterns, cloud/snow cover, ridge-trough axes, presence of super-cooled liquid water at the cloud tops, frontal locations, temperature and moisture profiles, dry slots, and wave clouds);
 - profiler data for wind patterns and shear;
- Integrate these multiple data sets in order to superimpose/combine salient features listed above;
- Using knowledge of icing patterns and known model biases perform an integrated 4-D analysis of future synoptic parameters to evaluate the large-scale threat of icing in the region in the next 3 hours;
 - Use the knowledge of climatology to modify expectation of icing (e.g. air mass type and icing);
 - Assess the current trends in profiler, satellite, and radar data and apply these trends to the anticipated icing region, both spatially and temporally;
 - Evaluate changes in icing potential using numerical model data. Do this by determining expected profiles of moisture and temperature at appropriate locations based on modifying the current profiles using gridded model data. These data may be automated using existing data sources (e.g., received from GDPS centres via the GTS, or from the Internet);
 - Determine expected (or forecast) parameters for existing icing algorithms, such as the stovepipe, in order to apply these algorithms on the synoptic scale;

- Forecast general type of icing (rime, clear, mixed, ground, and mechanically-induced icing) based on evaluation of expected patterns and parameter values;
- Repeat the above steps for the large-scale threat of icing in the region in a three- to twenty-four-hour time period, utilizing primarily gridded model predictions and icing algorithms. (Note: the break-up of time periods at 3 hours was chosen arbitrarily and is intended to separate the nowcast and forecast regimes).

Mesoscale

- Diagnose the current mesoscale-state of atmosphere using integrated satellite and Doppler radar data, surface and upper-air observations, profiler data and PIREPs;
- Conduct an analysis of gridded mesoscale model data to determine presence of physical mechanisms favourable for future icing;
- Anticipate how local geographic features impact the initiation and intensification of icing;
- Forecast type of in-flight and/or ground icing based on expectations of the mesoscale observations and model output;
- Determine from sounding data if conditions are favourable for icing to exist. Examine moisture profile, height of the freezing level, magnitude of warm layers aloft, and temperature structure above freezing level to assess if conditions would be conducive to super-cooled water droplets or ice particle formation;
- Use satellite data to evaluate changes in clouds (coverage, type, and temperature);
- Use bright band observations from radar, winds aloft, etc., to determine current height, extent, movement and slope of freezing/melting levels, multiple layers and reflectivity associated with moisture content above the freezing level, etc.;
- Utilize refined techniques for using radar observations to monitor changes in the height of melting levels;
- Define techniques that can be used to adjust the spatial extent of existing icing using PIREPs about icing, winds, and temperatures aloft. Look for areal and temporal trends in multiple PIREPs;
- Use numerical model data to assess areas of icing potential and the movement of those areas;
- Apply methods introduced in various research studies relating temporal and spatial (vertical and horizontal) parameters to icing events;
- Apply climatological/regional historical studies relating geographic influence possibly impacting or enhancing areal coverage or severity of icing events (orographic influences, etc.);
- Demonstrate and utilize knowledge of the physical and theoretical concepts and parameters related to icing type and severity (i.e. liquid water content (LWC), cloud processes/type/extent, temperature, droplet size, and precipitation) in the development of an icing forecast;
- Using observational tools (skew-T, PIREPs, satellite data and derived products) evaluate parameters such as cloud cover and type, temperature, and location of Super-cooled Liquid Water (SLW) for the purpose of locating possible icing and determining icing severity;
- Using national mosaic, local radar data, satellite data and surface observations, evaluate parameters such as precipitation location, precipitation type, and cloud cover for the purpose of locating areas of freezing precipitation and likely areas of Super-cooled Large Droplets (SLDs) aloft;
- Using numerical model output determine the current and future state of parameters such as SLW, precipitation, and location of subfreezing layers for the purpose of estimating locations of icing and icing severity;
- Integrate the diagnostic icing algorithms into the forecasting process to further evaluate the icing environment;

- Operations*
- Evaluate how icing conditions or the forecasts of icing conditions affect the day-to-day aviation operations within the global airspace. This includes whom these conditions and forecasts affect and how they are affected;
 - Readily communicate details of icing conditions or forecasts of those conditions in a tailored form that can be easily interpreted by decision-makers;
 - Determine the effects of over-forecasting the severity and/or coverage of icing;
 - Evaluate the impacts on airfield operations and aircraft at the airfield:
 - Mission cancellation/delay;
 - General flight delays;
 - Aerodrome closure;
 - Ground de-icing operations;
 - Holding patterns;
 - Air Traffic Control activities and dispatch;
 - Flight planning;
 - Fuelling.
 - Evaluate the impact on in-flight operations:
 - Refuelling;
 - Training;
 - Flight level and route assignments;
 - Anti-icing technology;
 - Phases of flight, including taxi, takeoff/climb out, en-route, emergency descent, descent-transition to final approach, final approach-landing-rollout and missed approach.
 - Determine the impacts of under-forecasting or not forecasting icing;
 - Evaluate the impact on these airfield operations and aircraft at the airfield:
 - Ice accumulation on aircraft;
 - Aircraft safety on takeoff and landing;
 - Holding patterns;
 - Runway conditions.
 - Evaluate the impact on these in-flight operations:
 - Communications and electronics;
 - Aerial collection systems;
 - Flight level and route assignments.
 - Ensure product consistency between icing forecasts and other aviation-related products (TAF, advisories, flight planning sessions, etc.);
 - Apply quality control procedures to ensure icing forecasts are logical and applicable;
 - Understand pilot reports of icing and the appropriate terminology: trace, moderate, severe, rime, clear, and mixed;
 - Keep a record of icing events and the severity of their impacts on aircraft operations.

Forecasting skills for fog and low stratus

Here is a list of procedures and skills required for forecasting fog and low stratus, as defined in the COMET/NWS Professional Development Series (PDS), in no particular order of importance:

- Climatology*
- Determine the frequency of fog and low cloud scenarios for your local area (or area of interest), including the typical duration of these events and the severity of their impacts on ceiling and visibility;
 - Determine the soil moisture and temperature climatology for your local area (or area of interest), and how it relates to the fog and low cloud climatology;
 - Determine the water temperature (if applicable) climatology for your local area (or area of interest), and how it relates to the fog and low cloud climatology.
- Diagnosis*
- Analyse atmospheric observational data, both synoptically and on the mesoscale, and address how the different data types might interrelate to create favourable or unfavourable conditions for fog or stratus; focus on:

- Existing cloud cover: current height, depth, and trend;
- Temperature and moisture profiles;
- Temperature and moisture sources and sinks;
- Inversion cap strength and height;
- Vertical motion;
- Radiation effects (cooling and heating);
- Wind effects (advection and mixing);
- Orographic effects.
- Analyse surface influences and their relationship to the low-level wind field, and how these factors might interrelate to create favourable or unfavourable conditions for fog or stratus; these surface influences include:
 - Land/water distribution (rivers, lakes, ocean, etc.);
 - Land use (dry land, irrigated farming, urban land);
 - Topography;
 - Vegetation and soil types and temperatures;
 - Wet ground as a moisture source;
 - Snow cover;
 - Sea-surface temperatures.

Prognosis

- Analyse the important radiative processes (including effects of deep and shallow moisture) and how they might change during the forecast period;
- Consider advective processes (temperature and moisture) and their effects on the vertical profiles;
- Assess rain- or snow-induced processes (soil moisture, convective outflows, low-level moisture, and snow cover);
- Consider orographic effects on low-level wind fields, vertical motion and potential gravity waves;
- Analyse the effect(s) of the synoptic-scale wind field evolution; estimate anticipated low-level vertical motion, and consider the associated effects on the boundary layer;
- Distinguish between factors that contribute to fog formation and factors that contribute to elevated stratus or stratocumulus;
- Utilize numerical models and gridded forecasts for large scale, regional scale, and mesoscale guidance for the fog and low clouds forecasts:
 - Assess the accuracy of model initializations;
 - Consider model biases and limitations;
 - Apply local or mesoscale model(s), if applicable, including prognostic or empirical algorithms;
 - Translate the appropriate numerical forecasts into effects on the local fog and stratus evolution.
- Anticipate atmospheric conditions important to ceiling and visibility forecasts by utilizing both observational data and the critical factors in the model data assessed in the preceding instructions which read: ‘utilize numerical models and gridded forecasts ...’:
 - Vertical and horizontal distribution of temperature and moisture;
 - Vertical atmospheric stability and motion;
 - Evolution of cap strength and height;
 - Radiation effects;
 - Wind effects on temperature and moisture (advection, mixing) and radiative situation;
 - Frontal effects;
 - Orographic effects;
 - Depth of fog or cloud;
 - Surface influences (including oceans/rivers/lakes, soil moisture and snow cover).

Tools for forecasting

The aeronautical forecaster must be proficient at utilizing a number of observational and numerical tools in preparing aviation forecasts. These generally include:

- Global meteorological models;
- Regional models;
- Local (mesoscale) models;
- Surface observational data (including radar);
- Satellite observations;
- Upper-air observations (including PIREPs and wind profiler);
- Ship reports;
- Model-based aviation forecast algorithms (current examples include algorithms for predicting turbulence, icing and wind shear).

Each of these tools has specific applications to forecasting aviation hazards and these applications must be clearly understood by the forecaster. Such understanding includes the advantages and limitations of each forecast tool. The tool applications may occur at various horizontal scales (global, regional and local) – according to the skills previously listed.

The tools listed above are embedded within the aviation icing and fog/low stratus skills listed in the last two sections respectively. As an example, the last but one skill under the heading Mesoscale in the icing section specifies the applications of numerical data in assessing the current and future state of icing-relevant atmospheric parameters. This skill involves applying the first three tools above (meteorological models – global, regional, local) for these parameters. Another example, for fog/low stratus, is the first skill under the heading Diagnosis (previous section) utilizing observational data to assess cloud cover and the dynamic-thermodynamic state of the atmosphere. The tools utilized for these skills relate to surface observational data, satellite observations, upper-air measurements and ship reports.

Product dissemination

In addition, the aeronautical forecaster must be proficient at issuing forecast products to users (e.g. pilots, controllers, dispatchers, ATC and private forecasters) in a clear, structured manner, so that the users can fully and safely utilize them. Typically, products are issued at predetermined time intervals and forecast amendments may be issued at any time. Communication between forecasters and users and forecast amendment procedures, are critical ongoing processes in the current global aviation environment.

The structure and format of aviation forecasts vary widely across the various centres and agencies that produce them. Media utilized for the products and forecast tools include the web, local information technology networks, and national/international networks. The aeronautical forecaster should have a working knowledge of all of these product media, including the methods of obtaining data and forecast products and procedures for issuing products and amendments.

PART B: Required competencies of an aviation forecaster at a regional office

By H. Pümpel, Austria: Civil Aviation Meteorological Service

Rapidly changing and evolving needs of the aeronautical community have led to a reappraisal of the services required and of the means and forms of communicating weather information (observations, forecasts, warnings) to clients. Automation of many activities together with a massive increase in information available to meteorological personnel, be it *in-situ* or remotely-sensed measurements, high-resolution model forecasts, statistical post-processing and IT techniques requires a new approach to training and assigning of tasks to aeronautical forecasters.

Routine duties at a regional aeronautical meteorological office

- (a) *Weather watch*: continuing monitoring of weather phenomena relevant to aviation, including the continuing interpretation of observations and forecast products to form a 4-dimensional understanding of the development of weather systems from the synoptic to the mesoscale;

- (b) *Effective communication* with forecasters at the relevant meteorological watch office and neighbouring regional offices, using synoptic guidance from — and giving regional feedback to — those offices;
- (c) *Deriving user-oriented forecast and warning products* at regular intervals and on demand;
- (d) *Oral briefings to aeronautical users and liaison with ATC personnel*. Specific briefings for flights where ready-made products are not sufficient and close liaison with Air Traffic Control personnel for an efficient use of terminal and aerodrome capacity;
- (e) *Ongoing user training for pilots, dispatchers and airport personnel*, to ensure effective and clear communications.

These duties require the following basic qualifications and competencies:

Knowledge and skills in weather watch and monitoring

Ability to attribute weather phenomena relevant to aviation (as specified in WMO *Technical Regulations* (C.3.1) – Volume II – Meteorological Service for International Air Navigation [WMO-No. 49]) observed at the aerodrome and farther afield to weather systems currently affecting the area. This requires both an understanding of dynamic meteorology including the dynamics of mesoscale processes from synoptic-scale systems down to rain-bands and mesoscale convective systems; and the ability to relate observed and/or reported phenomena to prior analyses of synoptic weather charts from the surface to levels beyond the tropopause.

Technical skills in handling and interpreting data; processing systems linked to both *in situ* and remote-sensing observing systems. It would include familiarity with the interpretation of satellite imagery in all available spectral bands (IR, WV, VIS), in particular the identification of cloud types using different images.

Handling skills in selecting the most appropriate image product for the problem at hand (e.g., WV imagery to identify tropopause folds and jet stream location, VIS imagery to locate KH-waves and gravity waves in cirrus cloud). Also, detection of convective systems forming and decaying, locating active cumulonimbus-tops, determination of icing potential in layer-cloud using cloud-top-temperature inferred from PDUS-IR data.

Manipulating skills in using modern weather radar data both from radar compounds and local, wind shear detecting Doppler radars. This includes the ability to detect the potential for MCS formation, identify rotational components suggesting tornado developments, hail potential using reflectivity and polarimetric information, indications of storm splitting and daughter-cell generation, squall line formation.

Correlative skills, including ability to incorporate surface observations into the picture formed from all other sources. Identifying the weather phenomena relevant to aviation in special pilot reports, classifying them and distributing this information to other pilots, ATS and the meteorological watch office. Also, ability in the interpretation of lightning detection displays and extrapolation of cell movement and splitting from lightning-data for nowcasting purposes.

Skills in communicating with central offices and neighbouring stations

At the regional offices, aeronautical forecasters will need the ability to:

Rapidly ingest guidance forecasts at the beginning of a shift where no hand-over is possible (stations not operating 24 hours), or to align local hand-over information with centrally issued guidance products. This process involves a critical appraisal, verifying that guidance products are still in line with the locally and regionally observed weather development.

Fill in the regional detail in the overall picture, ensuring that important features are fed back to central institutions (e.g., a PIREP of mod/sevicing when no SIGMET

has been issued needs to be brought to the immediate attention of the meteorological watch office).

Ensure correct interfacing to neighbouring regions, resolving any discrepancies – e.g., in adjacent route or area forecasts by communicating to and resolving the differences with the staff concerned.

Prepare a concise and comprehensive hand-over to subsequent shifts, remarking in particular on any unusual or unforeseen developments.

Deriving user-oriented forecast and warning products

Having gained a sufficiently detailed insight on the dynamic processes currently affecting the area of responsibility, user-oriented products need to be issued both at regular intervals and on demand (situation dependent). The competencies required for this work include:

Familiarity with all aeronautical meteorological codes as defined in the WMO *Manual on Codes* (WMO-No. 306) and WMO *Technical Regulations C.3.1/ICAO Annex III* (WMO-No. 49). Firm knowledge of all criteria applied to warnings and change groups in forecasts (TAF, TREND; GAMET, etc).

Understanding of the weather phenomena hazardous to aviation, their diagnostics and prediction. The forecaster needs to be intimately familiar with the analysis of weather parameters constituting hazards to aviation. This includes understanding of the capabilities and limitations of:

Algorithms and methods to derive icing potential from radiosonde ascents and model output, as well as statistically derived icing potential. As these methods are based on past observations and model runs, he/she should have the ability to monitor current developments using real-time information from satellite imagery and radar composites; at the same time he/she should also ensure that weather features conducive to icing are tracked correctly and their changes in intensity are well captured. Onset of precipitation, change of inversion heights and other factors affecting moisture supply or drop-size spectra (shallow convection) need to be monitored.

Turbulence detection algorithms typically based on Richardson numbers or dissipation of turbulent kinetic energy, both for rawinsonde data and model output;

Algorithms and methods to detect gravity waves and their breaking potential, applying both algorithms and manual analysis methods, again based both on rawinsonde data and model output;

Model-predicted convection and gust fronts, incorporating both output from high-resolution models, kinematics extrapolation techniques and interpretation of Doppler weather radar data.

Critical appraisal of model guidance used in preparing forecasts. This involves a fair understanding of the model characteristics, both in terms of horizontal and vertical structures and of the way in which sub-grid-scale processes are treated. In order to interpret correctly forecasts of convection, it is necessary to know the treatment of radiative processes (i.e., how often is the radiative flux recalculated based on changing cloudiness etc.), the way soil properties and vegetation is incorporated, and whether convection is explicitly treated or parameterized. For the prediction of local wind systems, be it sea breezes or topographically induced features such as valley winds, the exact knowledge of sea/land point distribution, grid point elevation, etc., is needed.

Good understanding of statistically derived guidance. Statistical interpretation of numerical model guidance is commonly used to predict surface winds, gustiness,

temperatures and cloudiness/rainfall characteristics for individual airports. In the case of forecast offices producing TAFs for distant aerodromes, such enable the incorporation of local climatology in the forecasts. An in-depth knowledge of the governing equations and stratification of the data used in their development is a prerequisite for the correct use of such methods.

Good appreciation of the needs and problems of aviation users. Aviation forecasters, although quite specialized already, still face a variety of clients with widely differing needs (for example, see the ICAO requirements for helicopter operations). Cloud bases or visibility restrictions in route forecasts for general aviation or helicopter operations in a maritime or mountainous environment need to be highly detailed to avoid endangering the safety of VFR flights. It is imperative that an aviation forecaster understands which parameters are critical for the safety and regularity of individual user groups in order to highlight essential information.

Oral briefings to pilots and dispatchers; liaison with ATS

Provision of oral briefings, where the written documentation is not sufficient. Although airline pilots nowadays rarely have the opportunity to attend face-to-face briefings, many situations still require competent personal briefings or telephone contacts. As in the preparation of tailor-made forecasts, the ability to 'speak the clients language', i.e., to understand the specific problems of a particular operation, is vital. The forecaster needs to have excellent communications skills in order to obtain all the necessary information about the planned flight or operation. He/she needs to focus on the important questions leaving aside any unnecessary information in order to avoid 'information overkill', risking the obliteration of safety-relevant information with details of weather developments that are irrelevant to the client.

Basic understanding of ATS procedures. The efficient use of airspace and terminal aerodrome capacity requires excellent cooperation of meteorological and ATS staff. ICAO regulations stipulate that warning and TREND criteria are to be fixed in close collaboration with air traffic services units, to ensure that essential information (e.g., change of runway direction, imminent thunderstorms, onset of snow or freezing rain) is effectively communicated, and proper action is taken. Feedback of information from ATC staff such as pilot reports, sudden speed changes due to wind shear is invaluable for forecasters.

Ongoing user training

As face-to-face briefings are becoming the exception rather than the rule in aviation, the ability of users to clearly understand the contents of forecast products and flight documentation is paramount to the safe operation of aircraft. As the staff of meteorological offices at or near aerodromes have the advantage of being near the users both physically and in terms of understanding their problems, they should also play a vital role in user training. Refresher courses on changes in meteorological codes and forecast products should be offered at regular intervals to all aviation users, be it pilots, dispatchers, or planning staff. Airport authorities in charge of activities such as snow clearing and passenger handling also need to be regularly updated on the warnings and forecast products intended for their use.

Meteorological staff therefore require basic training skills and the ability to present short lectures in an understandable language and with decent graphical displays. Such displays may have been produced centrally, but forecasters should have the ability to add and modify training material for special purposes, e.g. local needs and specialized user groups. User training should include the encouragement of users to request special briefings in circumstances where standardized briefing and documentation are considered insufficient (e.g., extreme or unusual weather situations, technical problems on the side of the operator such as, for instance, failure of de-icing equipment).

7.7 MARINE METEOROLOGY

By L. N. Karlin, Russian State Hydrometeorological University, Russian Federation

Marine meteorology is a vast area of knowledge. From the customer's point of view, the main products of marine meteorologists refer to meteorological and oceanographic services in support of human activities related to the use of marine resources. These services include weather and sea forecasts with different ranges, storm warnings for the various ocean areas and regime and analysis-type hydro-meteorological descriptions of the state of the Boundary Layer of the Atmosphere (BLA) and the Surface Layer of the Ocean (SLO). In providing these services, marine meteorologists (graduate professionals and technical personnel) should:

- (a) Fulfil the requirements of the relevant guides and manuals;
- (b) Take into account the geographical peculiarities of their area of responsibility;
- (c) Constantly improve their specialist knowledge and qualifications;
- (d) Interact with colleagues and their immediate supervisor in a spirit of constructive cooperation.

Marine Meteorologists in NMSs are usually involved in four different types of activity: marine forecasts, observing the characteristics of the BLA and of the SLO; regime descriptions of marine areas; and investigations of the BLA–SLO system. In addition, marine meteorologists and technicians prepare specific products for customers, and perform other duties, as appropriate in any given workplace.

Marine forecasts This section concerns duties such as: using modern methods for processing and analysing hydrometeorological data, and calculating and forecasting characteristics of the atmosphere and the surface layer of the ocean; and using data from actual observations, including standard radar and satellite data, data from soundings and special data.

The specialist must know:

- What reference documents are needed for his professional activity;
- How much of the information needed for preparing the product is at hand and where to find what is lacking;
- Modern methods for forecasting the state of the atmosphere and SLO;
- Regional peculiarities affecting the formation of BLA and SLO characteristics in his area of responsibility.

The specialist must be able to:

- Make use of the relevant guides and manuals;
- Receive the necessary information on request by modern communication methods;
- Use workstations quickly and efficiently to find the necessary information, i.e. observational data, forecasts, models, such as regional descriptions;
- Decode satellite and radar information and interpret it correctly;
- Analyse synoptic and hydrometeorological charts;
- Prepare forecasts with various ranges of the state of the atmosphere and the surface layer of the ocean, using modern methods, for his area of responsibility;
- Compile storm warnings concerning dangerous and natural hydrometeorological phenomena in his area of responsibility;
- Use the results of numerical forecasts to predict the hydrometeorological situation in local conditions relating to his area of responsibility;
- Monitor changes in the state of weather and sea situations, and the characteristics of BLA and SLO in his area of responsibility and respond to them in real time, making the relevant corrections to the products.

- Observing the characteristics of BLA and SLO
- The specialist must know:*
- The structure, composition and characteristics of the BLA–SLO system, including the near-water atmospheric layer and the skin layer, and its fundamental characteristics;
 - The main physical processes permitting the formation of the BLA–SLO system, including the atmospheric layer near the water and the skin layer;
 - The main methods for processing and analysing hydrometeorological information;
 - Methods and means for standard satellite and radar hydrometeorological observations, including both marine and sounding methods.

The specialist must be able to:

- Plan, organize and conduct standard and extended observations of the characteristics of the boundary layer of the atmosphere, the layer of atmosphere near the water, the skin layer, and the upper mixed layer of the ocean;
- Process the observation data, perform an initial analysis and reject erroneous measurements;
- Archive the observation sets obtained;
- Use methods for calculating and forecasting the state of the BLA, the near-water atmospheric layer and the SLO, including the skin layer;
- Meet the requirements for products submitted by the main customers.

Regime descriptions of marine areas

The specialist must know:

- The structure, composition and characteristics of the BLA–SLO system, including the skin layer and its fundamental characteristics;
- The main physical processes permitting the formation of the BLA–SLO system; including the atmospheric layer near the water and the skin layer;
- The main methods for processing and analysing hydrometeorological information;
- The methods for compiling the regime descriptions;
- The main regime descriptions of BLA and SLO in his area of responsibility;
- Air-ocean interaction parameters in the region to aid any calculations.

The specialist must be able to:

- Calculate the fluxes of momentum, radiant energy, heat, moisture and salt across the surface of the ocean–atmosphere interface using standard methods;
- Calculate the characteristics of the BLA and SLO using standard synoptic information and data from satellite and radar observations;
- Calculate the characteristics of the layer of the atmosphere near the water and the skin layer;
- Adjust data from land observations in order to extend them to the sea;
- Compile initial data and enter it on the computer for calculations using the available programmes;
- Calculate the statistical values for hydrometeorological characteristics necessary for regime descriptions;
- Compile a regime description.

Investigation of the BLA–SLO system

The specialist must know:

- The structure, composition and characteristics of the BLA–SLO system;
- The main physical processes in the BLA–SLO system;
- The methods for modelling and measuring the BLA–SLO system.

The specialist must be able to:

- Formulate new and improve the existing models of BLA–SLO system;
- Conduct numerical and *in-situ* experiments on BLA–SLO system investigation;
- Develop recommendations for the optimal use of the products by customers.

Preparation of the products for the customer

The specialist must:

- Interpret the observational and forecast data correctly;

- Submit the products in the formal, according to the specifications required by the customer;
- Develop recommendations for the customer for the optimal use of the products;
- Be helpful and polite to the customer, responding to criticism in a professional manner.

The specialist must be able to:

- Respond efficiently to the changing requirements of the customer and quickly adapt to them;
- Send the relevant products to the customer efficiently, quickly contact the customer and introduce any changes caused by unforeseen circumstances to the delivered products;
- Ensure that all products reach the customer on time;
- Ensure regional Collaboration between scientists and stakeholders.

Performing other duties The specialist must fulfill specific assistance responsibilities, which are an essential part of marine meteorological work in the given office.

The specialist must know:

- The structure, hierarchy and financial policies of his institution;
- The internal regulations and security techniques in his institution and apply them.

The specialist must be able to:

- Use the office's information systems, keep them in working order and eliminate any deficiencies at the user level;
- Use the organizational technology which is necessary for the work, keep it in working order and eliminate any deficiencies at user level (projectors, photocopiers, etc.).

7.8 ENVIRONMENTAL METEOROLOGY

By B. Angle, Canada, Atmospheric Environment Service

The science of meteorology has broad applications beyond traditional weather forecasting. There is a growing demand for expert scientific advice and information regarding the state of the atmosphere, atmospheric issues and their interrelationships with human health and security, the economy and natural ecosystems. Policy-makers, scientists, other orders of government, national and international institutions and organizations, academia, industry representatives, media, environmental non-government organizations, and citizens demand scientifically accurate information and relevant warning services. The following provides an introduction to required skills of an air quality meteorologist.

Understanding the role of NMSs in addressing environmental issues This section concerns the role and relationship of NMS to other government departments and other jurisdictions (e.g. multilateral, bilateral, national, provincial, municipal) in the development of policy, systematic observations and services related to environmental issues so that environmental services are developed, implemented or enhanced.

The trainee has achieved this by demonstrating knowledge of:

- The mandate, mission, policy development requirements and priorities of the NMS concerning atmospheric and related environmental issues, and environmental prediction;
- The organization, responsibilities, programmes and working arrangements with other departments, agencies, academia and the private sector relevant to atmospheric issues, environmental services and applied research;

- The planning, development, organization and conduct of scientific programmes for key atmospheric issues (air quality, climate variability and change, smog, stratospheric ozone depletion, ultra-violet radiation, etc.);
- The relevant legislation, regulations, bilateral and international agreements or protocols in order to understand the basis for work objectives and constraints and to advise stakeholders and partners;
- The organization, responsibilities, programmes and working arrangements concerning relevant science activities taking place in government and non-governmental environmental organizations, especially in bordering states; also the WMO and UN environmental programmes; to collaborate with all these agencies on activities of mutual priority and interest and to keep abreast of the latest scientific developments and programmes.

The skills and knowledge which relate to this section are:

- Explaining the role of government, national or international organizations and institutions;
- Listing relevant legislation and regulations related to the issues;
- Explaining the mandate of the NMS and its relationship with other partners or stakeholders;
- Locating sources of information on environmental issues and sciences (e.g. journals, virtual libraries, and institutions);
- Describing the main issues, with emphasis on the current status, extent of the problem, and policy related to:
 - Acidic deposition;
 - Stratospheric ozone layer depletion;
 - Climate change impacts and adaptation strategies;
 - Air quality (smog) and particulate matter;
 - Mercury deposition.

Understanding environmental sciences and their applications

Required job-competency, knowledge and skills: fundamentals of environmental sciences are thoroughly examined; the sources of data, the science and its applications are understood; and utilized in the preparation of environmental services and products.

The trainee has achieved this by demonstrating a knowledge of the:

- Theories, principles, and applications of meteorology, climatology, physics, mathematics, numerical modelling, chemistry and physical geography necessary to carry out the atmospheric science programme;
- Major atmospheric issues (e.g. air quality, climate change and variability, smog, stratospheric ozone depletion and acidifying emissions), including their cause, characterization, interaction, and health, socio-economic and natural environment effects;
- Statistical/mathematical theories and methods required to select appropriate measurement and analytical techniques;
- Instrumentation, observing networks, data collection and data management principles and practices used to develop environmental products and services;
- Contents of and access methods for national databases, such as the climate archives or the air pollution surveillance databases, and other related data stores;
- International sources of data and information on environmental issues, their retrieval, and limitations and intellectual property rights or copyright protection applied thereto;
- Operating and programming of computers, programming languages and specific software used for statistical analysis, database management and the visualization/presentation of data and information.

The skills and knowledge, which relate to this section, require the ability to:

- Describe the observational systems, measurement techniques, data availability and measuring networks related to pollution monitoring, UV-B, ozone, hydrometric or other networks;

- Explain the air pollution transportation cycle and meteorological conditions, which control the dispersion of pollutants;
- Distinguish between local, regional and global scales of pollutant transport;
- Explain how the following atmospheric factors affect dispersion:
 - Wind direction, speed, character;
 - Atmospheric stability (mixing height, ventilation coefficient);
 - Turbulence;
 - Weather;
 - Local effects (wake, terrain, sea-breeze, valley, urban, etc.);
- Explain the characterization of dispersion for neutrally buoyant gases, heavy gases and particulate material;
- Assess and describe the atmospheric chemistry important to pollutant transport and transformations through the atmosphere (e.g. molecular weights, gas laws, concentration units and concept of residence time);
- Describe the effects of cloud and weather on chemical transformations in the atmosphere;
- Describe the basic tropospheric chemical transformations and transportation processes from source to removal:
 - Natural versus anthropogenic sources;
 - Acidic deposition;
 - NO_x/VOCs/Ozone;
 - Greenhouse gases;
- Distinguish between the basic production process of low-level versus stratospheric ozone including the role of CFC's and other ozone depleting substances;
- Describe the causes, distribution and concentration of ozone in the boundary layer and stratosphere and its destruction or dispersion;
- Describe computer modelling of pollutant dispersion in long range, regional and local scales and its limitations;
- Diagnose the meteorological situation on various scales to assess the dispersion of air pollutants and thoroughly examine all sources of data including:
 - Analysing charts accurately and according to standard practices;
 - Assessing model output related to atmospheric dispersion and transport;
 - Examining satellite imagery, radar imagery and spherics data with an appreciation for the limitations of, and possible errors in, the data;
 - Using tephigrams and hodographs as a forecasting aid, making correct use of appropriate constructions (e.g. maximum temperature, cloud structure, stability indices etc.);
- Interpret actual and forecast data correctly and identify the most relevant data for any given situation, i.e.
 - Demonstrate an acceptable knowledge of the local geography, climatology and weather characteristics; and
 - Apply local forecasting techniques.

Providing services; delivery of scientific advice and information

Required job-competency: provide services, through the delivery of scientific advice and information, to departmental managers, policy-makers, scientists, other orders of government, academia, environmental non-governmental organizations, industry and the general public, on atmospheric issues pertinent to key environmental problems.

The trainee has achieved this by demonstrating a knowledge of the:

- Design and anticipated development of environmental services and products;
- Methods, techniques and practices used to determine user requirements for environmental services, products and customized investigations;
- Techniques, methods and practices for participating in interviews with radio, television and newspaper reporters to present and defend atmospheric scientific information, explain the scientific background behind atmospheric environment issues and avoid making embarrassing statements;

- Techniques for effective delivery of key messages during media interviews to present complex information in a meaningful form without making embarrassing or inconsistent statements;
- Techniques, methods and practices for scientific report writing in order to present concise and clear information to a variety of stakeholders;
- Provision of expert scientific advice and information on atmospheric issues to the media, general public and other lay audiences using the telephone, written articles, oral presentations – all at appropriate comprehension levels – in order to improve the public’s knowledge and awareness of atmospheric environment issues such as climate variability and change, and smog;
- Considerations relevant to the policies, practices and viewpoints of various media organizations, outlets and their environmental reporters.

The skills and knowledge that relate to this section involve the ability to:

- Utilize appropriate methods, techniques and practices to determine user requirements for environmental services, products and customized investigations;
- Collate, interpret, synthesise and prepare published reports and make oral presentations on the state of air issue knowledge and air issue impacts;
- Utilize analytical and problem solving skills to assess the request and develop solutions independently or in collaboration with other scientific investigators;
- Demonstrate effective communications skills to convey complex scientific information and advice in a manner which optimizes their understanding;
 - Consider client needs and the sensitivities (policy, jurisdictions, economic ramifications) of statements, warnings or scientific analyses on these issues;
 - Possess effective writing skills to produce reports, articles and papers in environmental publications and peer reviewed journals;
 - Possess effective public speaking and presentation skills to present scientific information at workshops, conferences and scientific meetings;
 - Possess the ability to summarize atmospheric issues in a coherent manner relevant to questions and at the comprehension level of the audience;
 - Employ active listening skills and interpret body language to understand the audience’s interpretation and reaction to the information;
 - Provide verbal consultations by phone or in person to clients or emergency response teams;
 - Write forecasts in a style appropriate to the audience;
 - Hand-over to the next shift effectively, making due reference to all relevant factors.
- Understand and employ appropriate procedures, i.e.:
 - Produce and disseminate information consistent with the appropriate standards and procedures;
 - Describe the environmental emergency response procedure;
 - Be proficient in the use of office IT systems to prepare and disseminate information;
 - Acquire necessary approvals from senior members of the team or management;
 - Prioritize duties appropriately, especially in emergency or rapidly changing situations to meet deadlines;
- Consider the customer’s personal capacity and knowledge when responding to inquiries, i.e.:
 - Be courteous and exercise tact and good judgement when dealing with clients or the media or in consultations with other specialists;
 - Be prepared to deal with complaints;
 - Seek advice from more experienced colleagues; ensure that queries are directed to a spokesperson if one has been identified.

Performing other related duties

This section concerns duties such as participating in committees, working groups and task forces; operating and providing first line maintenance on equipment; and contributing to a positive work environment.

The trainee has achieved this by demonstrating knowledge of the:

- Principles of operation, maintenance and care of personal computers, printers, peripherals such as storage devices used by the incumbent and speciality software for developing and maintaining atmospheric databases, analysing, synthesizing and presenting data and related scientific information, communicating and receiving information;
- Maintenance and care of field equipment such as real-time ozone and particulate monitors and analysers, data loggers and ultraviolet meters;
- Procedures and maintenance (e.g. back-up procedures) of computerized databases of observed atmospheric data and analysed data results;
- Roles, responsibilities and operations within the office to facilitate and expedite the work programme and promote teamwork;
- Environmental Assessment and Review Process (EARP);
- Development of applied research proposals;
- Hazardous materials in the workplace, harassment, safety and health, and other polices governing the work environment.

The skills and knowledge which relate to this section must provide the ability to:

- Participate in the planning, design, organization, coordination, implementation and evaluation of environmental services and products and their development;
- Conduct applied research studies and investigations which could include field measurement programmes:
 - Applying theories and principles of project management;
 - Demonstrating effective planning and organizational skills to design applied research projects, ensure that activities occur as scheduled, and to manage project resources;
 - Consider resource constraints and their solution;
- Carry out analyses using mathematical/statistical and scientific techniques and procedures, interpret results, prepare and publish articles, reports and refereed papers, make oral presentations at workshops and conferences on applied research findings for use by other scientists and for supporting the development or revision of government and organizational environmental policy, planning and decision-making;
- Design and implement internet and intranet Web sites for delivering atmospheric environmental services, scientific information relating to the atmosphere to service staff, the scientific community, partner organizations and the general public;
- Demonstrate proficiency in the use of office IT systems so as to be able to undertake routine user maintenance and trouble shooting of such systems:
 - Understand and carry out communications tasks, as laid down under office procedures;
 - Conduct first-line maintenance (e.g. change paper and ribbons in printers, photocopiers) and carry out any other routine maintenance as laid down office procedures – report faults;
- Maintain positive interpersonal relationships:
 - Demonstrate willingness to work as a team player, be courteous and respectful to co-workers, superiors and clients and maintain currency on environmental issues;
 - Establish or maintain liaison with scientific staff of other federal, provincial, university and international environmental organizations;
 - Maintain personal appearance in keeping with office or client standards;
 - Give due regard to policies on equal opportunity, harassment, occupational safety and health and other polices governing the work environment;
 - Accept constructive criticism;
 - Participate fully in the analysis of workload or production processes to improve efficiency;
 - Participate in public outreach programmes such as tours, lectures to schools.

7.9 SATELLITE METEOROLOGY

By Jeff Wilson: Australia, Bureau of Meteorology; Anthony Mostek: USA, National Weather Service; and Vilma Castro: RMTTC, Costa Rica

Background The preliminary fourth edition of the publication WMO-No. 258 was reviewed as part of the agenda of the third meeting of the CBS OPAG IOS Expert Team on Improving Satellite Systems Utilization and Products held from 3 to 7 July 2000 in Lannion, France. The review covered the change in educational philosophy of WMO-No. 258 and the content as it related to the use of satellite derived data and products. In connection with the competency requirements discussed under section 2.2 of the publication, the review identified two main areas of satellite activities:

- (a) Usage of satellite imagery and products by a range of staff in the professional branches for weather analysis and forecasting and climate monitoring and prediction, and in the various meteorological application and public service areas;
- (b) Usage of satellite data and imagery by specialist staff working in satellite remote sensing areas in either a specialist Satellite Meteorology Branch (SMB), or in areas such as: research and development; information systems technology and data processing; or observations and measurements.

As discussed in section 2.2 (Training for job-competency) there are certain skill areas that cut across several operational branches of activity in any NMS. One such skill area is that of Satellite Meteorology since satellite data and products are useful for a whole range of meteorological applications – from very short range weather forecasting to climate monitoring, from measuring sea-surface temperatures to depiction of upper-level winds, etc. Satellite data comes in a variety of formats (APT, WEFAX, HRPT, SVISSR and in the future LRIT and HRIT) and can be obtained directly from satellite, via the GTS, or via other networks such as the Internet.

Staff in most branches depicted in Figure 2.2 is expected to have basic competency in the routine interpretation and use of satellite imagery and products that are used as part of their every day activities. Some of these competencies are explicitly referred to in the abbreviated descriptions of each of the main branches in Chapter 2 and reiterated as appropriate in the previous sections of this chapter. A consolidated list of satellite meteorology competencies for staff working in areas such as weather forecasting, aviation and marine application areas is included here for completeness, (see the next sub-section below).

As the use of meteorological satellite data and products within a NMS becomes more quantitative, i.e. utilized in NWP and analysis schemes and other application areas rather than as imagery alone, a small number of staff start to specialize in satellite meteorology. The last sub-section represents a first step in adding a SMB to the listing of the main branches of activity at the NMS, to reflect the more specialized use of satellite data and products. Existing satellite meteorology groups in the USA are used as a basis for some of the activities presented below.

In some NMSs, the functions of a SMB may be spread across other branches, for example:

- The reception of satellite data may be undertaken within the branch for observations and measurements;
- Calibration and navigation use within NWP suites;
- Archiving of the data, within the branch for IT and data processing;
- Development of new techniques or implementing techniques from other institutions within the branch for research and development, etc.

Core competency requirements in satellite meteorology This paragraph outlines a suggested set of core competencies (basic skills) required by personnel working in weather forecasting and application areas, in their pursuit of the effective use of satellite data and products as described below:

- (a) Capable of identifying the characteristics and typical uses of the different channels, either separately or in combination, available from meteorological satellites and the relevance to various meteorological application areas;
- (b) Capable of identifying the types of products available from meteorological satellites and their utilization in various meteorological application areas;
- (c) Able to correctly use satellite products to identify special features in relevant areas:
 - Fog, ice cloud, warm water cloud, supercooled water cloud, sea ice, flooding, snow cover, etc;
 - Dust, ash and other aerosols in the atmosphere;
 - Volcanic eruptions;
 - Fires;
 - Synoptic phenomena such as cold fronts, jet streams, tropical storms, etc;
- (d) Capable of explaining how the various channels and products can be used to identify cloud types and amounts, cloud clusters and systems; and able to associate them with different scale phenomena and with the climatology of the region;
- (e) Able to integrate satellite data with other meteorological data to produce a diagnosis and assess the prognosis of the NWP guidance for the various application areas. Able to identify atmospheric processes that are relevant on various scales and that are revealed in satellite imagery;
- (f) Able to digitally manipulate satellite imagery and products to create new products or change their format (projections, enhancements) to allow ease of use;
- (g) Capable of using forecaster (or meteorological analysis) workstations to:
 - Manipulate sequences of images (loops);
 - Overlay meteorological observations and products;
 - Identify geographical features in the imagery;
 - Manipulate colour enhancements;
 - Measure surface and cloud top temperatures;
 - Estimate cloud top height;
 - Calculate distances;
 - Measure velocity of displacement of a feature;
 - Measure the latitude and longitude of a feature;
 - Measure the wind speed at different levels following cloud movement;
 - Display sounding information;
 - Estimate rainfall intensity and extension;
- (h) Able to describe the differences between Geostationary (GEO), Low Earth Orbiting (LEO) and other orbits and describe their relevance to the various application areas.

A Meteorological Technician would be aware of the items (a), (b), (d) and (f), but would not be required to be proficient in them.

Satellite Meteorology Branch (SMB) The mission of the SMB is to assist the other branches in the NMS with all activities associated with satellite observations and products. In addition, the SMB interacts with the SMBs of other NMS, the RMTCs, and the Virtual Laboratory for Satellite Meteorology training.

Mission and main activities The staff of the SMB will assist with development of and transfer of new satellite-based products and techniques to the other branches of the NMS. These activities can include some or all of the following:

- Operate equipment used for tracking/ingest/calibration/navigation/archiving of satellite data and products;
- Review new products from GEO and LEO satellites;
- Create satellite-derived products and displays useful for weather forecasting (i.e. multispectral products such as fog/stratus, reflectivity, low-level moisture, skin temperature, albedo, etc.);
- Create/implement algorithms to estimate atmospheric motions and their heights by tracking cloud and water vapour displacements in sequences of satellite images;
- Implement procedures to monitor and validate the calibration of measured radiances;

- Develop and maintain operational systems to ensure accurate navigation (geolocation) of satellite data;
- Create/implement algorithms for inferring radiative and cloud properties (amount, height, thermodynamic phase, particle size, optical depth and emissivity);
- Create/implement algorithms for deriving temperature and moisture soundings from satellite radiance measurements;
- Implement new algorithms operationally;
- Optimize the use of satellite-derived mass and motion information in data assimilation and numerical weather prediction systems;
- Create satellite-derived fire, smoke, aerosols, dust, trace gases and other products for real-time monitoring and climate change studies;
- Undertake satellite-based climatological studies to improve forecasts and information to the public;
- Develop and implement systems for quality and performance monitoring of satellite data and systems;
- Develop and maintain systems for archive, browse and metadata to ensure rapid efficient access by users to satellite data and products especially for research;
- Train the NMS staff in new satellite capabilities; and
- Collaborate with the international user community to improve utilization of satellite observations.

As well as being cognisant of the core competencies associated with satellite meteorology outlined above, staff in the various functional roles in a SMB would be expected to possess additional advanced skills, which will be outlined in the next sub-section.

Advanced competency requirements

The satellite meteorology functions will involve four basic groupings of personnel:

- Management and planning of the overall programme;
- Engineering, covering the reception and transmission of the data;
- Information technology for processing the data and development and maintenance of the software systems;
- Satellite application scientists, covering the research and operational implementation requirements.

Indicative skills for each of these staff areas are outlined below. As already indicated before, there are many crossover areas between these staff groups with the actual responsibilities and tasks differing from NMS to NMS.

Management and planning

- Be familiar with the capability of current and future generations of GEO and LEO satellites and their potential application within the NMS and its wider service community;
- Review and establish new procedures for the use of satellite products within the branches of the NMS with the specific goal of providing improved services;

Engineering

- Interpret information about weather satellites and instruments, such as radiation and spectral channels; characteristics of the data: resolution, noise/signal ratio, etc.; orbital characteristics; and satellite perspective;
- Apply, where relevant, the above information to current tasks;
- Operate, as appropriate, equipment required for the tracking/ingest/calibration/navigation/archiving of satellite data and products.

Information technology

- Explain the processes for generating, quality controlling derived products from GEO and LEO satellites;
- Monitor and modify the process for displaying satellite data and products both alone, and in combination with, other products (integrated displays);
- Assist with the integration and transfer of new satellite observations and products to the other branches of activity;

- Where appropriate assist with the utilization of satellite observations and products in data assimilation and NWP systems;
- Outline the theory of, and assist with, the implementation of satellite data processing algorithms for deriving cloud properties, cloud winds, temperature and moisture soundings, land and ocean surface characteristics, etc.;
- Explain the processes for archiving and accessing the archive of quality controlled satellite data and derived products from GEO and LEO satellites.

Satellite application scientists

- Be current with, and be able to utilize products from both, GEO and LEO satellites;
- Apply physics of radiation to interpret products obtained from satellite data: laws of Planck, Stephan-Boltzmann, Wien, Beer; radiative properties of earth surfaces; radiative properties of the atmosphere;
- Interpret information about weather satellites and instruments, such as radiation and spectral channels; characteristics of the data: resolution, noise/signal ratio, etc.; orbital characteristics; and satellite perspective and apply it to current tasks where relevant;
- Explain the processes for generating, quality controlling and improving derived products from GEO and LEO satellites;
- Monitor and modify the process for displaying satellite data and products both alone, and in combination with, other products (integrated displays);
- Explain the theory of, and assist with, the implementation of satellite data processing algorithms for deriving cloud properties, cloud winds, temperature and moisture soundings, land and ocean surface characteristics, etc.;
- Where appropriate assist with the utilization of satellite observations and products in data assimilation and NWP systems;
- Interpret satellite observations and products to assist with specialized applications such as fire weather, volcanoes, hazardous material dispersion, and space weather;
- Assist satellite-based climatological studies by incorporating new and archived observations and products;
- Assist with the integration and transfer of new satellite observations and products to the other branches;
- Help to prepare and assist with training of satellite-related materials;
- Interact through the RMTCs and Virtual Laboratory for Satellite Meteorology with other groups and organizations associated with satellite meteorology.

The prediction is that activities of the SMB will continue to expand as the access to satellite data from both GEO and LEO platforms increases across the globe. The number of both platforms is also increasing, as well as the number and types of instruments on these satellites. SMB staff will be vital to the increased and effective utilization of the satellite observations and products in NMSs' operations.

APPENDICES

Preface to the first edition of WMO-No. 258

The former classes of meteorological personnel

Survey on the revision of WMO-No. 258

Glossary of terms and abbreviations

Selected bibliographic references

APPENDIX 1

PREFACE TO THE FIRST EDITION OF WMO-NO. 258

Prof. J. Van Mieghem

Chairman of the Executive Committee Panel of Experts on Education and Training (1965–1971)

Since its creation, 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 in Article 2 (f) of the WMO Convention. As many WMO Members become 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 three reports:

- The problem of the professional training of meteorological personnel of all grades in the Less Developed Countries (LDCs);
- Plan for the development of professional meteorological training in Africa;
- 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 LDCs.

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:

- 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 that 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;
- In drawing up syllabi for the different grades of meteorological personnel, the Organization's purpose is to apprise the academic and educational communities of its Members of the level 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 connection, 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 observation 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 and 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 World Weather Watch (WWW), for instance the Global Atmospheric Research Programme (GARP) without highly qualified meteorological personnel. It goes without saying that the scientific personnel of every Meteorological Service should be supported by assistants.

The purpose of the Guidelines is two-fold:

1. To define the various Classes of meteorological personnel required for public service and scientific research; and
2. 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, professional and high technical school, or university level — are so diverse everywhere that a classification according to basic education does not appear feasible. On the other hand, because meteorology must be organized on an international

basis, it is essential to aim, so far as possible, at a standard level of professional training for each Class: many of the tasks of NMS 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 Class 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 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 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 assistance of Class III, to utilize them.

In the syllabi, a very sharp distinction is made for each Class between the prior 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 at 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 it that the various parts of the Guidelines are continuously kept up-to-date.

To conclude, I now enumerate the sources of information used in drawing-up the syllabi:

1. The surveys carried out in the last ten years by the WMO Secretariat on all questions related to meteorological education and training in the National Meteorological Services.
2. Report on meteorological training facilities by the WMO Secretariat published for the first time in 1959 and since kept regularly up-to-date.
3. *The problem of the professional training of meteorological personnel of all grades in the Less Developed Countries*; by J. Van Mieghem WMO Technical Note No. 50 (1963).
4. *Plan for the development of professional meteorological training in Africa*; by J. Van Mieghem WMO Information Report (1963).
5. *Plan for the development of professional meteorological training in South America*; by J. Van Mieghem WMO Information Report (1964).
6. *Survey on the National Meteorological Services of Central America, the Caribbean countries and territories*; by H. Taba WMO Information Report (1965).
7. Reports by Working Groups on Meteorological Education and Training of the WMO Technical Commissions;
8. Documents prepared for the various WMO Conferences on Meteorological Education and Training;
9. Reports of the Leningrad Conference organized in July 1967 by the Hydrometeorological Service of USSR.
10. Minutes of meetings of the Executive Committee Panel of Experts on Meteorological Education and Training; held from 1966 to 1969.

Acknowledgement I have great pleasure in expressing my warmest thanks to all those who helped me carry out the tasks entrusted to me, and especially to the Members and Secretary of the Panel of Experts on Meteorological Education and Training.

July 1969

APPENDIX 2

THE FORMER CLASSES OF METEOROLOGICAL PERSONNEL

Extracts from publication WMO-No. 258 third edition, 1984

- Class I 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. The period of instruction includes at least 4 years of university education (in prerequisite subjects and meteorology), supplemented by at least six months of on-the-job training. Main duties: operational day-to-day work, such as weather forecasting; consulting, directing and decision-making; also, responsibility for research and development, management.

These personnel must have a thorough grounding in dynamic, synoptic and physical meteorology. They should also have a basic knowledge of climatology, hydrology, oceanography and ocean-atmosphere interaction, meteorological instruments and methods of observation, meteorological data processing, satellite meteorology, and air pollution meteorology.

- 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. This training should be given at a university or other appropriate institution over a period of two years, and a minimum of nine months on-the-job training is required. Main duties, under guidance by Class I personnel, include: analysis of synoptic charts, weather forecasting, study of data relating to physical meteorology, observational instruments and methods, telecommunications, inspections of networks.

These personnel must exercise skill and judgement in the interpretation of meteorological data. They must have a thorough understanding of the underlying meteorological principles, particularly the weather analysis and forecasting 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.

- Class III These personnel will have received complete secondary or equivalent school education (minimum 12 years) and adequate training in meteorology. The period of the meteorological course should be of eight to ten months, supplemented by adequate practical and on-the-job training. Main duties include: decoding and checking of incoming messages; plotting of meteorological charts, aerological diagrams and cross-sections; assisting personnel of higher Classes in the analysis of observational data; supplying meteorological information (under supervision). Other related duties: checking monthly weather summaries of the network stations, and calculating statistical parameters on the basis of such summaries; calibration of instruments used in the surface observation network, calibration of radiosondes, operation of aerological and radiation stations.

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. However, syllabi given in general meteorology, surface and upper-air observations and measurements and general climatology, were designated for all Class III personnel.

Class IV These personnel 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. A period of minimum four months formal meteorological training is required, and it should be followed by an extensive period of on-the-job training. Main duties include all routine surface observations; instruments maintenance; office work such as the reduction of observation data, transmission of synoptic messages, maintenance of the observation log and preparation of monthly summaries. Related duties: processing of recording diagrams; calculation of hourly totals, means and extreme values; plotting charts and diagrams.

Although 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. Accordingly, if a student is weak in some subjects, it is left to the instructor to decide whether he requires supplementary training.

APPENDIX 3

SURVEY ON THE REVISION OF WMO-NO. 258

During 1997, following a request by the EC Panel of Experts on Education and Training, the Secretariat prepared and distributed to all Members a comprehensive questionnaire on the revision of the WMO classification and curricula. Replies to this Survey were then interpreted as guiding constraints in the revision of the publication WMO-No. 258.

The WMO survey In addition to specific questions relating to the use/non-use, content and design, and potential improvement/restructuring of the current classification and curricula, the above-mentioned questionnaire included draft proposals for two possible schemes for the classification of meteorological and hydrological personnel, namely:

- (a) *A two-tier scheme* for (graduate) Professionals and Technicians; career development stages were suggested for each of these main categories;
- (b) *A three-tier scheme* for (graduate) Professionals, Technicians and Observers; this scheme was essentially a version of proposal (a), but with two distinct categories of Meteorological Technicians.

WMO Members were asked whether they prefer maintaining the traditional four-tier classification, or if they favour one or the other of the schemes, (a) or (b).

Members' opinions Over 80 Members responded to this Survey. The degree of convergence amongst the respondents' opinions was determined as follows:

- (a) *Strongly convergent opinions* – shared by more than 90 per cent of respondents:
 - The traditional WMO classification was used by many Members as a basic reference and by several Members as an occasional reference; some Members used it even as an official reference. Only a few Members did not use this classification at all; usually, they proffered their civil servants classification;
 - In the future, there will still be the need for a WMO classification to be used as a basic reference, particularly in an international context; the general thrust of the traditional scheme could be maintained, but with a smaller number of classes;
 - In designing revised classes, due consideration should be given to formal educational qualification; in particular, university graduation must be considered as a basic criterion to differentiate Class I personnel from the other personnel. However, for the non-graduate personnel, the class-distinction (if needed) should relate more to the demonstrated job-competency rather than to the initial education qualification;
 - For each major Class there should be a core curriculum of required knowledge.
- (b) *Moderately convergent opinions* – shared by 66-90 per cent of respondents:
 - The revised classification may reflect some generic career development stages and some general job-competencies. Specific job-competencies, although theoretically desirable, are practically impossible, given their dependence on the local context;
 - The current WMO curricula were used, particularly in developing countries, most often as a basic reference and the structure of the curricula seemed generally adequate for instructors from those countries. However, in several other NMS, these curricula were used only occasionally;
 - Many respondents stressed the need for a regular updating of the curricula contents; several other respondents suggested that samples of a few actual curricula could be presented in the new edition of WMO-No. 258;

- Full secondary school or equivalent education may be taken as a mandatory pre-requisite for future Meteorological Technicians. Exceptions may be acknowledged, provided a trainee's knowledge in basic sciences is adequate;
- (c) *Weakly convergent opinions* – shared by 50-66 per cent of respondents:
- A special Class of 'Meteorological Technologist' is not a priority for a fair majority of NMS; this group's emphasis was on defining a classification for the meteorological personnel proper. Yet, a substantive minority requested defining a Technologist Class, to accommodate personnel employed in meteorological instruments, information technology – communications, computing, etc;
 - It will not be necessary to maintain the degree of detail of the traditional curricula; several respondents stressed the lack of flexibility of its syllabi and the need for a focus on learning outcomes and job-competencies;
 - Meteorological specializations' curricula should be revised on an ongoing basis.
- (d) *Divergent opinions* – shared by (much) less than 50 per cent of respondents:
- A few respondents did not agree in general with the above opinions, in particular, with the overall thrust of the traditional classification and curricula, which emphasises too much the role of the initial education and training;
 - Respondents from three (highly advanced) NMS preferred a concentration on technical competencies rather than on individual classes; moreover, 'classification would need to be based on job function not on education qualification';
 - For other respondents, classification should not consider actual job-competencies, which are not only context-dependent but also rapidly changing in time;
 - A few respondents suggested that the classification should not reflect any career progression, indicating that this is a matter best left over to individual NMS.

GLOSSARY OF TERMS AND ABBREVIATIONS

-
- Basic Instruction Package (BIP)* A framework education and training programme recommended by WMO for the initial professional formation of meteorological personnel. Consistent with the new WMO classification of personnel, there are two different BIPs – one qualifying job-entry level meteorologists (BIP-M), and another qualifying job-entry-level Meteorological Technicians (BIP-MT). It is mentioned that the word instruction, utilized in the BIP-title is meant to address both education (particularly BIP-M) and training (particularly BIP-MT).
- The content and delivery of the BIP-components (e.g. requisite topics in basic sciences, compulsory and elective topics in atmospheric sciences, etc.) can be organized with a variety of emphases and perspectives, in many different curricula. Those who would have to design and implement actual curricula should specifically enable the scope, sequence and coordination of concepts, processes and topics.
- Branch of activity* An ensemble of technically related jobs, forming a relatively independent operational structure or unit of a NMS, and performing an aggregate of specialized activities and services, in order to accomplish a significant part of the overall mission of the NMS. For each branch identified in this publication, it is provided a list of generic competency requirements (Chapter 2) together with an example of actual competencies (Chapter 7).
- Guidelines* Brief reference to the present volume of WMO-No. 258, which is a technical document setting out recommendations for the categorization and initial instruction of meteorological personnel; for the principal job-competency requirements in various operational areas; and for the methods and strategies of continuing education and training in meteorology. Whilst fostering innovation and adaptation to local circumstances, these guidelines are aimed at facilitating common understanding and a degree of uniformity and stability in an international context.
- Job-competency* An ensemble of related knowledge, understanding and skills, as well as positive work attitudes, required for the efficient execution of a given job. Competency involves not only the ability to perform in a given context, but also the capacity to transfer and use knowledge and skills in a new situation.
- Learning outcomes* Achievement of defined standards of knowledge and especially job-skills, following completion of education/training modules whose objectives are specified independently of mode, duration or location of learning; evidence would have to be made available to demonstrate achievement of the learning objectives.
- Lifelong learning* Concept according to which learning is dynamic and continuous, encompassing a flexible approach to learning procedures, credit structures, curriculum and pedagogic method; emphasising access and a symbiosis with the world of work; and going throughout and possibly beyond the working life.
- Meteorological personnel* The group of NMS employees that possess formal meteorological qualification: Meteorologists and Meteorological Technicians. It is noted that clerical, labourer, or other auxiliary staff may not be included in this group.
- Meteorological Technician* A person who, following the completion of the secondary school, or equivalent education, has also completed meteorological training consistent with the requirements set forth in the 'Basic Instruction Package for Meteorological Technicians (BIP-MT)'. Duties include: carrying out weather, climate and other environmental observations and measurements; assisting forecasters in the preparation and dissemination of analyses, forecasts, weather warnings, and other related information, products and services.

- Meteorologist* A person with specialized education who uses scientific principles, concepts and techniques to explain, understand, observe or forecast the Earth's atmospheric phenomena and/or how the atmosphere affects the Earth and life on the planet. This specialized education would be a Bachelor's or higher degree in meteorology (or atmospheric sciences), consistent with the requirements set forth in the 'Basic Instruction Package for Meteorologists (BIP-M)'. Holders of a first degree in physical sciences, mathematics, electronic or geo-sciences engineering, may also qualify as meteorologists by completing a 'condensed BIP-M' programme, subject to adequate pre-requisite knowledge in mathematics, physics and chemistry.
- Meteorology* Is the study of the atmosphere and its phenomena – especially the weather and climate conditions – and the practical applications of this study. In addition to the physics, chemistry and dynamics of the atmosphere, meteorology encompasses many of the direct effects of the atmosphere upon the Earth's surface, the oceans and life in general.
- As a science, meteorology (the term 'atmospheric sciences' may be used with the same meaning) belongs to the applied physical sciences and its main disciplines are dynamic, physical, and synoptic meteorology, and climatology. As a profession, meteorology focuses mainly on weather analysis and forecasting and on climate monitoring and prediction.
- National Meteorological Service (NMS)* An organization established and operated primarily at public expense for the purpose of carrying out those meteorological and related functions, which governments accept as a responsibility of the State in support of the safety, security and general welfare of their citizens and in fulfilment of their international obligations under the Convention of the WMO.
- Semester-hour* A measure of the time spent by the student in formal instruction (in USA). A normal semester is 15 weeks in length. For traditional lecture classes, a class, which meets one hour per week in lecture format, is 'one semester-hour'; a class, which meets three times per week, is 'three semester-hours'. Laboratory sessions are generally given less weight, so a three-hour laboratory session meeting once per week is also 'one semester-hour'.
- Skill* Practised mental or physical ability or dexterity, and/or natural facility in doing something, without necessarily understanding all the processes by which this is done. It is an aptitude developed by special training and experience; in the absence of sustained practice, skills weaken in time and are eventually lost. Acquiring job-skills in meteorology requires both basic professional instruction and job-specific training, including on-the-job training.
- Task* The smallest element of work effort, identifiable in terms of output and quality, that must be performed in order to accomplish some purpose/mission, at a specific moment in time.
- Trainee* One who is receiving training and whose acquisitions are periodically evaluated by means of objective measures involving pre-specified criteria.
- Trainer/Instructor* An instructional leader who plans and conducts a learning activity designed to help participants acquire information, knowledge, skills, and adequate attitudes in a particular job.
- WMO classification of meteorological personnel* A systematic, generalized scheme of categorising meteorological personnel according to their achievements in formal education; acquisitions in meteorological knowledge and understanding; and acquired job-competency in their career progression. The new WMO scheme defines two main categories of personnel and three career levels for each category.

ABBREVIATIONS

AAS	Agrometeorology advisory service
AGCM	Atmospheric general circulation model (WMO)
AIREP	Aircraft weather report
AMDAR	Aircraft meteorological data relay
APT	automatic picture transmission (satellite; now LRPT)
ARFOR	Area forecast for aviation
ASDAR	Aircraft to satellite data acquisition and relay
ATC	Air traffic control
ATS	Air traffic services
AVHRR	Advanced very high-resolution radiometer (satellites)
AWS	Automatic weather station
BAPMoN	Background air pollution monitoring network
BATHY	Report of bathythermal observation (code form)
BIP	Basic Instruction Package (WMO)
BIP-M	Basic Instruction Package for Meteorologists
BIP-MT	Basic Instruction Package for Meteorological Technicians
BIP-H	Basic Instruction Package for Hydrologists
BIP-HT	Basic Instruction Package for Hydrological Technicians
BLA	Boundary Layer of the Atmosphere
CET	Continuing Education and Training
CBS	Commission for Basic Systems (WMO)
CFC	Chloroflourocarbon
CLIMAT	Report of monthly means and totals from a land station
COMET	Co-operative Programme for Operational Met. Education and Training
CPD	Continuing Professional Development
DRIBU	Report of a drifting buoy observation (now DRIFTER)
EC	Executive Council (WMO, previously Executive Committee)
ETF	Editorial Task Force
ENSO	El Niño/Southern Oscillation
ETR	Education and Training (WMO Department)
ESS	Earth Science System
GAW	Global atmospheric watch (WMO)
GCM	General Circulation Model (of the atmosphere)
GCOS	Global Climate Observing System
GEO	Geostationary orbiting
GIS	Geographic Information Systems
GO3OS	Global Ozone Observing System
GTS	Global Telecommunication System
HRPT	High resolution picture transmission (satellite)
IAVW	International Airways Volcano Watch
ICAO	International Civil Aviation Organization
ICT	Information and Communication Technology
IPCC	Inter-governmental Panel on Climate Change
IT	Information Technology (now ICT)
ITCZ	Inter-tropical convergence zone
LEO	Low Earth orbiting
LRIT	Low rate information transmission (satellite, formerly WEFAX)
LRIT	Low rate picture transmission (satellite, formerly APT)
MET	Meteorology
METAR	Aviation routine weather report
MOS	Model output statistics
MSS	Message switching system
NMHS	National Meteorological and Hydrological Service
NMS	National Meteorological Service
NWP	Numerical weather prediction
O&M	Observations and Measurements
PILOT	Upper-wind report from a land station

PMO	Port Meteorological Officer
PWS	Public Weather Services
RMTC	Regional Meteorological Training Centre
SATEM	Report of satellite upper-air soundings of pressure, temperature and humidity
SATOB	Report of satellite observations for wind, surface temperature, cloud, humidity and radiation
SHIP	Report of surface observation from a sea station
SIGWX	Significant weather
SLD	Super-cooled Large Droplets
SLO	Surface layer of the ocean
SLW	Super-cooled Liquid Water
SMB	Satellite Meteorology Branch
SPECI	Aviation selected special weather report
SST	Sea surface temperature
SYNOP	Report of surface observation from a land station
TAF	Terminal aerodrome forecast; aerodrome forecast (code form)
TC	Tropical cyclone
TCP/IP	Transmission control protocol/internet protocol
TEMP	Upper-level temperature, humidity and wind report from a land station
TEMP DROP	TEMP message from a sonde released by carrier balloons or aircraft
TEMP SHIP	TEMP message from a sea station
TESAC	Temperature, salinity and current report from a sea station
TOEFL	Test of English as a Foreign Language
TOMS	Total Ozone Mapping Spectrometer
UCAR	University Co-operation for Atmospheric Research (USA)
UN	United Nations (organization)
UNESCO	United Nations Educational, Scientific and Cultural Organization
UV	Ultraviolet
VAAC	Volcanic Ash Advisory Centres
VISSR	Visible and infrared spin scan radiometer (satellites)
VOC	Volatile organic compound
VSAT	Very small aperture terminal
WAFS	World Area Forecast System (WMO/ICAO)
WEFAX	Weather facsimile transmission (now LRIT)
WHYCOS	World Hydrological Cycle Observing System
WMO	World Meteorological Organization
WWW	World Weather Watch

SELECTED BIBLIOGRAPHIC REFERENCES

- American Meteorological Society (AMS), 1996: *Glossary of Weather and Climate with related Oceanic and Hydrologic Terms*, (ed. Ira W. Geer), Boston, 272 pp.
- Andrews D. G., 2000: *An Introduction to Atmospheric Physics*; Cambridge University Press; 229 pp.
- Barry R. G. and R. G. Chorley, 1998: *Atmosphere, Weather and Climate*; 7th edition; Routledge; London and New York; 409 pp.
- Bryant E., 1997: *Climate Process and Change*; Cambridge University Press; 209 pp.
- Bulletin of the AMS, 1995: 'The Bachelor's Degree in Atmospheric Science or Meteorology', *BAMS* Vol. 76, No. 4, April 1995, pp. 552-553.
- Craig R. A., 1965: *The Upper Atmosphere; Meteorology and Physics*; Academic Press; New York, London; International Geophysics Series, Vol. 8; 509 pp.
- Daly, K., 1995: 'Training Needs and Task Analyses', in *Proceedings of the WMO/Météo France Symposium on Education and Training in Meteorology and Operational Hydrology*; Toulouse 24-28 July 1995, 5 pp.
- Dennis A. S., 1980: *Weather Modification by Cloud Seeding*; Academic press; New York, 267 pp.
- Diaz H. F. and Vera Markgraf (eds.), 2000: *El Niño and the Southern Oscillation: Multiscale Variability and Global and Regional Impacts*; Cambridge University Press; UK, 496 pp.
- Dobbins R. D., 1979: *Atmospheric Motion and Air Pollution*; John Wiley & Sons, Inc; New York; 323 pp.
- Doviak R. J. and D. S. Zrnic 1993: *Doppler Radar and Weather Observations*; Academic Press; New York; 562 pp.
- Durran D. R. 1999: *Numerical Methods for Wave Equations in Geophysical Fluid Dynamics*; Springer-Verlag; 465 pp.
- Gill A., E. 1982: *Atmosphere-Ocean Dynamics*; International Geophysics Series, Vol. 30; Academic Press; 662 pp.
- Hobbs P. V, 2000: *Basic Physical Chemistry for Atmospheric Sciences*; 2nd edition; Cambridge University Press; Cambridge, UK; 209 pp.
- Hobbs P. V, 2000: *Introduction to Atmospheric Chemistry*; Cambridge University Press; Cambridge, UK; 262 pp.
- Holton J. R., 1975: *The Dynamic Meteorology of the Stratosphere and Mesosphere*; Meteorological Monographs, Vol. 15, Nr. 37; American Meteor. Society; 218 pp.
- Holton J. R., 1992: *An Introduction to Dynamic Meteorology*; 3rd edition; International Geophysics Series Vol. 48; Academic Press Inc. New York, London; 511 pp.
- Houze R. A. Jr., 1993: *Cloud Dynamics*; Academic Press, Inc.; 573 pp.
- Intergovernmental Panel on Climate Change 1996: IPCC Second Assessment Report: *Climate Change 1995*, Edited by J. T. Houghton *et al.* and published by Cambridge University Press; see in particular *The Climate System: An Overview* by K. E. Trenberth, J. T. Houghton, L. G. Meira Filho; 50-64 pp.
- Johnson, D. R., M. Ruzek and M. Kalb, 1996: 'Earth System Science Education: A Continuing Collaboration', in *Proceedings of the 1996 International Geoscience and Remote Sensing Symposium (IGARSS'96)*, Lincoln, NE pp. 1175-1177.
- Linacre, E., 1992: *Climate Data and Resources; a Reference and Guide*; Routledge, Chapman and Hall, Inc. New York, London; 366 pp.
- Lowry W. P., 1969: *Weather and Life: An Introduction to Biometeorology*; Academic Press; New York and London; 2nd edition, 305 pp.
- Megginson, D. and V. Whitaker, 1996: *Cultivating Self-Development*. Institute of Personnel and Development, London, 120 pp.
- Murphy A. H and R. W. Katz (editors), 1985: *Probability, Statistics and Decision Making in Atmospheric Sciences*; Westview Press Inc.; Boulder and London; 545 pp.
- Nicholls N., 1999: 'Cognitive Illusions, Heuristics, and Climate Prediction'; in *Bulletin of American Meteorological Society*, Vol. 80, No. 7; pp. 1385-1396.

- Obasi, G. O. P., 1999: 'National Meteorological and Hydrological Services and the Management of Change for the 21st Century'; Lecture at the *Technical Conference on the Management of Meteorological and Hydrometeorological Services of RA VI (Europe)*, Geneva 9 March 1999, 24 pp.
- Obasi, G. O. P., 2000: 'WMO – 50 years of service'; Message from the Secretary General of WMO for the *World Meteorological Day 2000*, 7 pp.
- Parker, S. P. (editor), 1980: *McGraw-Hill Encyclopedia of Ocean and Atmospheric Science*, New York: McGraw-Hill Book Company, 580 pp.
- Patrick, J., 1992: *Training: Research and Practice*, London: Acad. Press, 561 pp.
- Pielke R. A., 1984: *Mesoscale Meteorological Modeling*; Academic Press Inc. Orlando, Florida; 612 pp.
- Ryder, P., 1996: *Guidelines for National Meteorological Services on 'Alternative Services Delivery'*; draft paper prepared for the EC Working Group on Long-Term Planning; 13 pp.
- The National Academy Press, 1998: *The Atmospheric Sciences Entering the Twenty-First Century* 382 pp.;, ISBN 0-309-06415-5; Washington, DC 20055; see in particular page 276.
- Thomas G. E. and K. Stamnes, 1999: *Radiative Transfer in the Atmosphere and Ocean*; Cambridge University Press; 517 pp.
- UNESCO, 1998: *World Declaration on Higher Education for the twenty-first century: Vision and Action*, adopted by the World Conference on Higher Education; Paris, 5-9 October 1998; 10 pp.
- Van der Beken, A., 1993: *Continuing Education in Hydrology, Technical Documents in Hydrology*, IHV-IV Project E- 4.1, UNESCO, Paris, 27 pp.
- Wallace J. M and P. V. Hobbs, 1977: *Atmospheric Science: An Introductory Survey*, Academic Press, New York; 467 pp.
- WMO-No. 258, 1969: *Guidelines for the Education and Training of Meteorological Personnel*, 1st edition, TP No. 144, 164 pp.
- WMO-No. 258, 1984: *Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology*, 3rd edition, 301 pp.
- WMO-No. 49, *WMO Technical Regulations*; Basic Documents No. 2, Volume I—General meteorological standards and recommended practices, 1988; Volume II—Meteorological service for international air navigation, 2001; Volume III—Hydrology, 1988.
- WMO/OMM/BMO-No. 182, 1992: *International Meteorological Vocabulary*, 2nd edition, 784 pp.
- WMO, 1995: *Proceedings of the WMO/Météo France Symposium on Education and Training in Meteorology and Operational Hydrology; Training beyond the year 2000*; France, Toulouse, 24-28 July 1995.
- WMO, 1999: *Proceedings of the WMO Symposium on Continuing Education and Training in Meteorology and Operational Hydrology*; 6-10 November 1999, Tehran, Islamic Republic of Iran.
- WMO-No. 834, 1999: *Guide to Public Weather Services Practices*, second edition; 172 pp.
- WMO Bulletin*, Volume 49 No. 2, April 2000; pp. 127-160.
- Zillman, J. W., 1999: 'The National Meteorological Service', in *WMO Bulletin Vol. 48 No. 2*, pp. 129-159.