Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology


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

Education and Training Programme

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FOREWORD

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(Text to be included in the final version)
PREFACE TO THE FOURTH EDITION

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(Text to be included in the final version)
The scope and pace of changes in education during the past decade were unprecedented and, most likely, this pattern will continue in the coming years. Within the global tendency toward an information society, the key word is restructuring, which touches every educational aspect, including curriculum development and delivery, pedagogical methods, lifelong learning culture and Internet networking, etc.

There are no reasons to consider that meteorological (and hydrological) education and training are escaping these fundamental trends. On the contrary, as shown by the Secretary General of WMO in his message for the 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, which will require "specific adaptation" by possible users. In particular, Part A provides recommendations for personnel classification; job-competency, main disciplines and basic instruction requirements; and continuing professional development, with the understanding that educators (and managers) will adjust these recommendations for human resources development according to the evolving priorities of the national Meteorological Service.
Chapter 1:  
WMO CLASSIFICATION OF PERSONNEL

Background information
Classification of personnel in meteorology and operational 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 recognising 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, third edition, page 15)

Following the presentation of the new WMO classification of personnel in meteorology and operational hydrology, the second part of this chapter is focused on meteorological personnel - their initial qualification requirements and subsequent career progression.

Although the classification is focused on two main categories of personnel, the user does have large freedom in adapting it to specific circumstances, for instance in line with national regulations for civil service classification.
1.1 Background information

This chapter explains the need to revise the publication WMO-No. 258, third edition. It then describes the new WMO classification of personnel in meteorology and operational hydrology and elaborates on its implications for meteorological personnel.

1.1.1 Need to change the classification and curricula

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 technology;

(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 philosophical and pedagogical approach to the professional instruction and specialisation, particularly as a result of the increasing importance attached to continuing education and training.

1.1.2 Basic assumptions in revising WMO-No.258

In 1997, a comprehensive questionnaire on the review and updating of the WMO classification of personnel and curricula for training was distributed to all WMO Members. 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 curriculum 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 re
categorised 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: Vol. I: Meteorology and Vol. II: Operational Hydrology. Volume I should address firstly 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, the main job-competency requirements, to provide the relevant knowledge and skills required in specific operational areas.

1.2 Classification of personnel in meteorology and operational hydrology

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

1.2.1 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.

1.2.2 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) For meteorological personnel:

• **Meteorologist** - a person who holds a university-level degree, or equivalent; has acquired an appropriate level of knowledge of mathematics, physics, and chemistry; 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) For 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).

1.2.3 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. This 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.

1.2.4 Relation to the previous classification

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

*(a) For 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.

*(a) For 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 - Meteorologists and Meteorological Technicians.

1.3.1 Initial qualification requirements for Meteorologists

These personnel may satisfy the three qualification requirements (e.g. getting a degree, acquiring the appropriate knowledge in basic and computational sciences, and reaching the required standard in meteorology) either simultaneously or sequentially, through completion of one of the following two programmes:
(a) University-level degree in meteorology

Candidates should possess an adequate prerequisite knowledge in mathematics, physics and chemistry, at the level usually required for university admission in mathematics, physical science or engineering faculties. Normally, this Complete BIP-M programme will require four academic years, but the period will be dependent upon the degree of specialisation in academic institutions. The main components of the BIP-M include:

(i) **requisite topics in basic and computational sciences**: mathematics and computational science, physics and chemistry, all at the level of majors in physical science, mathematics, or selected engineering faculties; and **required complementary topics** in foreign languages, general culture in history and geography, and communication and presentation skills;

(ii) **compulsory topics in atmospheric science**: introduction to earth system science; general, physical, dynamic and synoptic meteorology; and climatology);

(iii) **elective topics in atmospheric science**: advanced observations and measurements, weather analysis and forecasting, climate monitoring and prediction, environmental meteorology, atmospheric boundary layer and surface processes;

(iv) **recommended optional topics**, including higher mathematics, advanced dynamic meteorology, advanced cloud and precipitation physics, advanced atmospheric physics - acoustics, optics and electricity; hydrology, physical and dynamical oceanography, bio-meteorology, technological meteorology, space weather, marketing, meteorological management and administration.

Besides the obligation to complete the above-listed requisite and compulsory topics, the student must choose (and complete) at least one of the elective topics in atmospheric science. Then, the final degree award may specify that the student has got a "Major" in the relevant speciality. To increase their opportunities to obtain a broader initial qualification, students may wish (but are not obliged) to choose also one additional "Minor" option from the remaining elective topics or the recommended optional topics.

(b) Postgraduate diploma or Master degree in meteorology

Candidates should possess a university-level degree in selected scientific/technical domains such as mathematics, physics, chemistry, electronic or geo-sciences engineering; and should have acquired the knowledge in mathematics, physics and chemistry at the level of the Complete BIP-M. Normally, this Condensed BIP-M programme, requires one or two academic years, and its main components are:

(i) **compulsory topics in atmospheric science**;

(ii) **elective topics in atmospheric science**;

(iii) **recommended optional topics**.

The actual content of these components is similar with the content of the Complete BIP-M, see item (a) above.
1.3.2 Initial qualification requirements for Meteorological Technicians

These personnel need to have pre-requisite knowledge in mathematics, physics and chemistry at the secondary-school-level (or equivalent education) before starting the BIP-MT programme proper, which, normally, will consist of post-secondary-school-level education and training in meteorology. It may take between a few months and one or two years, depending on the targeted qualification. The main components of the Complete BIP-MT programme are as follows:

(i) **required background in mathematics and physical sciences**: mathematics, physics and chemistry at the level of secondary school, first cycle;

(ii) **requisite topics in basic and computational sciences**: calculus, probability and statistics, information technology operation, physics and chemistry at the level of secondary school with Major in mathematics and physics;

(iii) **compulsory topics in meteorological training**: general meteorology, including introduction to synoptic meteorology; and meteorological instruments and methods of observation;

(iv) **elective topics in meteorological training**: upper-air measurements; meteorological data processing; delivery of products and services; environmental measurements.

1.3.3 Career levels and responsibilities

After the completion of the appropriate BIP programme, normally candidates enter the job, where they start with an adequate period of orientation and on-the-job training. Generic responsibilities for the three career levels (entry-, mid- and senior-level) of Meteorologists and Meteorological Technicians are described briefly below (see also Chart 1.1).

(a) **For Meteorologists**:

Duties include operational day-to-day work such as weather analysis and forecasting, climate monitoring and prediction, or other meteorological applications, as well as consulting, directing, decision-making and management. Some Meteorologists, following appropriate formal training and/or personal study, will undertake teaching, research and development activities. Generally, it is assumed that:

(i) **job-entry-level Meteorologists** mainly carry out routine duties, to be performed under supervision and, most often, in collaboration with others;

(ii) **mid-level Meteorologists** carry out a broad range of activities to be performed in a wide variety of contexts, many of which are complex and non-routine. Capacity to apply knowledge and skills in an integrated way, and ability in problem-solving are required; important personal autonomy and responsibility, including for the control or guidance of others, may also be expected;

(iii) **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 - is assigned to these senior-level professionals.

Chart 1.1: Framework for the initial qualification streams and subsequent career progression levels for meteorological personnel.

(b) For 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 other 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 radiosondes, automatic weather stations, telecommunications equipment, or weather radars. Generally, it is assumed that:

(i) job-entry-level Technicians mainly carry out routine and predictable duties, to be performed under supervision and, most often, in collaboration with others;
(ii) *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;

(iii) *senior-level Technicians* require competencies in a wide range of complex technical 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 others. Individual autonomy, within an established menu of responsibilities, may also be expected.
Chapter 2:
MAIN BRANCHES OF ACTIVITY IN METEOROLOGY

Principal activities in a typical NMS
Professional branches
Technical branches
Meteorological applications and public services branches
Meteorology-support branches

This chapter describes the principal job-competency requirements in the main branches of activity of a typical 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 proposed branch-delimitation and the recommended job-competencies, according to the more specific mission and functions of his NMS.

The next step will be made in chapters 4 and 5, where the framework curricula of the Basic Instruction Packages for Meteorologists and Meteorological Technicians will be oriented according to the knowledge and skills required for the job-entry level. Then, the examples from chapter 8 will highlight additional job-competency requirements enabling the actual practice of individual jobs, at the current operations level within various branches.
2.1 Principal activities in a typical NMS

Generally, the mission of a typical national Meteorological Service (NMS) is to:

(a) observe, monitor, understand, and predict the weather and climate of its country;

(b) provide meteorological and related environmental services in support of national needs;

(c) meet relevant international commitments under the WMO Convention.

This formulation is based on the Executive Council statement on *The National Meteorological Service and Alternative Service Delivery*, circulated to all WMO Members in April 1999.

2.1.1 Generic branches of activity

The practical implementation of the NMS mission requires a wide range of activities, organised into a large number of jobs, which may be assembled into a smaller number of technically specific units that may conveniently be characterised as branches of activity. One simple model of these branches is shown in Chart 2.1.

*Chart 2.1 Generic branches of activity in a typical NMS*

<table>
<thead>
<tr>
<th>Management and administration</th>
</tr>
</thead>
<tbody>
<tr>
<td>METEOROLOGICAL APPLICATIONS AND PUBLIC SERVICES</td>
</tr>
<tr>
<td>Agriculture</td>
</tr>
<tr>
<td>WEATHER (analysing and forecasting)</td>
</tr>
<tr>
<td>Education and training</td>
</tr>
<tr>
<td>INFORMATION SYSTEMS TECHNOLOGY AND DATA PROCESSING</td>
</tr>
<tr>
<td>OBSERVATIONS AND MEASUREMENTS; INSTRUMENTS</td>
</tr>
</tbody>
</table>

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 branches of activity is inevitable. However, the above branch-structure may be helpful in assessing the overall demand for basic meteorological competencies, while suggesting also the main specialised competencies required.

Among these generic branches there are important differences with respect to the number of employed personnel and, particularly with respect to their job
requirements—a fact that will impact on the necessary education and training of the personnel concerned.

Generally, the predominant staffing would be at graduate level in the "professional branches" for Weather and Climate, and at technician level in the "technical branches" for Observations and Information technology. It is noted, however that information technology scientists and electronic engineering graduates are required, more and more, under these latter branches; for instance in operating interactive observing-processing systems or in developing and implementing numerical weather prediction schemes. In branches for Meteorological applications and public services there would be a combination of professional and technical personnel having some common competencies, but also specialised individual competencies. In the "support branches" such as Research and development or Education and training, the number of personnel would be comparatively smaller and their jobs usually require additional competencies outside the normal meteorological qualifications.

Chart 2.2: Career progression path of Meteorologists (M) and Meteorological Technicians (MT) and their branches of activity

Note: Some flexibility has to be accepted when considering this Chart; for instance there are Meteorologists working under the Client relations branch, while there are Technicians working in the Weather forecasting branch, etc. Thus, one should consider more the specificity of each branch, rather than its actual location within the Chart. At the same time, one should be aware that most often the personnel working in one branch will have to possess certain competencies "native" in another branch; e.g. any Meteorologist should be familiar with the basic observations and measurement methods, and with the operation of common data processing systems, etc.

Chart 2.2 broadly relates the designated branches of activity to the hierarchy and career of the NMS personnel. The two curves show the likely career path for the two categories of personnel. 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 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 BIP-MT. It is recalled that dedicated Meteorological Technicians may become Meteorologists, by acquiring a university-level degree and the BIP-M standards.

2.1.2 Overview of competencies; transferable skills

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. In principle the performance standard should include information about:

(a) the task;

(b) the performance criteria for the successful completion of the task;

(c) the knowledge and understanding required.

The outcome of the training process should be a person who has demonstrated the required competencies. In this publication the emphasis will be put on defining the task. The performance criteria and the underlying knowledge and understanding need to be defined in a way which takes account of the national situation, both in terms of the weather and employment practices.

Personnel in a NMS not only need to be competent in their occupation skills, but they also need to be able to adapt to changing circumstance and develop their careers. They need a 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 and hazards by following health and safety procedures;
- communicate effectively;
- apply a problem-solving approach to non-routine tasks;
- manage several tasks at any one time;
- manage one's own learning and performance;
- work effectively with others;
- acquire new skills, knowledge and understanding demanded by changes in products, technology and working practices;
- understand how one's job contributes to meeting national and international commitments.

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

The mission, typical jobs, and general competency requirements for the personnel employed under the branches of activity identified above will be presented under this, and the next two sections. Essentially, this information may be used as a background requirement in designing core curricula (see chapter 4) according to pre-established outcomes in terms of knowledge and skills.

2.2.1 Weather analysis and forecasting

Mission: 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 (see WMO-No. 834). Individual jobs: operational (dependent, field, or main) weather forecaster: agricultural forecaster; aeronautical forecaster; marine forecaster; air-quality or environmental forecaster. Competency requirements:

- know and understand the main atmospheric processes and phenomena at all scales;
- apply weather analysis and forecasting principles, methods and techniques; understand the operation of numerical weather prediction (NWP) models, and their strength and weaknesses;
- perform weather monitoring and other "real-time" operations; analyse and interpret synoptic charts, diagrams and graphics depicting current atmospheric conditions;
- know and understand the region-specific weather phenomena and major mesoscale-local scale particularities of the atmospheric dynamics over the assigned area;
- utilise the main/guidance forecast and NWP products, or other means, to create real-time weather products and to generate predicted fields; assess the evolution of weather systems, and interpret predicted fields in terms of the future state of relevant weather elements;
- perform selected post-processing of NWP-outputs and add value to model or guidance forecasts where appropriate; utilise radar surveillance and satellite imagery to monitor clouds' evolution and to improve precipitation estimates;
- elaborate and distribute regional or local, and user-specific forecasts; verify the ongoing forecasts; identify errors and amend those forecasts as appropriate;
- monitor the severe weather aspects in the assigned area and issue warnings; provide reliable emergency services; comprehend users' needs and constraints.

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 8.1.

2.2.2 Climate monitoring and prediction

Mission: 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 to inter-annual time-scales; elaborating and distributing climate warnings, as appropriate. Individual jobs: operational climatologist; agrometeorologist; micro-climatologist; environmental meteorologist. Competency requirements:
• know and understand the physical-dynamical principles governing the functioning of the Earth's climate system, from global to national and local scales; climate classification;
• understand the climate analysis and prognosis principles, methods and techniques;
• know and understand the region-specific weather phenomena, particularly the regional climatology; appreciate the normal impact of climate on various economic sectors, particularly the vulnerability of human activities to climate-related severe events;
• monitor climate data and perform other routine operations; assemble climate records;
• execute appropriate processing (statistical and dynamical) of data to depict climate patterns and variability; interpret the climate data;
• assess the evolution of the identified 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;
• verify ongoing forecasts and identify errors; amend forecasts according to the latest findings;
• understand the operation of general circulation models (GCM); utilise, if available, current climate prediction products from large climate centres; and,
• based on the long-term integration of climate models for a range of greenhouse gas and aerosol emission scenarios, along with national climate records and regional adaptation techniques, prepare scenarios on possible decades-to-centennial climate change.

An example of actual competency requirements in the branch is given in section 8.2.

2.3 Technical branches

Traditionally, the personnel employed in the technical branch for Observations and measurements were mostly at technician level; to some extent, this situation was also valid for the personnel processing the observational data. Currently, this work becomes more and more IT-oriented and requires more and more specialised personnel, particularly for the branch of Information systems technology and data processing. The mission, typical jobs, and general competency requirements for these branches will be described under the following two sub-sections. This information will then be used as a background requirement in designing curricula for Meteorological Technicians, (see chapter 5).

2.3.1 Observations and measurements; instruments

Mission: producing observational data on an operational basis for the purposes of weather and climate services; operating and controlling the network; specifying and standardising instruments and methods of observation; calibrating, maintaining and repairing instruments. Individual jobs: weather observer; radio-sounding technician; instruments technologist; AWS (automatic weather station) technician. Competency requirements:

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

An example of actual competency requirements in the branch is given in section 8.3.

2.3.2 Information systems technology and data processing

Mission: assembling and processing of incoming observational data; creating data sets for weather analysis and forecasting; maintaining information technology; archiving specific data sets; delivering products to users. Individual jobs: Operational weather technician; meteorological technologist; data manager; software development engineer. Competency requirements:

• recognise basic hardware and software components;
• understand basic operating systems, particularly transmission and computing systems;
• apply standard methods and techniques for processing, quality control, and error analysis;
• know the general operations used to generate fields of meteorological variables, possibly including assimilation of data from various sensors and platforms;
• manipulate and process meteorological data, including collecting, organising, managing and preserving information; capability to operate message switching system;
• know the purpose of the international meteorological telecommunication system, and the WMO regulations in organising this system;
• assist in the development and/or upgrading of information systems technology.

An example of actual competency requirements in the branch is given in section 8.4.

2.4 Meteorological applications and public services branches

Generally, these branches foster meteorological studies and provide services aimed at increasing the 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 utilise relevant forecasts and predictions, and adapt them (add value) for very specific purposes.

2.4.1 Agrometeorology

Mission: the study and application of meteorology (including climatology) to the specific problems of agriculture - farming, ranching and forestry, as well as the utilisation of substances required for production, e.g. water for irrigation, fertiliser, and agricultural chemicals. Individual jobs: professional agrometeorologist; agricultural engineer; agrometeorological technician. Competency requirements:

- be aware of natural climate variability and anthropogenic climate change; know basic concepts in agricultural and biological sciences; understand the adaptation of plants, crops and animals to climate; be aware of the need for sustainable agriculture practices;
- understand the relation of growth rate and crop yields to the various climatic factors; optimum and limiting climates for any crop; the length of the growing season; the impact of water balance and evaporation on field crops; critical growth periods in relation to temperature and soil moisture; geographical limits for profitable crop production;
- understand the weather and climate hazards affecting agricultural output, e.g. drought, hail, frost, strong wind; effects upon storage and transportation;
- know the impact of weather and climatic conditions on insect pests and plant diseases;
- carry out agrometeorological observations and perform routine data processing; determine net photosynthesis and water use of crops as a function of meteorological, crop and soil moisture conditions; determine irrigation demands; operate models for phenology and yield forecasting;
- prepare, based mainly on operational meteorological forecasts and climatological statistics, specific agrometeorological outlooks, which may include: accumulated temperature or sunshine likely to be available during the growing seasons; rainfall probability including return periods; work days, e.g. how many days are normally available for crop spraying;
- provide other specialised agrometeorological information and products; tailored services; assist the agricultural industry to produce commodities economically and to reduce risk.

An example of actual competency requirements in the branch is given in section 8.5.

2.4.2 Aeronautical meteorology

Mission: the study, analysis and forecasting of the atmospheric effects - particularly weather hazards - on the operation of aircraft, rockets, missiles, and projectiles. Effects usually considered are: low visibility at terminals; low-level jets and wind shear; turbulence and clear-air turbulence; icing; lightning strikes; upper winds and temperature; jet streams and tropopause, volcanic ash Individual jobs: aeronautical forecaster; meteorological technician. Competency requirements:

- understand the weather phenomena hazardous to aviation, their diagnostics and forecasting; understand which meteorological parameters are crucial for the safety and regular operations of individual user groups, in order to tailor specific information, products and services;
- know all aeronautical meteorological codes, and all criteria applied for warnings and change groups in forecasts (TAF, TREND, GAFOR, etc); follow
the standard regulations agreed with the International Civil Aviation Organisation ICAO; know the ICAO agreed and supported cost recovery principles and guidance; co-operate operationally with ATC staff;

- perform continuing monitoring of weather phenomena relevant to aviation, and understand the evolution of the weather phenomena observed at the aerodrome in the context of the underlying mesoscale and synoptic scale weather systems;
- know and apply standard methods, techniques, and other numerical tools for forecasting low-altitude clouds, fog, winds, reduced visibility conditions at terminals, gustiness and squalls; heavy rains; hail hazards, lightning;
- know and apply customary algorithms and methods to derive the icing potential, the turbulence conditions; convective, thunderstorm and mountain wave turbulence; clear-air turbulence;
- know how to interpret satellite and radar imagery, including in appreciating the evolution of convective systems, location of gravity waves in cirrus cloud, active cumulonimbus-tops, detection of icing potential in layer cloud using cloud-top temperature inferred from PDUS-IR-data; wind-shear detection by Doppler radar; Significant Weather (SIGWX) charts;
- perform competently the "local" forecaster's responsibilities, especially aerodrome warnings, SIGMETS and low-level hazards, which are critical for flight safety and cannot be represented accurately from global numerical forecasting models;
- be able to identify from pilot reports the relevant weather phenomena; classify those reports and, if appropriate, make that information available to other pilots.

Examples of actual competency requirements in the branch are given in section 8.6.

2.4.3 Marine meteorology

Mission: to make available to marine users at sea or on the coast the marine meteorological and related oceanographic information that they require, with the aim of maximising the safety of marine operations and promoting the efficiency and economy of marine activities. Concerned services may be specialised for the high seas, for the coastal and offshore areas, and for the ports and harbours. Individual jobs: marine observers on board ships, seafarers whilst at sea and in navigation schools, port meteorological officers, and meteorological personnel who are engaged in observational, forecasting and climatological duties for marine purposes. Competency requirements:

- understand the weather phenomena hazardous to marine operations; know the relevant meteorological and oceanographic codes (e.g. SYNOP, SHIP, DRIBU, BATHY, TESAC); know the criteria for storm, and other warnings;
- carry out surface observations and measurements; and where/when appropriate, on the state of sea ice; height and period of wind-waves; height, period and direction of swell; speed and direction of currents, etc; make upper-air measurements;
- know how to interpret remote sensing data from satellites and drifting boys, to derive characteristics of water masses and the behaviour of waves and ocean currents;
- assist in monitoring of surface and sub-surface movements of contaminants and the tracking of ice motions in areas of potential threat;
- prepare marine climatology summaries; provide climatic data required by the designers and operators of offshore exploration and exploitation facilities;
• know meteorological forecasting techniques: empirical, statistical, analogue and dynamical;
• issue, whenever the need arises, warnings of strong winds, rough seas, poor visibility, heavy precipitation, ice accretion, storm surges, harbour tsunamis;
• provide services for high seas circumstances: search and rescue operations, storm warnings, weather routing, fishing industry, small vessels, expert advice including in cases of litigation;
• provide services for coastal and offshore areas; issue weather and sea bulletins including sea-ice bulletins where appropriate, climatological services, expert advice and oral briefings;
• provide services in ports and harbours to assist activities such as: movements of ships into, out of and within ports and harbours; cargo handling and safety, industrial projects and operations, commercial activities, litigation and insurance, icebreaking in and close to ports and harbours, waterborne recreational activities, operations to combat marine pollution, etc.

An example of actual competency requirements in the branch is given in section 8.7.

2.4.4 Environmental meteorology

Mission: the utilisation 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 optimise 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 (e.g. biota) and the outer space. Individual jobs: environmental meteorologist; bio-meteorologist; urban meteorologist; forensic meteorologist. Competency requirements:

• understand the impact, range, and potential of the weather and climate effects on life, society and environment in general;
• 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;
• know and understand the region-specific weather phenomena and major mesoscale-local scale particularities; if appropriate, be aware of environmental problems in megacities;
• comprehend the general principles, methods and techniques used in other geo-sciences, and relate them to relevant concepts from meteorology; have an inter-disciplinary approach to “assembling of knowledge”;
• assist in the development of policy planning and decisions on environmental issues, or environmentally-related issues e.g. location of new towns and the design of industrial sites, including the siting of power stations;
• provide expert advise in policy- and decision-making on various operational problems - from short-term-managerial to mid-long-term-planning decisions - in which users/customers attempt to optimally utilise (or limit) the influence of meteorological factors;
• provide “forensic meteorology” services - the use of meteorological information to legal cases, e.g. determining the sequence of weather/climate-affected events that is subject to litigation;
• be aware of the major environmental policies on scientific, technical and economic development; and on public health, tourism, etc.; facilitate
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application of integrated approaches to sustainable development, management and use of environmental resources.

Job-competency requirements for environmental meteorologist are exemplified under section 8.8.

2.5 Meteorology-support branches

The personnel employed in the meteorology-support branches, may be required to possess a basic meteorological qualification (e.g. those working in branches for education and training or research and development), or may not be required to acquire the appropriate BIP (e.g. those working in client relations and service promotion, management and international relations). However, certain "General meteorology" knowledge would be required even in the latter case. The following presentation will use a format similar to that used in the previous sections.

2.5.1 Management and administration

Mission: supervising, guiding and directing to maximise the use of available human, technical and financial resources; representing NMS in national and international arenas. Individual jobs: operational manager; network inspector. Competency requirements:

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

The role of managers and administrators in planning and implementing continuing professional development programmes for the NMS staff is essential, see sections 6.1 and 6.5.

2.5.2 Education and training

Mission: 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. Individual jobs: Meteorological trainer; instructor; scientist; professor. Competency requirements:
• identify organisational training and development requirements; identify learning requirements of individuals; plan and design training strategies for NMS;
• design training and development programmes, as well as teaching and learning materials; deliver training; facilitate learning with individuals and groups;
• manage the implementation of training and development programmes; constantly review their progress and effectiveness; assess achievement, including individual competency achievement;
• understand and use new pedagogical approaches to education and training, including modern presentation tools;
• know and understand the region-specific weather phenomena; continuously improve his own knowledge in the earth system sciences;

Note that chapter 6 deals specifically with methods and strategies for continuing education and training in NMS.

2.5.3 Research and development

Mission: undertaking applied research and development to ensure continuing enhancement of the future operations and services; developing new ideas in meteorological science or technology. Individual jobs: meteorological researcher; applied scientist; system development meteorologist. Competency requirements:

• understand his/her own speciality at the in-depth level of a national expert or consultant;
• demonstrate a high degree of innovation in the analysis of problems, and use science and technology intelligently to solve those problems;
• know, understand and use a range of software packages or hardware;
• 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;
• demonstrate skills in lifelong learning, application of scientific method, investigation, experimental inquiry, invention, and information searching, identification, selection;
• demonstrate critical and independent thinking; recognise and encourage creativity, innovative analysis and problem solving in others;
• know and understand the region-specific weather phenomena;
• help, as appropriate in the implementation of continuing education and training programmes.

2.5.4 Client relations and services promotion

Mission: marketing planning; promoting and selling of meteorological data, information and other products; tailoring services to support end-users' current activities and strategic planning decisions. Individual jobs: meteorological marketer; client services officer. Competency requirements:

• know and understand the basics of marketing methods, techniques and procedures; know a range of alternative promotional strategies; the importance of customer needs, product benefits,
• understand the NMS contractual regulations and procedures; be aware of legal implications (for NMS) in case of failure to follow the process;
• be familiar with standard ‘market research’ software packages and databases in current use; understand particularities of the weather market system;
• demonstrate entrepreneurial mentality and innovation in the analysis of problems and use of techniques in solving them; apply marketing principles and utilise appropriate instruments;
• develop and manage projects and execute financial and resource accounting;
• understand a range of customer needs and constraints so as to relate and present their needs;
• demonstrate skills in personal relations, particularly in communication and presentation; ability to handle complaints;
• be aware of the general meteorology concepts, and main region-specific weather phenomena.
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 potential user does have large freedom in prescribing the curriculum content, the depth and pace of teaching delivery, etc.

The terms "atmospheric science" and "meteorology" are used with the same meaning, namely the study dealing with the phenomena of the atmosphere; see also "meteorology" in the WMO International Vocabulary. The inter-disciplinary connections of meteorological disciplines and specialities are viewed also within the broader context of the earth system science.

In order to design a job-specialised training programme one would need to firstly assess the actual job-circumstances and the needs in terms of knowledge and skills. The local instructors are best suited to undertake such assessments, which are essential for specifying relevant training outcomes (chapter 8 provides some useful examples). In establishing those outcomes, instructors (and managers), may co-operate also with their trainees, who must be active partners, truly committed to their own professional development.
3.1 Basic meteorological disciplines

Meteorology includes, in addition to the physics, chemistry and dynamics of the atmosphere, many of the direct effects of the atmosphere upon the Earth's surface, the oceans, and life in general. The goals often ascribed to meteorology are the complete understanding, accurate prediction, and artificial control of atmospheric phenomena (see AMS Glossary, 1996). In this context, the basic meteorological disciplines - distinguished more in function of the state of the science rather than of the subject matter itself – are as follows:

- Physical meteorology (including atmospheric chemistry and air pollution);
- Dynamic meteorology (including numerical weather prediction);
- Synoptic and mesoscale meteorology (including local scale phenomena);
- Climatology (including general circulation and climate models).

These disciplines will be described briefly in this section. The presentation is not meant to be comprehensive, but rather to fix, for the purposes of present publication, a common understanding on the general coverage of each discipline.

3.1.1 Physical meteorology

This discipline deals with optical, electrical, electromagnetic, acoustical, and thermodynamic phenomena of the atmosphere; its chemical composition; the laws of radiation; and the explanation of clouds and precipitation. Basic thermodynamics concepts will be introduced under this discipline, since they play an essential role in the quantitative (and qualitative) understanding of atmospheric phenomena, ranging from the smallest cloud microphysics processes to the general circulation of the atmosphere. Parts of atmospheric thermodynamics will be treated also under dynamic meteorology, where the focus will be on the mathematical theory of atmospheric motions and the associated forces.

Physical meteorology also includes a wide range of other topics closely related to the standard disciplines of physics and chemistry. Furthermore, noting that the problems of air pollution require specialists with a multidisciplinary knowledge of the atmospheric science, aerosol physics and chemistry, what is often referred to as atmospheric chemistry and air pollution meteorology is here treated under the physical meteorology discipline. A similar approach is adopted for basic topics on the use of remote sensing techniques, particularly radar and satellite-based observations of the atmosphere.

3.1.2 Dynamic meteorology

This main discipline 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. Its main objective is to provide 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.

As concerning the major practical application, dynamic meteorology, empowered by modern numerical analysis methods and techniques, offers the theoretical basis and the methodology for modern weather forecasting and for climate prediction by dynamical methods. Powerful electronic computers and sophisticated computational
models are required for the operational elaboration of numerical weather prediction (NWP). Actually, the scope of NWP is rapidly expanding from the weather, to new topics, such as cloud development simulations and environmental predictions.

3.1.3 Synoptic and mesoscale meteorology

This discipline is concerned with the study and analysis of weather information taken concurrently, i.e. synoptic, over a wide area, to identify synoptic scale (and mesoscale) atmospheric systems and diagnose their structures. Its traditional tool is the synoptic analysis - a detailed diagnostic study of the state of the atmosphere, based on actual weather observations.

It is stressed that in meteorology, unlike in the common usage of pertaining or affording an overall view, the term "synoptic" takes on the additional connotation of simultaneity. In addition, there is the basic concept of synoptic scale, which could imply that synoptic meteorology concerns only the cyclone scale phenomena. This is not however sufficient, particularly in the modern "synoptic meteorology", where a major accent falls on the mesoscale phenomena; to avoid possible confusion, one may prefer to use the longer designation of "synoptic and mesoscale meteorology". At the same time, synoptic meteorology deals also with the "supra-synoptic" scale patterns (e.g. weather regimes with time-space scales of the order of 10 days and 5000 km, respectively).

Today's technical basis for the daily weather forecasting includes operational databases, standardised sets of automatically plotted diagnostic meteorological maps and diagrams, NWP outputs, other products and auxiliary material. The traditional interpretation of the synoptic situation still constitutes an important tool for weather analysis, but a better understanding of the baroclinic processes is facilitated 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).

With the ever-increasing application of sophisticated objective methods, particularly the use of NWP products, the distinction between synoptic and dynamic meteorology is rapidly diminishing. A useful practical result of this ongoing "merging" is the fact that synoptic meteorologists with enhanced dynamic meteorology insight, can make, through "man-machine interaction", skilful subjective interventions to add value to numerical objective products. Thus, human forecasters' contribution, although no longer dominant, will remain important for the foreseeable future.

3.1.4 Climatology

This discipline concerns the scientific study of climate and climate phenomena. In addition to the presentation of climatic data, it includes the analysis of the underlying causes of differences of climate, climate classification and, the application of climatic data to the solution of specific design or operational problems. More recent dynamic climatology deals with the physical and dynamical explanation or interpretation either of the contemporary climate-patterns with their anomalous fluctuations, or of the long-term climate changes or trends.

A distinction has sometimes been made between applied meteorology, on the restricted sense of the application of current weather data, analyses, and/or forecasts to specific practical problems, and applied climatology, which deals with the similar application of long-period statistically treated weather data. Today, under the impact of rapid progress in information technology, there is an emerging trend of services
based on broader *environmental data streams* of past, present and forecast conditions.

### 3.2 Meteorological Specialities

Within any one of the four basic meteorological disciplines defined in the previous section, there are several sub-disciplines or specialities i.e. particular subjects or topics of study or research. For instance, cloud physics is a sub-discipline of physical meteorology; and NWP, which is a particular branch of dynamic meteorology, may be viewed as a speciality in its own right; etc. Some specialities may have came into existence without inheriting just a single parent discipline. For instance, boundary-layer meteorology, rooted in classical fluid dynamics, was developed further within the framework of physical and dynamic meteorology and its use in synoptic meteorology and climatology is very important. Similarly, mesometeorology utilises concepts and methods from synoptic, physical and dynamic meteorology, as well as from climatology (see also Chart 3.1).

*Chart 3.1: The Main Meteorological Disciplines and Specialities*

(*) Meteorological specialities, or Special applications of meteorology, include: Aeronautical meteorology; Agricultural meteorology; Atmospheric chemistry and air pollution meteorology; Atmospheric turbulence; Bio-meteorology; Boundary layer meteorology; Cloud and precipitation physics; Computational meteorology; Dynamic climatology; Environmental-applied meteorology; Hydrometeorology; Marine meteorology; Meteorological marketing; Meteorological measurement and instrumentation; Mesometeorology; Micrometeorology; Numerical weather prediction; Radar meteorology; Remote sensing; Satellite meteorology; Space weather; Tropical meteorology; Urban meteorology; Weather forecasting; Severe weather warning; Weather modification.

Other specialities may "borrow" knowledge from non-meteorological disciplines, for instance, meteorological instrumentation and measurement or remote sensing require complementary competency in mechanical and electronic engineering. Similarly, urban meteorology may include meteorological subjects (e.g. in climatology, boundary layer, atmospheric chemistry and aerosols, etc), as well as topics on urban design, transport, building construction, architecture, etc. At the
same time, as already noted for the case of synoptic-dynamic meteorology "merging", the boundaries between various disciplines/sub-disciplines are gradually becoming less distinct and the whole of atmospheric science is becoming less isolated from the other sciences. The trend is towards an ensemble earth system science (see the next section).

3.3 Earth system science

Earth system science (ESS) involves an integrated approach to the study of the Earth that stresses investigations of the interactions among the Earth's components in order to explain Earth's dynamics, evolution and global change; a special emphases is placed on the physical climate system and bio-geo-chemical cycles. In this approach, the Earth is regarded as a unified system of interacting components, including:

(i) **geosphere** - physical elements of the Earth's surface, crust and interior; relevant processes include continental drift, volcanic eruptions, earthquakes;

(ii) **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;

(iii) **atmosphere** - thin layer of gas or air that surrounds the Earth; relevant processes include winds, weather, the exchange of gases with living organisms;

(iv) **biosphere** - the wealth and diversity of living organisms on the Earth; relevant processes include life and death, evolution and extinction.

It is underlined that ESS covers not only the natural processes, with their complex three-phase nature, but also the effects of the 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.

"Addressing the scientific issues of ESS demands both breadth across disciplines and depth within disciplines; there is also an overriding need to embrace the interests of a broader range of disciplines than those which traditionally have represented geosciences (e.g. meteorology, oceanography, geology, hydrology, glaciology, etc.). Still, the knowledge residing in the geoscience disciplines is central to emergence of ESS as a holistic discipline" (quoted from Johnson et. all, 1996).

3.4 Job-specialisation

In the context of the myriad of intra-/inter-disciplinary connections, the need for job-specialisation remains. It implies acquiring professional knowledge and skills beyond the basic professional competency required for the job-entry qualification, i.e. beyond BIP. At the same time, initial elements of specialities concerning individual jobs may already be found in the elective topics of the BIP-M curricula (see section 4.3). Eventually, the optional topics (recommended in section 4.4) provide opportunities for further specialisation.
A distinction has to be made between the job-specialised personnel and the specialists - individuals, who, through study and experience, develop in-depth knowledge or skill 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-specialisation, where personnel are required just to appropriately apply conventional knowledge from a given speciality. For example, a weather forecaster does not need to know NWP modelling at the specialist level; rather he must know how to skilfully interpret and use NWP products. At the same time, a job-specialisation may not address just a single speciality. For instance, the weather forecaster, in addition to possessing the ability to use NWP products should be able to interpret satellite imagery, although satellite meteorology is a different speciality.

Most often, job-oriented training requires assembling a specific package of relevant topics from more than one speciality. The syllabi and the level of in-depth treatment of those subjects would vary from one country to another, and possibly even within a given country. To support instructors in preparing such specialised syllabi, chapter 8 highlights principal job competencies, with relevant knowledge and skills, required in practising common jobs in the branches of activity identified under section 2.1.1.
Chapter 4:
BASIC INSTRUCTION PACKAGE FOR METEOROLOGISTS
(BIP-M)

Requisite topics in basic and computational sciences, and required
complementary topics
Compulsory topics in atmospheric science
Elective topics in atmospheric science
Recommended optional topics
Beyond the BIP-M

It is essential for an individual preparing for a career as a professional meteorologist to come to know and understand the functioning of the Earth's atmosphere in the context of the earth system and to develop the ability to apply that knowledge and understanding to new problems and situations. More specifically, this preparation requires achieving the mandatory competencies specified in chapter 2, by completing the Basic Instruction Package for Meteorologists (BIP-M).

This chapter describes the BIP-M in terms of major topics that, as an ensemble, provide the foundation necessary for entry into the profession and form the basis for lifelong learning and future professional development. For convenience, the major topics have been grouped into four topic-categories (see sub-section 1.3.1). It is emphasised that this listing of major topics is neither a BIP-M "curriculum" nor a listing of "courses". Rather, a curriculum covering the BIP-M topics should be developed locally by faculty with expertise in relevant disciplines, with due regard being given to available resources and the interests of the NMS.

To assist in the preparation of appropriate curricula, each major topic provides a representative (not exhaustive) list of elements that a student must come to know, understand, and be able to apply. Some elements are intentionally repeated under different major topics to indicate connections between topics and to suggest elements that will be revisited several times during a curriculum.

The level of instruction and depth of coverage of the topics comprising the BIP-M should be similar to that used in a university physical science or engineering faculty for students majoring in applied mathematics, physics, or an engineering discipline. Some topics require not only classroom instruction, but also hands-on experience in the laboratory and practical experience in the field.
4.1 Requisite topics in basic and computational sciences, and required complementary topics

The following pre- or co-requisite topics, mandatory for completion of the BIP-M, provide the intermediate level of knowledge and understanding of mathematics and physical sciences essential for an in-depth study of atmospheric science. As a result of instruction in these requisite topics, students should develop an understanding of, and an ability to apply basic mathematical skills and general knowledge of physical and natural science to the solution of meteorological problems.

Required complementary topics, see sub-section 4.1.4, address general cultural knowledge, foreign languages, and oral and written communication and presentation skills necessary for a professional meteorologist. Many of these topics are usually included in the general requirements required by universities for completing a Bachelor’s Degree or equivalent.

4.1.1 Mathematics and computational sciences

(a) Algebra, the calculus, and differential equations: Linear algebra, to include matrices; vector algebra; plane and spherical trigonometry; analytic geometry; differential and integral calculus; ordinary differential equations; functions of two or more variables; partial derivatives.

(b) Basic probability theory and statistics: Probabilities; grouped/ungrouped occurrences; contingency and correlation analysis; univariate and multivariate time series.

(c) Introduction to information technology: Basics of computers and related peripherals; programming and applications; analysis and display software; networks of various types; telecommunications using modern computer.

(d) Introduction to computational methods: Numerical differentiation; numerical integration; differential versus difference equations; methods for the numerical solution of ordinary differential equations; stability criteria; standard transcendental equations to include effects of initial and boundary conditions; methods for the numerical solution of non-linear algebraic equations.

4.1.2 Physics

(a) Fundamentals of mechanics: Force and inertia; velocity and acceleration, momentum and kinetic energy, work and potential energy gravitation; Newton's laws of motion; rotating systems -centripetal acceleration, Coriolis and centrifugal effects; orbital mechanics - Kepler's laws, trajectories and orbits; Newtonian mechanics; stability and instability of mechanical systems.

(b) Introductory thermodynamics: Temperature and pressure; ideal gas; thermal energy; first and second laws - entropy, reversible and irreversible energy transformations, heat engines and cyclic processes; changes of phase; mixtures of gases - partial pressures; thermal boundary layer; Newton's law of cooling.

(c) Wave theory: Waves - description, propagation, transmission, refraction, diffraction; simple water waves; applications of wave theory - electromagnetism, geometric optics, and acoustics; the electromagnetic spectrum.
(d) **Fluid motion**: Nature of fluids; pressure and density; streamlines, streak lines, and trajectories; Bernoulli’s theorem; circulation and vorticity; rotation - Rossby number; stratification - buoyancy, Richardson number; combined effects of rotation and stratification - Burger number; flow near a boundary - surface boundary layer, surface stress, momentum flux, power-law profiles; Ekman number; Lagrangean-Eulerian relations.

(e) **Turbulence in fluids**: Viscosity, Reynolds number, transition to turbulent flow; turbulent diffusion; empirical and statistical representation of turbulent flow.

### 4.1.3 Chemistry

(a) **Basic chemical concepts**: The elements and the periodic table; compounds; bonding; valence; bonds; acids and bases; inert gases; metals and non-metals; reactions and reaction rates; simple rate equations.

(b) **Bio-geo-chemistry of the earth system**: Key elements in the earth system (oxygen, silicon, iron, hydrogen, carbon); water as a unique compound - physical properties, use as a solvent, etc.; the biogenic elements - oxygen, carbon, etc.; properties of the macro- and micro-nutrients; atmospheric photo-chemistry; chlorophyll, ozone.

### 4.1.4 Required complementary topics

(a) **Foreign languages**: The student should be conversant with one foreign language from among the WMO working languages: English, French, Russian, and Spanish.

(b) **History and geography**: Global, regional and national history; physical, human, cultural, and political geography.

(c) **Communication and presentation skills**: Written and oral communication; presentation skills; technical writing – reports, technical notes, and articles for journals; establishment and maintenance of web sites.

### 4.2 Compulsory topics in atmospheric science

Completion of the following major topics is mandatory for completion of the BIP-M. These provide the intermediate level of knowledge and understanding about the Earth and its atmosphere required for job entry and further specialisation. They build on and extend the basic scientific knowledge and understandings established from prior study (i.e. the requisite topics).

#### 4.2.1 Introduction to earth system science

(a) **Formation and evolution**: Formation of the Sun, Earth and Moon, and their evolution over geological time; the appearance and evolution of life; formation and evolution of the atmosphere and the ocean; plate tectonics, volcanoes, processes of wind and water that shape surface features.

(b) **Current composition, structure and spatial features**: Composition and vertical structure of Earth's atmosphere and ocean; hydrostatics; synoptic climatology and major circulation features of Earth's atmosphere; major features of the
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Oceans - currents at surface and at depth, up-welling and down-welling; structure of the geosphere - Earth's interior. Current distribution of land and sea and major features of Earth's surface; major climatic and ecological regions.

(c) The rise of modern earth science: Organisation of earth science in the early 1800s into the disciplines of geology, oceanography, meteorology and physical geography, and their evolution to the present day. The scientific approach to studies of the earth system science; distinctions between science and its applications in engineering and technology; impacts of science on human societies.

(d) Development of meteorology as a scientific discipline and profession: Evolution of the understanding of the atmosphere in the 18th and 19th centuries; birth of the concept of real time observation networks in the 19th century (weather, earthquakes). The shift from description to development of analytical and numerical models of atmospheric phenomena and their application to prediction in the 20th century. The rise of the Norwegian school and the theory of fronts and cyclones; the co-evolution of meteorology and aviation; discovery of the jet streams; development of the information technology and the numerical prediction of weather and climate. Contributions from major international research programs (e.g., GATE, TOGA-CORE); recognition of global teleconnections and the beginnings of climate prediction services.

(e) Organisation of meteorology: Roles of national Meteorological Services and private sector meteorology; history and role of the World Meteorological Organisation; establishment of the global observing system and its growth over time; World Weather Watch and other global programs; international assistance and technical co-operation in meteorology.

(f) Use of meteorological information: Weather and climate monitoring and forecast services; hazardous weather - warning services; special services to aviation, agriculture, shipping and the offshore petroleum industry, utilities, and industry and commerce. Relationships between scientists and decision-makers (especially with respect to taking judging risks arising from intrinsic uncertainty in scientific knowledge); environmental issues and judicious management of towns and country space for ensuring sustainable development.

4.2.2 General meteorology

(a) Observations, measurements and data streams: Physical principles used in instruments to measure temperature, moisture, pressure, precipitation, wind, and solar radiation. Tools, techniques, and procedures for measuring basic meteorological variables; observing cloud height and type; ceiling and visibility; techniques and procedures for estimating visibility and cloud type, height and ceiling; upper-air sounding systems. Common sources of error in standard instruments and observing techniques; techniques for estimating the confidence to be placed in a particular measurement. Organisation and operation of the global meteorological telecommunications network; coding and decoding of meteorological data; quality control of data.

(b) Analysis of weather data and display of meteorological information: Quality control and analysis - in the vertical as well as in the horizontal - of weather data. Display and interpretation of analysed data to reveal the ever-changing patterns.
of temperature, moisture, pressure, and wind; tropical versus mid-/high-latitude weather patterns; monitoring of evolving weather situations in near-real-time.

(c) *Scales of motion:* Scales of horizontal motion; planetary waves; synoptic scale cyclones and anticyclones, fronts, jet streams and jet streaks; mesoscale features - hurricanes, thunderstorms, and outflows; smaller scales, cloud, turbulence.

(d) *Weather phenomena:* Clouds - types, altitudes and conditions under which each type forms, convection, recognition from the ground and in satellite imagery. Evaporation and condensation of water - formation of frost and dew, fog and haze; precipitation - types and conditions of formation. Locally severe and hazardous weather - winter storms, hurricanes, tornadoes, blowing sand, dust, and smoke; floods.

(e) *Climates past and present:* Types of climate found on Earth today and in the past; climate classification schemes; major climatic and ecological regions; changes in the global climate over the last 150,000 years. Natural records of past climates - ice core, tree rings, ocean cores; glacial and interglacial periods - Milankovitch cycles, patterns of snow and ice cover. Determination of climate on local, regional, and global scales; seasonal cycles and natural variability; Earth's radiation budget - the planetary "greenhouse". Coupled ocean - atmosphere system; the general circulation of the atmosphere and the oceans; teleconnections between El Niño/La Niña and global patterns of weather and climate.

4.2.3 Physical meteorology

(a) *Radiation in the atmosphere:* Radiation laws - albedo, black and grey bodies, emission and absorption; solar and terrestrial radiation - measurement, latitudinal dependencies, seasonal and diurnal variations; radiation budget; radiative processes in the middle and high atmosphere.

(b) *Atmospheric thermodynamics:* First and second laws of thermodynamics in an atmospheric context; hydrostatic balance, standard atmosphere; adiabatic and diabatic processes. Changes of phase of water, latent heats of fusion and evaporation, Clausius-Clapeyron equations; convection, stability and instability criteria; adiabatic transformations of dry and moist air. Development and application of aerological diagrams.

(c) *Cloud and precipitation physics:* Evaporation and condensation, melting and freezing, sublimation and deposition of water; aerosols - hygroscopic and hydrophobic, condensation nuclei. Processes leading to the formation of clouds and to the various forms of precipitation; supersaturation; glaciation; release of latent heat and its impact on cloud dynamics. Differences and similarities of convective clouds, orographic clouds, oceanic and continental clouds; hail and ice particle formation and the relationship for the precipitation process to atmospheric electrification; formation of dew, frost, and warm and cold fogs. Processes that offer opportunities for cloud and fog modification, precipitation enhancement, and hail control; precipitable water.

(d) *Introduction to boundary layer meteorology and micrometeorology:* Boundary layer structure; significance of the boundary layer; surface heat balance; thermal
response at the surface; laminar boundary layer; characteristics and origins of turbulence;

(e) Remote sensing of Earth's atmosphere using radar: Physical principles of weather radar - the radar equation, and refraction, reflection, and absorption of electromagnetic radiation by meteorological and other atmospheric targets. Radar altimeter; Doppler effect and its applicability to radar measurement of winds; radar calibration and estimating rainfall rates; wind profiling; multiple Doppler retrievals of the full wind field.

(f) Remote sensing of the Earth's atmosphere using satellite-borne radiometry: Physical principles of satellite-borne radiometry; retrieval of winds and estimation of the atmospheric temperature profile and the sea surface temperature field from satellite radiometry; sensing atmospheric water vapour and mapping its flow. Estimation of the height of the ocean surface from satellites; sensing atmospheric ozone and monitoring its global distribution.

4.2.4 Dynamic meteorology

(a) Basic equations: Scalar and vector fields and their gradients; Gauss and Stokes theorems; kinematics of flow fields; Eulerian and Lagrangean rates of change; equations of mass, momentum and energy conservation. Navier-Stokes equations. Fluid motion on a rotating planet; inertial and rotating frames of reference; Coriolis and centrifugal forces; basic equations in isobaric co-ordinates.

(b) Applications of the basic equations: Scale analysis; the Rossby number; Taylor-Proudman theorem; geostrophic and ageostrophic flow; gradient wind; trajectories and streamlines; hydrostatic approximation; thickness and thickness tendency - effects of advection and adiabatic heating and cooling; thermal wind.

(c) Vorticity and vertical motion: Vertical motion; vorticity and potential vorticity; vorticity equation; mechanisms for generating and changing vorticity; the barotropic vorticity equation; effects of friction; boundary layers and boundary layer pumping; potential vorticity - conservation and invertibility.

(d) Quasi-geostrophic theory: f- and β-plane approximations: the quasi-geostrophic approximation for motion of a stratified fluid on a rotating sphere; quasi-geostrophic vorticity and vorticity advection; quasi-geostrophic thermal advection; the omega equation; processes leading mid-latitude cyclones and fronts; links with synoptic meteorology concepts

(e) Atmospheric waves: Basic concepts and terminology; classical wave equation; dispersion relations; phase and group velocity; acoustic waves; surface waves; internal gravity waves; beta effect and Rossby waves; linear behaviour of atmospheric motions - introduction to the atmospheric instability theory.

(f) Boundary layer: Richardson number; logarithmic wind profile in the surface layer; exchange of heat, moisture, momentum, and trace constituents between the surface and the atmosphere for various types of surfaces. Vertical profiles for the fields of heat, moisture, momentum and trace constituents and their diurnal evolution; soil temperature profile and its diurnal variations; Taylor-Ekman theory. Air flow over uneven surfaces (e.g. slope winds, sea breezes, mountain waves);
heat island effect; characteristics of boundary layers over land and sea; transition from one surface to another of different properties.

(g) **Principles of numerical weather prediction**: Finite differences, finite elements, and spectral techniques for the discretisation of partial differential equations; semi-Lagrangian techniques; stability criteria; elimination of gravity and acoustic waves; surface characteristics; model variables; boundary conditions. Dynamical equations; parameterisation of sub-grid scale atmospheric and surface processes - large-scale cloud and precipitation, convection and convective precipitation; radiative processes; gravity wave drag; sub-surface and surface layer processes; model output statistics; description and principles of a typical numerical weather prediction system - from data assimilation to production of products.

(h) **Fundamentals of objective analysis and data assimilation**: Subjective and objective analysis techniques; data assimilation from a broad range of sources - production of four-dimensional meteorological fields; preparation of gridded data to provide the necessary initialisation for regional and small-scale numerical models. Filtering of data to eliminate unwanted short-wave information, balancing and preparation of data for initialisation of numerical models; possible feedback from numerical models (first guess); dedicated analysis methods (e.g. variational).

(i) **Current operational models**: Characteristics of current operational global, regional, and local (high-resolution, nested) models; application of model output to the prediction of routine parameters and specific events (e.g. thunderstorms, hurricanes, typhoons). Specific effects in mountainous regions (e.g. waves, gusts, turbulent shear flows, etc.); known shortcomings and sources of error in the models. Role of the human forecaster in interpretation and numerical guidance translation into forecast products.

4.2.5 Synoptic and mesoscale meteorology

(a) **Analysis and display of weather data**: Map projections; plotting and contouring of spatially distributed data; identification of features observed in analysed fields (e.g., fronts, dry lines, centres of high and low pressure); vertical cross-sections through fronts and other boundaries. Preparation, display, and interpretation of basic meteorological products (e.g., surface charts, upper-air mappings, and vertical cross-sections).

(b) **Mid-latitude cyclones and anticyclones**: Classic wave cyclone models - applications, strengths and weaknesses; characteristic patterns of cloud associated with evolving cyclones and frontal boundaries as observed in satellite imagery; modern views of frontogenesis and cyclogenesis, barotropic and baroclinic zones, tropopause folds.

(c) **Tropical weather systems**: Main features of tropical weather - the Inter-Tropical Convergence Zone, hurricanes/typhoons, monsoons, tropical/sub-tropical jet streams; characteristic patterns of cloud associated with evolving easterly waves, tropical storms, hurricanes/typhoons, and convective regional processes, as seen in satellite imagery; streamline and trajectory analysis of tropical wind fields. Structure and basic processes of tropical weather systems, including the tropical easterlies and the seasonal evolutions of the tropical wind systems. Coupling between the ocean and the atmosphere present in the Southern Oscillation (El
Niño and La Niña) and the Quasi-Biennial Oscillation; tropical/extra-tropical interactions.

(d) *Mesoscale weather systems*: Structure and basic processes driving thunderstorms in the tropics and in the mid-latitudes - from simple convective cells to rotating super-cells. Interaction between thunderstorms and their environment; squall lines and mesoscale convective systems; tropical thunderstorms and squall lines; the structure and processes occurring in the rainbands and eye-wall of hurricanes and typhoons. Mountain winds lee waves and rotor clouds; land- and sea breezes; anabatic and katabatic winds.

(e) *Weather forecasting*: Basic principles of weather forecasting - extrapolation, persistence, and analogue schemes; application of the wave cyclone model, numerical prediction schemes; methods to be used for forecasts on different space and time scales. Interpretation and use of numerical model outputs and forecast guidance to prepare forecasts; use of "model output statistics"; hydrometeorology and river/flood forecasting; forecasting of severe weather throughout the year; nowcasting.

4.2.6 Climatology

(a) *The physics of the Earth's climate system*: Astronomical influences; local surface albedo and the planetary albedo; impact of humankind on Earth's surface and planetary albedo (e.g., impact of deforestation and desertification, especially in the tropics); the role of water in the earth system; ice - water storage in glaciers, polar ice sheets; water in the oceans - thermal inertia; surface currents in the oceans and their relation to atmospheric winds; transportation of energy by ocean currents, the global oceanic conveyor system; role of water vapour in the atmosphere; "atmospheric window" and its relation to the concentration of water vapour and carbon dioxide; Earth's radiation budget - dependence on albedo, clouds; greenhouse effect and its possible enhancement in the future; the role of living things in maintaining the global climate system; climate classification and its applications;

(b) *Climate dynamics*: General circulation of the atmosphere and ocean and the equator-to-pole transport of heat, moisture, and momentum; influence of the Earth's rotation on the global circulation of the atmosphere and ocean. Fundamentals of modelling the general circulation of the atmosphere; evolution from general circulation models to global climate models; examples of the coupling of land, sea, and air (e.g. Southern Oscillation).

(c) *Climate change*: Lessons from the ice ages - onset and demise; astronomical factors; rapid changes in atmospheric dust, trace gas amounts, and climate; sea level fall and rise; possibilities for global climate change.

4.3 Elective topics in atmospheric science

One of the five major topics listed below has to be included in a student's program of study. Accordingly, each student will elect one domain, which then becomes compulsory for that student. By completing appropriate topics, students lay the foundation for subsequent specialisation. Each institution offering BIP-M programmes should provide for several of these electives to be available to the student, consistent with the mission and requirements of the supporting NMS.

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4.3.1 Advanced observations and measurements
(Builds upon and extends 4.2.2 (a), 4.2.3 (e) and (f))

(a) **Aircraft observations**: Aircraft observations of cloud and pollution transport; dropsondes; airborne Doppler radar; "hurricane hunting".

(b) **Ocean arrays**: Ship observations; fixed and drifting buoys; measurements of current, salinity, and temperature; measurement of surface characteristics - wave height; radar and satellite measurements - estimation of the height of the ocean surface from satellites; the TOGA-TAO array.

(c) **Satellites**: General characteristics of polar orbiting and geo-synchronous satellites; operational radiometers; footprints; sensing water vapour and monitoring its flow through the troposphere; retrieval of vertical profiles of temperature and moisture; GPS-based measurements of temperature and water vapour; sensing stratospheric ozone and monitoring its global distribution; measuring tropospheric winds from space; characteristics of current meteorological satellites.

(d) **Weather radars**: Radar equation, and refraction, reflection, and absorption of electromagnetic radiation by meteorological and other atmospheric targets; radar altimetry; Doppler effect and its applicability to radar measurement of winds; radar calibration; wind profiling; multiple Doppler retrievals of the full wind field; radar calibration; characteristics of modern Doppler weather radars.

(e) **Advanced observing systems**: Planning optimal observing systems; simulation experiments; adaptive observations.

4.3.2 Weather analysis and forecasting
(Builds upon and extends 4.2.4 and 4.2.5)

(a) **Weather analysis**: Assimilation of data from a broad range of sources to produce four-dimensional meteorological fields; monitoring of evolving weather systems in real time.

(b) **Forecasting techniques**: Extrapolation, persistence and analogue schemes; application of conceptual models; numerical weather prediction; nowcasting; categorical and probability forecasts.

(c) **Forecasting specific weather phenomena**: Cloud type and amount; fog; maximum and minimum temperatures; wind - speed, direction, and gusts; blowing dust and snow; precipitation - type and amount, onset and duration; deep convection and related hazardous conditions - damaging winds, severe winds, tornadoes. Nowcasting hazardous phenomena such as gusts, outflows and shear flows; route and terminal forecasting in support of aviation operations, weather warning for fire prevention.

(d) **Interpreting NWP products**: Development and use of model output statistics; interpretation of ensembles; assessing reliability of the model forecasts. Limitations of numerical models; adaptation for complex terrain and data sparse regions; sources of uncertainty and error in numerical models; systematic versus random errors;
(e) Producing forecasts: Interpretation and use of NWP output and forecast guidance to prepare forecasts; tailoring forecasts to meet requirements of individual customers; organising and presenting the forecast in a timely manner.

(f) Verification of forecasts: Statistical techniques; skill scores and other measures of merit for site-specific categorical and probability forecasts; post-event analysis - verification of meteorological fields; determination of the reasons for bad forecasts and preparation of a plan of corrective actions; assessing economic value of weather forecasts.

4.3.3 Climate monitoring and prediction
(Builds upon and extends 4.2.2 (e), 4.2.6 (a), (b), (c))

(a) Earth’s bio-geo-chemical cycles: Carbon cycle and its influence on the water cycle - roles of biota on land and in the ocean in the global cycling of carbon; bio-geo-chemical cycling; global and regional cycles of carbon, nitrogen, sulphur, and other macro/micro-nutrients.

(b) Climatic impacts of oceanic circulations: Global oceanic conveyor and its role in the climate system - importance of thermo-haline convection at high latitudes leading to deep oceanic circulation; isotope methods and the concept of elements as tracers of oceanic circulations. Likely global circulations during the last glaciation; sensitivity of the ocean circulations to bottom topography, sea level, injection of fresh water, possibilities and mechanisms for rapid changes in hemispheric climate.

(c) Earth’s climate system: Earth’s radiation budget, and its coupling to the global cycle of water; controlling influences of ice/snow-albedo/water vapour/cloud on maintaining Earth’s climate, different feedback; coupling between atmospheric and oceanic currents in determining phenomena such as El Niño/La Niña.

(d) Teleconnections: Coupling of Earth’s land, sea, and air; coupling between sea surface temperatures and atmospheric weather patterns - linkages between the tropical easterlies, tropical surface oceanic currents, sea surface distortion, wind-driven ocean currents; monsoons. Hadley and Walker Circulations - the Southern Oscillation and El Niño/La Niña, North Atlantic Oscillation; teleconnections between the tropics and the mid-latitudes; impacts of these phenomena on humankind and other elements of the earth system.

(e) Global climate change: Systems for monitoring climate; natural variability versus anthropogenic forcing; possible effects of anthropogenic effects on global and regional climate - enhanced greenhouse effect and global warming; impacts of climate and climatic change on humankind and other elements of the earth system; implications for sustainable development.

(f) Climate predictions: Fundamental of numerical climate models; climatological zoning; downscaling of global climate model products to obtain regional products.

4.3.4 Environmental meteorology
(Builds upon and extends 4.2.1 (b), 4.2.3 (a), (c), (d) and 4.2.4 (f), (g))

(a) Stratospheric chemistry: Formation of ozone and its interaction with UV radiation; ozone depletion at low and high latitudes; CFCs as catalysts in the ozone destruction process. Observing strategies and monitoring tools; the particular
case of the polar regions and the seasonal formation of the "ozone hole"; Montreal protocol and subsequent agreements - impact and the long term prognosis for stratospheric ozone; considerations of the impact of excessive UV-B on the biosphere.

(b) **Tropospheric chemistry:** Natural and anthropogenic sources of pollutants and normal atmospheric cleansing processes; characterising pollutant sources - burning of fuels, tall stacks, industrial processes, vehicles; transport and mixing of pollutants on local, regional and global scales. Tropospheric photo-chemistry - NOx, VOCs, formation of smog and tropospheric ozone; scavenging of acidic particulates by the precipitation processes - acid rain, mist, fog, frost, and dew.

(c) **Air and water quality:** Tools and techniques for monitoring and sampling pollutants in air and water; storage and extraction of environmental information from databases; permissible levels of pollutants; monitoring the meteorological situation and forecasting levels of pollutants likely to occur. Using NWP to predict the transport and chemical evolution of pollutants; relevant policy, legal, and regulatory matters; relationship of air and water quality to human health.

4.3.5 Boundary layer and surface processes
(Builds upon and extends 4.2.3 (d) and 4.2.4 (f))

(a) **Physics of the boundary layer:** Diurnal evolution of the planetary boundary layer; spectrum of atmospheric turbulence; turbulent (eddy) transport of momentum, heat and water vapour; measurement of turbulent quantities; the heat flux equation; Richardson criterion; Monin-Obukhov length scale; semi-empirical and similarity theories; diurnal evolution of the planetary boundary layer. Techniques for determining the surface energy budget for different surfaces and estimating the fluxes of momentum, energy, and moisture; boundary layer stability under a variety of conditions.

(b) **Applications:** Formulation and application of numerical models to describe the diurnal cycle of meteorological parameters in the atmosphere's first two kilometres; introduction to parameterisation schemes - the "closure" problem. Markov models of the diffusion process; turbulent diffusion in the atmosphere - applications to air pollution; relationship between boundary layer stability and the transportation and mixing of pollutants.

4.4 Recommended optional topics

The following topics provide desirable additional depth in areas important to modern meteorology and give breadth necessary to work on multidisciplinary terms. Accordingly it is recommended that one of these topics be included in BIP-M programme. Alternatively, a student may elect to complete a second of the topics listed in the electives' section 4.3, to supplement and extend the required topics of the BIP-M.

The topics in higher mathematics and advanced physics prepare students for postgraduate work. In particular, students anticipating careers in research and development should consider them carefully.

4.4.1 Higher mathematics
Advanced calculus, non-linear system dynamics - chaos and complexity, strange attractors, relationships to weather and climate. Advanced statistical analysis of spatial and temporal variables; discriminant and principal component analyses.

4.4.2 Advanced dynamic meteorology

The physical principles embodied in the theory of quasi-geostrophic motion of a stratified fluid on a rotating sphere; f- and β-plane approximations; Rossby number; Kelvin and Rossby waves in the tropical atmosphere; Kelvin waves in the tropical oceans; barotropic and baroclinic instability; isentropic potential vorticity; Eliassen-Palm fluxes.

4.4.3 Advanced cloud and precipitation physics

Hail and ice particle formation and the relationship of the precipitation process to atmospheric electrification; tools and techniques for making measurements in clouds - radar, balloons, aircraft; processes that offer opportunities for cloud and fog modification, precipitation enhancement, and hail suppression.

4.4.4 Advanced atmospheric physics - acoustics, optics and electricity

Acoustics in a stratified, refracting atmosphere - propagation, trapping, wave guides, focusing; atmospheric visibility - transparency, aerosols and haze formation, turbidity; refraction in a stratified atmosphere and by droplets and ice crystals. Common optical phenomena - mirages, rainbows, halos, and glories; the fair-weather electromagnetic field; corona discharge; thunderstorms - charging mechanisms, lightning, other thunderstorm-related discharge phenomena - sprites and jets; the global electric field and its maintenance.

4.4.5 Hydrology

The hydrological cycle; precipitation and runoff; roles of soil type and texture; ground and related subsurface geology; vegetation and evapo-transpiration; structure of streams and rivers; unit hodograph; catchement models. Flow measurements; river/flood forecasting; flooding and control techniques; flash flooding; erosion; drought and drought management; irrigation systems.

4.4.6 Physical and dynamical oceanography

Physical properties of seawater; temperature and salinity distributions in the vertical and across the oceans; production of ocean sediment; water, heat and salt budget; ocean acoustics; ocean topography, plate tectonics; chemical oceanography; marine biology. Arctic oceanography, ice physics and climatology; coastal oceanography, coastal processes; tides. Ocean observational data; collection, analysis and presentation; in situ instrumentation and remote sensing. Equations of motion; scales of variability; planetary waves, currents without friction, geostrophic currents; hydrodynamic instabilities, turbulence; west coast and east coast oceanography; El Niño/La Niña; numerical modelling; operational wave forecasting.

4.4.7 Bio-meteorology
Relationships between weather and climate, and the health of humans, animals and plants; meteorological support to agriculture; the impact of the "near surface" environment in the major climatic regions around the world.

4.4.8 Technological meteorology

Advanced meteorological instruments and observation methods; instrument design and construction; application of modern information technology and advances in computer to support observing systems; synthetic aperture and phased-array radar; profiling systems; surface-based microwave radiometers, satellite radiometer; lidar-systems for detecting turbulence in clear air.

4.4.9 Space weather

The active Sun - solar structure, solar wind; solar flares, sunspots, and solar cycles. Tools and techniques for monitoring the Sun; surface and satellite-based solar monitoring systems; numerical models of the Sun and prediction of solar activity; Earth's magnetic field and its interaction with the solar wind; polar auroras; impact of solar storms on power grids, satellites and communications systems.

4.4.10 Marketing

Marketing and advertising meteorological products and services; managing sales programs; assessing economic value of weather and climate products and services; interfacing between customers and meteorologists and researchers; designing and/or "tailoring" products and services to customer needs; customer service - organising client services and provision of technical support, consulting services.

4.4.11 Meteorological management and administration

Organisation and operation of national meteorological services; finance and personnel matters; responsibilities and accountability of middle and senior managers; project design and implementation; interaction with the World Meteorological Organisation and other international bodies.

4.5 Beyond the BIP-M

The topics comprising the BIP-M provide the foundation necessary for entry into the profession and the basis for life-long learning. Completion of the BIP-M is only the first step in professional development (for some possible avenues see the BIP samples from chapter 7, in particular sub-section 7.1.3). Individuals pursuing a career in meteorology (including climatology) require routine updates and refresher training to stay in touch with the continual growth of understanding of Earth's atmosphere and the rapid advances in technology.

Career progression to mid- and senior-level positions requires additional specialised instruction that builds on and extends the scientific knowledge and understanding provided by the BIP-M. chapter 8 provides examples of the job-competencies and the required knowledge and skills in several operational areas. Some senior-level positions, such as 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, marketing, or law, as well as 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, and show indications of leadership, willingness and ability to acquire skills outside of meteorology, evidence of managerial skills and a desire to take on more responsibility.
### Chapter 5:
**BASIC INSTRUCTION PACKAGE FOR METEOROLOGICAL TECHNICIANS (BIP-MT)**

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<td>Beyond the BIP-MT</td>
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</tbody>
</table>

Meteorological Technicians may perform a wide variety of tasks, such as: the 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 and maintain meteorology-specific and information 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 major topics required to acquire the knowledge and skills necessary for the job entry-level. It is emphasised that this listing is not a curriculum proper. Rather, a curriculum covering the BIP-MT topics should be developed locally by instructors with expertise in relevant disciplines, with due regard being given to the available resources and interests of the NMS.

To assist in the preparation of appropriate curricula, each major topic provides a representative (not exhaustive) list of elements that a student must come to know, and be able to apply. The level of instruction and depth of coverage of the topics in the BIP-MT should be equivalent to that used in post-secondary vocational or technical schools preparing individuals for careers such as electronic, mechanical, or chemical technicians. Many of the topics will require both classroom instruction and hands-on experience in the laboratory and/or practical experience in the field.
5.1 Required background in mathematics and physical sciences

An individual entering a BIP-MT program should have completed secondary school (or an equivalent educational program) and so have a background in physical science and mathematics that includes the topics listed below. If the secondary school education does not provide this background, then the individual should undertake the necessary preparatory work prior to beginning the BIP-MT program. As a minimum, the required background in mathematics and physical sciences would include:

5.1.1 Mathematics

(a) Algebra: Natural logarithms, radicals, and quadratic equations, to elementary knowledge of functions, their continuity and limit; graphical representation.

(b) Geometry: Plane and simple solid geometry, plane analytical geometry, including representation of simple curves like parabola, ellipse, and hyperbola.

(c) Trigonometry: Arcs and measurement of angles, circular functions, reduction to the first quadrant, trigonometric tables, solutions of simple trigonometric equations.

5.1.2 Physics

(a) Elementary mechanics: Force and inertia; velocity and acceleration, momentum and kinetic energy, work and potential energy; Newton's laws of motion.

(b) Nature of fluids: Pressure and density; Archimede's principle; hydrostatics.

(c) Heat: Temperature, density and pressure; expansion of gases; ideal gas; nature of heat; Dalton's law; mechanical equivalent of heat; introduction to the kinetic theory of gases.

(d) Acoustics and light: Nature of sound; propagation, transmission, refraction; nature of light; visible and invisible radiation: simple waves; geometric optics, and acoustics.

(e) Electricity: Static electricity; induction; electric potential; Ohm's and Kirchhoff's laws electrical units; magnetic phenomena; terrestrial magnetism; electromagnetic induction.

5.1.3 Chemistry

(a) Basic chemical concepts: The elements and the periodic table; compounds; valence; bonds; acids and bases; inert gases; metals and non-metals; reactions and reaction rates.

5.2 Requisite topics in basic sciences and communication skills

This section outlines requisite topics in mathematics and computational sciences and the elements of physical sciences that are necessary to develop the knowledge base and skills expected of all meteorological technicians. Establishment of this post-
secondary level of knowledge of science and mathematics is essential for enabling the proper acquisition of a BIP-MT program of technical instruction and on-the-job training. Consequently, completion of the following topics as pre-requisites or co-requisites is mandatory for completion of the BIP-MT.

5.2.1 Calculus; probability and statistics; information technology

(a) *Introductory differential and integral calculus*: Continuous differential functions of one and two variables; simple derivatives and integrals; simple applications.

(b) *Elementary probability theory and statistics*: Simple frequency distribution, or tabulation and graphical representation of statistical data, the mean, median, mode, variance, and measures of dispersion - mean deviation and standard deviation; simple linear regression by least squares; correlation; measures of uncertainty and confidence.

(c) *Introduction to information technology*: Basics of computer and related peripherals; programming and applications; numerical calculations; data storage, analysis, and display software; networks of various types; telecommunications using computers.

5.2.2 Physics

(a) *Mechanics*: Rotating systems - centripetal acceleration, Coriolis and centrifugal effects.

(b) *Basic thermodynamics*: First and second laws; reversible and irreversible energy transformations.

(c) *Fundamentals of radiation*: Basic laws; corpuscular and wave theories; characteristics of radiant energy; reflection, absorption, and scattering; electromagnetic spectrum.

(d) *Introductory hydrodynamics*: Circulation and rotation; stratification and buoyancy, convection; surface boundary layer, surface stress.

5.2.3 Chemistry

(a) *Geo-chemistry*: Chemistry of the earth system: key elements in the earth system (oxygen, silicon, iron, hydrogen, carbon); water as a unique compound - properties, use.

(b) *Bio-chemistry*: Bio-genic elements - oxygen, carbon, etc.; properties of macro- and micro-nutrients; atmospheric photo-chemistry; chlorophyll, ozone.

5.2.4 Expression and communication skills

(a) *Communication skills*: Course work and/or activities to develop oral and written skills.

5.3 Compulsory topics in meteorological training
Completion of the following major topics is mandatory for completion of the BIP-MT. These provide an introductory, broad overview of the discipline as a whole, establishing and then extending the basic knowledge of the subjects concerned, which is essential to satisfactory performance at the job-entry level.

5.3.1 General meteorology

(a) *Observing Earth's atmosphere and oceans*: Surface and upper air observations; remote sensing of atmospheric phenomena using radar and satellite sensors; buoys, ships and planes; establishment of the global observing system and its growth over time; the global observing systems of the World Weather Watch and other programs.

(b) *Earth's atmosphere and radiation budget*: Composition of the atmosphere; characteristics of solar radiation; scattering, absorption and reflection of solar radiation; specific role of the oceans; terrestrial radiation and the greenhouse effect; Earth's heat budget; horizontal transport of heat; vertical structure of the atmosphere.

(c) *Atmospheric moisture*: Moisture variables; evaporation and condensation processes; formation of clouds; cloud types; formation of precipitation; types of precipitation; formation of fog; thunderstorms.

(d) *Atmospheric motion*: Atmospheric pressure; gravity; pressure gradient force; Coriolis force in the atmosphere; geostrophic wind; frictional force; hydrostatic balance; variation of wind and pressure with height; upper winds. General circulation of the atmosphere; global distributions of temperature, pressure, moisture, wind; major climatic zones. Orographic effects (föhn) and local winds (e.g. mountain and valley winds, land and sea breezes).

(e) *Synoptic meteorology*: Formation and modification of air masses; frontal waves and depressions; characteristics of extra-tropical depressions and anticyclones; characteristics of warm, cold and occluded fronts; relationship between surface and upper-air features; non-frontal depressions; tropical cyclones and hurricanes; monsoon, ITCZ.

(f) *Meteorological analysis*: Principles of contour analysis; analysing surface pressure charts to identify centres of high and low pressure, frontal boundaries, and other features; prepare standard analysis charts and diagrams.

(g) *Organisation of meteorology*: Historical, international and regional context of meteorology; the key-importance of the network concept in meteorology; roles of national Meteorological Services and private sector meteorology; history and role of the World Meteorological Organisation.

(h) *Use of meteorological information*: Weather and climate monitoring and forecast services; hazardous weather - warning services; special or tailored services to aviation, agriculture, shipping, offshore petroleum industry, utilities, industry, commerce, various environmental agencies concerned with issues for ensuring sustainable development.

5.3.2 Meteorological instruments and methods of observation
(a) **Meteorological instruments:** Constraints/specifications regarding different meteorological measurements; cloud base recorders; visiometers; dry bulb and wet bulb thermometers; maximum and minimum thermometers; grass and ground minimum thermometers; soil thermometers; thermographs. Hygrographs; aspirated psychrometers; cup anemometers and wind vanes; anemographs. Aneroid barometers; mercury barometers; barographs; rain-gauges; recording rain-gauges; sunshine recorders; instruments for measuring solar and terrestrial radiation.

(b) **Making an observation:** Procedure for producing routine observations; routine for producing non-routine observations (special reports); identifying cloud types and various meteors; estimating cloud cover (total and layers); estimating and measuring cloud height; estimating visibility. Reading thermometers; calculation of relative humidity; measuring wind speed and direction; assessing mean and gust wind speeds and direction. Recognising weather types and intensities for current and past weather observations; reading barometers and calculating QFF, QFE and QNH; calculating the three-hour pressure tendency; measuring rainfall and snow depth; measuring sunshine; assessing state of ground.

(c) **Quality control, coding, and transmission of observations:** Avoidance of errors; recognising normal and anomalous readings; recording observations in a register; completing messages in standard codes - SYNOP, METAR, and other codes; transmitting observations using telephone or IT links.

(d) **Operating, maintaining and resetting instruments:** Resetting thermometers; time marking recording instruments and changing charts and pens; adjusting recording instruments; be familiar with methods of cleaning instruments; carrying out simple repairs to instruments; maintaining the enclosure and instrument screen to the operationally acceptable standard.

(e) **Automatic observing systems:** Operate display functions; enter manually observed data; quality control completed message, transmit message; maintain IT equipment; comply with health and safety, and security regulations associated with the use of IT equipment.

(f) **Decoding and plotting observations:** Read standard meteorological codes; plot observations on surface and upper air charts; plot soundings on aerological diagrams.

### 5.4 Elective topics in meteorological training

At least one of the major topics listed below is to be included in a student's program of study as a foundation for subsequent specialisation. Accordingly, each trainee will elect one topic, which then must be completed by that trainee.

#### 5.4.1 Upper-air measurements

Pilot balloon observations of winds aloft using single and double theodolites; using a radiosonde system to obtain temperatures, humidity, pressure-height, and winds aloft. Testing and preparation of instruments prior to launch; quality assurance of received data; plotting of soundings on aerological diagrams; coding and transmission of aerological data using telecommunications equipment; maintenance of upper-air observing equipment.
5.4.2 Meteorological data processing

Information technology operation; use standard statistical, weather analysis and display software; analysis of weather data and display of meteorological information: quality control and analysis - in the vertical as well as in the horizontal - of weather data; display and interpret analysed data to reveal the patterns of main meteorological parameters.

5.4.3 Delivery of products and services

Customer services and relations; organise and display weather observations, NWP output, and forecast guidance; monitor the receipt of forecasts and warnings; communicate forecasts/warnings to the public/authorities and individual customers; assist the forecaster in briefings; prepare forecast verification data; maintain climatological records; prepare and disseminate climatological information.

5.4.4 Environmental measurements

Natural and anthropogenic pollutants and normal atmospheric cleansing processes; pollutant sources - fuels, tall stacks, vehicles; transport processes; legal levels of pollutants; formation of smog and tropospheric ozone; acid precipitation; tools and techniques for measuring pollutants; particulates; surveying and sampling techniques.

5.5 Beyond the BIP-MT

The BIP-MT provides the foundation necessary for entry into a technical career. However, completion of the BIP-MT is only the first step in career development. Individuals pursuing a technical career in meteorology require routine updates and refresher training to stay in touch with the continual growth of understanding of Earth's atmosphere and the rapid advances in technology. Moreover, career progression to senior-level positions will require additional specialised formal instruction that builds on and extends the knowledge and understanding provided by the BIP-MT.

As the competencies required for technical staff in a NMS cover a wide range of activities, it can be envisaged that the formal instruction for senior level technicians includes some specialisation in one of the professional job families (i.e. weather analysis and forecasting, climate monitoring and prediction, or meteorological applications). The topics to be included in this instruction will be largely based on those described in chapter 4 for the BIP-M, and adapted to each specialisation and to the needs of the NMS. However, the treatment of the different subjects will be mainly on the practical side and focused on applications rather than on theoretical approaches. This instruction could also include complementary topics addressing general cultural knowledge, a foreign language, and oral and written communication and presentation skills. A sample of a complete program for qualifying higher technicians may be found in section 7.3.

Moreover, 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 designing, implementation or supervision of networks, systems, and observing standards and other relevant activities).
To understand the importance of continuing education and training, it is first necessary to consider how and why organisations change, and how this change can be managed. This leads to the concept of the "learning organisation". 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 organisation.

It is likely that increasingly organisations are going to be successful if they make full use of the creativity and learning potential of the people within the organisation. 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 organisation 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 (CPD) will be used to illustrate ways in which people within an organisation, such as a national Meteorological Service (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.
6.1 Introduction

6.1.1 Factors affecting NMSs

Change is a natural process for all organisations. Indeed, without change it is unlikely that an organisation could continue to be successful. 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" to be done which were previously impractical;
- change arising from improvements in understanding of physical processes in the earth system, which underpins the developments 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 commercialisation and/or cost recovery by many governments;
- growth of the provision of meteorological services by the private sector;
- increased interdisciplinary co-operation 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 driven by rapid developments in information technology and telecommunications, and increased globalisation.

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

6.1.2 The learning organisation

There are strategic benefits in an organisation being able to manage change so that it is always in harmony with the changing technology and the environment in which it is operating. The need for an organisation to change in this way has led to the concept of a "learning organisation". Some of the features of a learning organisation 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 organisation often requires a complete change in culture. Indeed the whole structure and operation of the organisation may need to be realigned. It needs to be recognised, however, that this cannot be done successfully without full commitment to the process throughout the organisation.

There are many factors that need to be examined if an organisation wants to move towards becoming a learning organisation. 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 organisation proactive in identifying future skill requirements and providing education and training to meet these requirements?
• does the organisation encourage planned professional development activities?
• is the identification of training and professional development needs integrated into the organisation'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 organisation.

6.1.3 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 realisation 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 people's full potential by:

• anticipating and responding to change in employment pattern and in individuals' expectations;
• supporting and motivating individuals in developing their capabilities;
• adapting its organisational 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 continuing education and training. This is applicable to an NMS just as much 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 6.1 gives an indication of how an organisation can demonstrate that it is following good practice for the continuing education and training of its employees.

**Table 6.1 Indicators of whether an organization is following good practice for continuing education and training**

<table>
<thead>
<tr>
<th>Principle</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commitment</td>
<td>- the organisation has considered what employees at all levels will contribute to the success of the organisation;</td>
</tr>
<tr>
<td></td>
<td>- and has communicated this effectively to them.</td>
</tr>
<tr>
<td>Planning</td>
<td>- a written plan identifies resources that will be used to meet training and development needs;</td>
</tr>
<tr>
<td></td>
<td>- objectives are set for training and development actions at the organisation, individual and team level;</td>
</tr>
<tr>
<td>Action</td>
<td>- all new employees are introduced effectively to the organisation and all employees new to a job are given the training and development they need to do the job;</td>
</tr>
<tr>
<td></td>
<td>- all employees are encouraged to meet their job-related training and development needs;</td>
</tr>
<tr>
<td>Evaluation</td>
<td>- top management understands the broad costs of developing and training employees;</td>
</tr>
<tr>
<td></td>
<td>- action takes place to implement improvements to training and development identified as a result of evaluation.</td>
</tr>
</tbody>
</table>

These considerations indicate that continuing education and training must be placed within an organisational 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 organisation. Continuing education and training for an individual requires direction, support and recognition from within the organisation.

**6.2 Basic concepts**

**6.2.1 Continuing education and training**

In order to describe the role of continuing education and training it is important that the meaning of terms such as continuing education and training is understood. The following definitions might prove useful, though they are not unique.
**Education.** The learning process in which the transfer of knowledge and the development of critical thinking are the principle aims.

Increasingly the educational process is focussing 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.

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.

The education that forms part of a planned and systematic process can be divided into "formal education" and "non-formal education".

*Formal education.* Education provided in a regular and highly structured system (e.g. in schools and academic institutions).

*Non-formal education.* Education provided after an individual has left formal education and/or assumed adult responsibilities.

Continuing education consists mainly of non-formal education, though sometimes, formal education can have a role.

*Continuing education.* 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 principle 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 organisation in which that person works.

Having defined various aspects of education, it is appropriate to define training.

*Training.* A planned process directing 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 these 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.

6.2.2 Development, continuing professional development and lifelong learning

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 6.2.

**Table 6.2: The characteristics of training and development**

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

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

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

*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 organisation to develop different types of knowledge, understanding and skills through hands-on experiences. This process can be institutionalised by organisation 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 organisation:
• 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 recognises 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.

### 6.3 Getting the most from CET activities

#### 6.3.1 Importance of CET

CET is of importance to both an organisation and the individuals within that organisation.

For an organisation 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 organisation;
• provide a mechanism for regularly updating the skills of staff;
• induction of new employees into methods of work and organisational culture;
• improve staff morale and job satisfaction;
• allow staff to appreciate how their work fits into the broader business activities of the organisation.

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

• CET activities fully take into account the training needs and business objectives of the organisation;
• the cost of CET is assessed, though it should be recognised that CET leads to benefits that are very difficult to put 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, and 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;
• provide professional accreditation.

Figure 6.1 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.

Figure 6.1 *Impact of lifelong learning through CET on knowledge and skills required during employment.*

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

### 6.3.2 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 organisation;
• clearly identifying the needs of the individual and the organisation.

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

6.4 Methods for continuing education and training

6.4.1 General issues

For CET to be most effective it is important that the method of delivery is:

• appropriate for the learning preferences of the individual;
• appropriate for the learning objectives.

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

There are four other factors that need to be considered when agreeing a CET programme for an individual.

• 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.

6.4.2 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;
• 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;
• time available to complete the training.

Table 6.3 gives and 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.

Table 6.3: Impact of various CET methods and attitude, knowledge and skills and the way they are usually delivered

<table>
<thead>
<tr>
<th>Method</th>
<th>Attitude</th>
<th>Knowledge</th>
<th>Skill</th>
<th>Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coaching</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>On-the-job</td>
</tr>
<tr>
<td>Conference/seminar</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Off-the-job</td>
</tr>
<tr>
<td>Computer-aided learning</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Off-the-job</td>
</tr>
<tr>
<td>Courses</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Off-the-job</td>
</tr>
<tr>
<td>Guided reading</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Off-the-job</td>
</tr>
<tr>
<td>Observation</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>On-the-job</td>
</tr>
<tr>
<td>Secondment/temporary placement</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>On-the-job</td>
</tr>
<tr>
<td>Self-study material</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Off-the-job</td>
</tr>
<tr>
<td>Simulation</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Off-the-job</td>
</tr>
<tr>
<td>Video-based learning</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Off-the-job</td>
</tr>
</tbody>
</table>

There are advantages and disadvantages associated with each method of delivering CET. These are outlined in Table 6.4 below.

Table 6.4. Characteristics of various methods for delivering CET

<table>
<thead>
<tr>
<th>Method</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coaching</td>
<td>• good way to practice new skills on the job;</td>
</tr>
<tr>
<td></td>
<td>• success depends upon the effectiveness of briefing and de-briefing sessions before and after a task execution;</td>
</tr>
<tr>
<td></td>
<td>• the support of the coach is required;</td>
</tr>
<tr>
<td></td>
<td>• the individual must be prepared to discuss openly areas in which performance is not adequate;</td>
</tr>
<tr>
<td>Learning Method</td>
<td>Advantages</td>
</tr>
<tr>
<td>------------------------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Conference/seminar</td>
<td>• of most value in complementing other CET activities;</td>
</tr>
<tr>
<td></td>
<td>• can be stimulating and broadening experience;</td>
</tr>
<tr>
<td>Computer-aided learning</td>
<td>• may contain both instructional and illustrative information;</td>
</tr>
<tr>
<td></td>
<td>• learning can be done in the individual's own time and at his own pace;</td>
</tr>
<tr>
<td></td>
<td>• needs to be supported by other activities to develop skills in using the concepts learned;</td>
</tr>
<tr>
<td></td>
<td>• content may not reflect the organisation's structure and needs;</td>
</tr>
<tr>
<td>Courses</td>
<td>• useful when several people have the same training need;</td>
</tr>
<tr>
<td></td>
<td>• needs to be scheduled in advance;</td>
</tr>
<tr>
<td>Guided reading</td>
<td>• good for acquiring new knowledge;</td>
</tr>
<tr>
<td></td>
<td>• essentially a &quot;solo&quot; activity so may not appeal to people who prefer to interact with others and learn in groups;</td>
</tr>
<tr>
<td>Observation</td>
<td>• good way to study the practical work-based applications of theoretical concepts;</td>
</tr>
<tr>
<td></td>
<td>• rapport between the individual and &quot;shadow&quot; is essential;</td>
</tr>
<tr>
<td>Secondment/temporary placement</td>
<td>• can provide a good broadening experience;</td>
</tr>
<tr>
<td></td>
<td>• effective induction is necessary;</td>
</tr>
<tr>
<td>Self-study material</td>
<td>• useful for acquiring knowledge;</td>
</tr>
<tr>
<td></td>
<td>• support in using the material is often required;</td>
</tr>
<tr>
<td>Simulation</td>
<td>• good way to give exposure to real work-based practices and problems;</td>
</tr>
<tr>
<td></td>
<td>• complex simulations take a long time to set up and run;</td>
</tr>
<tr>
<td>Video-based learning</td>
<td>• can be a quick way to learn;</td>
</tr>
<tr>
<td></td>
<td>• videos can be expensive and of variable quality;</td>
</tr>
</tbody>
</table>

6.5 Some trends in CET
Any CET programme developed within a NMS should take account of:

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

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

6.5.1 Training plans

Increasingly CET programmes are being based upon an analysis of the training needs of the organisation. 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;
- 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.

6.5.2 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 get out of date 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 scrutinised 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;
- 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.

6.5.3 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 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 recognised 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 qualification 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 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.

6.5.4 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. NMSs 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 now being 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;
- 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 someone'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.

6.5.5 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 about:

- the subjects being covered by the CET activity;
- the systematic approach to training - identify training needs, plan training, design and deliver training, and evaluate training;
- 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 recognised 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.

6.6 Final remarks

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

- commitment from throughout the organisation for the training and development of individuals;
- a clear understanding of the purpose and needs of the organisation and the role of the individual in that organisation;
- effective planning of training and development so that the needs of the individual and the organisation 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;
- 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 organisation.
The spirit of "focused flexibility" and "specific adaptation" followed under Part A is somehow reversed under the present Part B, where the given real-life examples are "specifically focused", but these may still be "flexibly adapted" to the local priorities.

The three examples from chapter 7 illustrate the basic qualification requirements for the 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 eight examples from chapter 8 highlight the job-competency requirements at the current operation level in some national Meteorological Services. It is recalled that defining job competencies is only the first step in identifying the requirements in terms of knowledge and skills. Once these requirements are known, then appropriate training programmes and the associated curricula for specialised training (e.g. beyond that required by the BIP-M and BIP-MT) 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.
This chapter gives three examples of Basic Instruction Packages - two for Meteorologists and one for Meteorological Technicians.

The first example describes the minimum curricular composition and career options for an undergraduate four-year degree programme in atmospheric science. The second example describes a 12-months postgraduate diploma course in meteorology, for students who already possess a university degree in selected domains (e.g. mathematics, physics or chemistry). The third example illustrates a complete two-year course for qualifying Higher Meteorological Technicians.

These examples may inspire instructors and managers in developing 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.
7.1 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.)

7.1.1 Introduction

This statement describes the minimum curricular composition, faculty size, and facility availability recommended by the American Meteorological Society for an undergraduate degree program 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 programs who enter government service normally complete additional specialised 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 the university later in their careers to obtain a master's degree to enhance their career progression. Accordingly, the program described in 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 programs 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 program 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 program attributes listed in Section 7.1.2 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 section 7.1.3 for a few selected careers.

While many similarities exist, the curricular program described in Section 7.1.2 differs somewhat from that required for employment as a meteorologist by the federal government. Although the 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.

7.1.2 Attributes of bachelor's degree programs

(a) General objectives

The objectives of a bachelor's degree program 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.

(b) 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:

• 12 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;
• 3 semester hours of atmospheric physics with emphasis on cloud/precipitation physics and solar and terrestrial radiation;
• 3 semester hours of atmospheric measurements, instrumentation, or remote sensing, including both lecture and laboratory components, and
• 3 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 3 semester 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 utilise 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 system 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.

(c) Faculty

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

(d) Facilities

There should be coherent space for the atmospheric science program 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 sub-section (b), the atmospheric science program 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.

(e) Student recruitment and retention

Institutions should provide academic programs with resources and the flexibility necessary to recruit and retain students with diverse educational and cultural backgrounds.

7.1.3 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.

(a) Weather forecasting careers

Students intending to enter this career field should seriously consider including the following coursework or types of experiences in their program of study:
(i) 3 courses in synoptic and mesoscale meteorology, to include an introduction to numerical weather prediction (these courses would include any taken as part of the courses recommended in basic requirements under item (i) of sub-section 7.1.2b);

(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 7.1.2b).

(b) Air pollution careers

Students intending to enter this career field should seriously consider including the following coursework or types of experiences in their program 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 7.1.2b);

(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 having courses such as (ii) and (iii) above as prerequisites;

(v) A course involving dispersion analysis and the use of air quality models.

(c) Business-related careers

Students intending to have 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;

(iv) Either a course in organisational behaviour or one in entrepreneur-ship or small business management.

7.2 Example of a Condensed BIP-M Programme

(Adapted by L. A. Ogallo from the curriculum for Postgraduate Diploma in Meteorology, University of Nairobi, 1998; Kenya)

7.2.1 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;
- 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, the 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.

### 7.2.2 Examinations scheme

(a) for all the courses other than the project work, the continuous assessment marks will constitute 30% of the total marks while the written examinations will take the remaining 70%. Students will undertake research projects in specific fields of Meteorology or Meteorological Applications under supervision by academic member(s) of staff. The Project work is presented orally before a panel of examiners including the external examiner. Final oral presentations constitute 50% 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%;

(b) pass mark for each unit course is 50%;

(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%;

(d) a candidate who fails between 7 - 12 units with an average of 50% 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% - pass;
- 60 - 69% - pass with credit;
- >=70% - pass with distinction.

### 7.2.3 Core courses offered in postgraduate diploma in meteorology:

- 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.

7.2.4 Description of courses

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.


Tropical Meteorology I: Differences between the tropics and extra-tropics. Tropical general circulation: observed mean fields; temperature, zonal wind, mean meridional motions, humidity, seal 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 the 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.


**Applications of Statistical Methods in Meteorology I:** Methods of presentation and analysis 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


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.


Tropical Meteorology II: The tropical boundary layer processes. Tropical convection, CIFK, 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 by academic member(s) of staff. The students are required to consult with the relevant supervisor(s) at least once every two weeks for guidance. The students will be guided on how to prepare a project proposal in their areas of choice. The Project work is presented orally before a panel of examiners including the External Examiner. Final Oral presentations constitute 50% of the total marks. Students should submit typewritten project reports duly signed by their respective supervisor(s). These reports shall be examined by internal examiners, from which the student will get the remaining 50%. 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.


7.3 Example of a Complete BIP-MT Programme
(Adapted by C. Billard from the curriculum for Higher Meteorological Technician Diploma; Météo-France, 1998; France)

7.3.1 Aims and organisation of the programme

This programme is aimed at training the students in order 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.

The programme duration is two academic years, and it includes:

- theoretical and practical courses in turn, at the Ecole 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 knowledge and competencies previously acquired.

7.3.2 Description of the courses

**Mathematics** - 20 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).

**Physics** - 20 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.

**General meteorology** - 100 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 on the other hand. 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** - 15 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** - 20 hours (over 7 weeks): General course especially devoted to 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** - 100 hours (over 25 weeks): Qualitative approach, measuring and coding meteorological parameters, upper atmosphere observations, automated methods. General organisation 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** - 100 hours (over 35 weeks): This course deals with 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** - 120 hours (over 40 weeks): Course including lessons and practical activities aimed at delivering basic knowledge and skill to the 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; specialised forecasts for aviation, marine activities, agriculture, air-quality; weathercasting; some features of the forecasting activities in tropical regions.

**Interpretation of satellite imagery** - 15 hours (over 5 weeks): The main direction of this course is how to use as efficiently as possible 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** - 15 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** - 52 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** - 70 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** - 20 hours (over 10 weeks): Enabling the students to use classical office software.

**Meteorological telecommunications** - 12 hours (over 3 weeks): The global telecommunications system of WMO; the national meteorological telecommunication network; different techniques used for telecommunications in meteorology.
CHAPTER 7 – EXAMPLES OF BASIC INSTRUCTION PACKAGES

Geography - 18 hours (over 9 weeks): Map marking; climatology and geography of climates: definition and classification; climatic areas; basics about numerical geographical information systems.

Tropical meteorology - 14 hours (over 4 weeks): Energy budget of the Earth; recalling main facts about general circulation; meteorological equator; tropical disturbances and hurricanes.

Meteorological services and products - 91 hours (over 25 weeks): These topics are presented according to the needs of various kinds of users and different economics sectors concerned.

Administrative Law - 20 hours (over 10 weeks): Origins of law; national and European political institutions; administrative organisation at central and territorial levels; specific rules for finance management in a public body; human resources management and regulations.

Foreign languages, especially English - 100 hours (over 40 weeks): General and specific "meteorological" foreign language; standard evaluation systems (Test of English as a foreign language); presenting meteorological bulletins in foreign language.

Sport - 2 hours per week (over 30 weeks).

Workshop Sessions (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):

- 8 weeks workshop covering: analysis (2 weeks); observation (2 weeks); computer techniques (2 weeks); oral communication (1/2 week); commercial methods (1/2 week);
- 9 weeks workshop covering: analysis/forecasting (3 weeks); observation/local climatology (3 weeks); climatology/computer techniques (3 weeks).

7.3.3 Training periods

Two training periods are foreseen during the programme:

- a one week early stage in a professional team, enabling the trainee to discover the professional standards required within a national meteorological service;
- a two-weeks 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.

7.3.4 Personal project

This is the final activity in the programme during 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.
Chapter 8:
EXAMPLES OF JOB-COMPETENCY REQUIREMENTS IN THE
MAIN BRANCHES OF ACTIVITY

Weather analysis and forecasting
Climate monitoring and prediction
Observations and measurements; instruments
Information systems technology and data processing
Agrometeorology
Aeronautical meteorology
Marine meteorology
Environmental 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 these examples in response to specific requests from WMO, and 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 certain overlapping in the subject coverage of some examples.

The given examples concentrate mainly upon the technical competencies, but as noted in section 2.1.2, it may also be necessary to specify general abilities such as: dealing with physical constraints and hazards by following health and safety procedures; communicating effectively; applying a problem-solving approach to non-routine tasks; managing several tasks at any one time; managing one's own learning and performance; working effectively with others; acquiring new skills, knowledge and understanding demanded by changes in products, technology and working practices; understanding how one's job contributes to meeting national and international commitments.

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.
8.1 Weather analysis and forecasting
By R. W. Riddaway; United Kingdom Meteorological Office

8.1.1 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.

8.1.2 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.

8.1.3 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 personalise 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.

8.1.4 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 against another.

*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.

**8.2 Climate monitoring and prediction**
By Y. Kimura; Japan Meteorological Agency

8.2.1 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.

8.2.2 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;
8.2.3 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.

8.2.4 Prediction of climate

The climatologist must:

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

8.2.5 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.

8.2.6 Verification of forecast (prediction)

The climatologist must:

- be aware of the purposes of forecast verification;
- have knowledge of methods used in forecast verification:
  - terministic 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..

8.2.7 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.

8.2.8 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.

8.2.9 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.

8.2.10 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 as
well as unambiguously;
• apply appropriate knowledge of meteorology and climatology when explaining
the climate monitoring and prediction information to users.

8.3 Observations and measurements; instruments

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

Meteorological data sets 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 the
National Meteorological Service (NMS), there is continuing pressure to ensure
maximum effective utilisation 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 the 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 diffused 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 Branch:

**Basic skills:**

- basic meteorology;
- basic measurement science;
- quality systems;
- safety & 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).

8.3.1 Branch management

**Tasks:**

- establish and manage contracts for basic data, including: upper-air observatories; ‘voluntary’ observers; ‘voluntary’ ships; climate data; METARs, AMDAR;
- establish Service Level Agreements with other divisions of the NMHS 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 co-operative 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 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 NHMS 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 World Weather Watch;
• job scheduling to meet operational targets;
• working under pressure to meet deadlines.

8.3.2 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;
• 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.

**Competencies:**

• understanding of forecasting and climatological data requirements;
• detailed practical knowledge and experience of all observing standards and techniques;
• problem solving ability;
8.3.3 Observing standards

Tasks:

- 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;
- co-ordinate 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.

Competencies:

- 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, Guide to Instruments and Methods of Observation;
- a well-developed quality culture;
- good analytical ability- statistical methods; problem solving.

8.3.4 Systems engineering

Tasks:

- 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;
- co-ordinate 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 synthesise appropriate solutions; excellent problem solving skills;
• able to manage projects to tight time and cost targets.

### 8.3.5 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.

### 8.3.6 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 practised 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.

8.3.7 Measurement standards; instrument calibration; quality assurance

**Tasks:**

- manage and maintain NMS standards and their adherence to national and international standards, according to the ISO9000 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 and WMO No.8 Guide to Instruments and Methods of Observation;
- 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.

8.3.8 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 an ‘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 organised with good planning skills and attention to details.

8.4 Information systems technology and data processing

By H. J. Koppert; Germany, Deutscher Wetterdienst

The tasks performed at today’s Information Technology (IT) Department of NMHSs differ little 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 at the IT Department require skills and knowledge in certain areas (see sub-sections 1 to 6 below). For all of those areas, a basic set of IT skills is necessary:

- recognise 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;
- 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.

8.4.1 Information systems operating

Typically NMHSs rely on mainframe/server computers. Numerical Weather Prediction (NWP) models are run on vector or massively parallel supercomputers. Post-processing is done on powerful servers. Some NMHSs 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 NMHS 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 European Center of Medium Range Weather Forecasts);
- proficiency in UNIX/Windows NT operating system;
- system commands, tools and applications;
- shell programming (UNIX).

8.4.2 Database administration and programming

NMHSs have to store large amounts of observational, processed and gridded data. These data are stored in commercial Relational-Databases.

A Data Base Administrator Associate:

- is responsible for the storage and retrieval of NMHS 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, optimise 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 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).

8.4.3 Networking

NMHS 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 NMHS network needs to make sure that it fulfils the needs of timely and secure data transmission;
- set-up NMHS Local Area Network (LAN) and Wide Area Network (WAN) according to his or her assessment of NMHS 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 X25, 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 centralised);
proficiency in configuring firewalls and in implementing NMHS 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.

8.4.4 International meteorological telecommunication

Advanced NMHSs 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 NMHS 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;
  - backup operations;
  - upgrades;

- knowledge of:
  - network and communication protocols in use, like X.25 and TCP/IP;
  - data exchange via the internet;
  - the parameters to be set for each of the connections in co-ordination with the remote installation;

- knowledge of:
  - the codes used for meteorological information in messages;
  - common practices in operating the international data exchange;
  - the WMO regulations organising the international meteorological message exchange;
  - the overall structure of the GTS.
8.4.5 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 Microsoft's Windows operating 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, visualisation packages, mathematical and physical libraries, image manipulation programs, word processors, spread sheets;
- distribute software throughout the NMHS 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 utilising 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.

8.4.6 Software engineering
Most of the meteorological application software is very specific. Therefore the Software Engineer 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 program 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 NMC;
- 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.

8.5 Agrometeorology
By H. P. Das; India Meteorological Department

8.5.1 Developing weather forecasts for agriculture; products for the customer

(a) 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.
(b) *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 bio-meteorological observations on the health and diseases of livestock.

*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 co-efficient 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 livestock 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 Farmer's Weather Bulletins, 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-wise 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 Farmer's Weather Bulletin 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 having 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 devices to superiors, when IT equipment should not be touched;
• be able to use IT equipment such as answerable phones, tele-fax etc.

8.5.2 Developing an agrometeorological advisory service (AAS)

(a) Competency requirements:

• developing operationally useful forecasts of meteorological parameters important for current farming operations;
• utilising 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;
• creating a standing machinery for the evaluation of the effectiveness of the advisories issued;
• framing the AAS bulletins consistent with the guidance and relevant information mentioned above.

(b) 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 the authorities concerned 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 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 disease to the animals;
• be able to get any further specific guidance material needed on the spot 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 for advising potential users of the tentative nature of the monthly and seasonal outlook;
• develop suitable crop yield forecasting models for the 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 forest fire danger or any phenomenon that could affect the agricultural activities of a region (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 right time for sowing which is decisive for 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 the 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, hardiness, 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 dessication, so temperature variables are often more important than wetness variables;
• be aware that the key factors for the effective utilisation 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 timely dissemination of advisories to the farmers, i.e.
• be able to disseminate the 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 requirement from the users and co-ordinate diffusion of information;
• be able to evolve appropriate means to get feedback from progressive 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 agro-climatic zones;
• be able to inform the 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 during assimilation of data and framing advisories, i.e.**

• discusses with the group possible questions during formulating of 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.

8.5.3 Developing computer based information system for operational application

*(a) Competency requirements:*  
• standardising data collection - information delivery system for user requirements by incorporating new technological innovations;
• using the agrometeorological data base judiciously for advisories and other operational decisions.

*(b) 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 the farm community centre using all available channels from telephone lines to personal computers through 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 check critically 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 region-wise.

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 the satellite information and imageries for operational purpose;
- be able to make 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 Normalised 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 discern.

8.6 Aeronautical meteorology

- Part A: Principal job competencies required for the aeronautical forecasting

By T. C. Spangler and D. Wesley, USA: Cooperative Program 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.

8.6.1 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;
• 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 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.

8.6.2 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

• recognise 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

• recognise the hemispheric wave patterns that favour widespread overrunning 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 the 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:

1. surface and upper-air observations (temperature and moisture profiles, precipitation type, fronts, cloud height). Utilise vertical cross sections;
2. pilot Reports (PIREPs);
3. radar mosaics (areas of precipitation);
4. 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; see also item 1);
5. 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. airmass 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. 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 the 3-24 hour time period, utilising 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 droplet or ice particle formation;
• use satellite data to evaluate changes in clouds (coverage, type, and temperature);
• use WSR-88D bright band observations, 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.;
• utilise 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 where icing is likely with respect to the potential icing severity within 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 utilise 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, mixed;
- keep a record of icing events and the severity of their impacts on aircraft operations.

8.6.3 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 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 conditions favourable or unfavourable 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 conditions favourable or unfavourable 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;
• utilise 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 initialisations;
  - 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 utilising both observational data and the critical factors in the model data assessed in the above part on "utilise 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);

8.6.4 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 (see sections 8.6.2 and 8.6.3).

The tools listed above are imbedded within the icing and fog/stratus skills listed in sections 8.6.2 and 8.6.3 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/stratus, is the first skill under the heading Diagnosis (section 8.6.3) utilising observational data to assess cloud cover and the dynamic-thermodynamic state of the atmosphere. The tools utilised for these skills relate to surface observational data, satellite observations, upper-air measurements, and ship reports.

8.6.5 Product dissemination

In addition, the aeronautical forecaster must be proficient at issuing forecast products to the users (pilots, controllers, dispatchers, FAA 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.

Structure and format of aviation forecasts vary widely across the various centers 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, the means and forms of communicating weather information (observations, forecasts, warnings) to the 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 require a new approach to training and assigning of tasks to aeronautical forecasters.

8.6.6 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** both 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:

8.6.7 Knowledge and skills in weather watch and monitoring

*Ability to attribute weather phenomena relevant to aviation as specified in ICAO International Standards and Recommended Practices (Annex 3 - Meteorology) 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, ATC 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.

8.6.8 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 hrs), 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 (i.e. a PIREP of mod/sev icing 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.

8.6.9 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 and the ICAO Annex III. Firm knowledge of all criteria applied to warnings and change groups in forecasts (TAF, TREND; GAFOR, 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, ensuring 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 parameterised. 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. See ICAO requirements for e.g. 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.

8.6.10 Oral briefings to pilots and dispatchers; liaison with ATC personnel

*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. understand the specific problems of a particular operation, is vital. The forecaster needs to have excellent communicating 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 ATC procedures*. The efficient use of airspace and terminal aerodrome capacity requires excellent co-operation of meteorological and ATC staff. ICAO regulations stipulate that warning and TREND criteria are to be fixed in close collaboration with air traffic 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 etc. is invaluable for forecasters.

8.6.11 Ongoing user training

As face-to-face briefings are becoming the exception rather than the rule in aviation, the ability of the 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 snow clearing, passenger handling etc. also need to be regularly updated on the warnings and forecast products intended for their use.

Meteorological staff therefore require basic training skills, 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 (local needs, specialised user groups). User training should include the encouragement of users to request special briefings in circumstances where standardised 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).
8.7 Marine meteorology
By L. N. Karlin; Russian State Hydrometeorological University

Marine meteorology is a vast area of knowledge. From the customer's point of view, the main products of the 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 hydrometeorological 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 the immediate supervisor in a spirit of constructive co-operation.

In the National Meteorological Service, marine meteorologists are usually involved in four different types of activity: marine forecasts, observing the characteristics of the boundary layer of the atmosphere (BLA) and of the surface layer of the ocean (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.

8.7.1 Marine forecasts

This section concerns duties such as: using modern methods for processing and analysing hydrometeorological data; using modern methods for calculating and forecasting characteristics of the atmosphere and the surface layer of the ocean; 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 working 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 surface layer of the ocean;
- regional peculiarities affecting the formation of the 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, regional descriptions, etc.;
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 the BLA and SLO in his area of responsibility and respond to them in real time, making the relevant corrections to the products.

8.7.2 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, organise 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;

8.7.3 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.
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 programs;
- calculate the statistical values for hydrometeorological characteristics necessary for regime descriptions;
- compile a regime description.

8.7.4 Investigation of 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 the customer.

8.7.5 Preparation of the products for the customer

The specialist must:

- interpret the observational and forecast data correctly;
- submit the products in the form, and at the level that the customer requires;
- 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.
8.7.6 Performing other duties

The specialist must do this, fulfilling the 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 user level;
- use the organisational technology which is necessary for the work, keep it in working order and eliminate any deficiencies at user level (projectors, photocopiers, etc.).

8.8 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 organisations, academia, industry representatives, media, environmental non-government organisations, and citizens demand scientifically accurate information and relevant warning services. The following provides an introduction to required skills of an Air Quality meteorologist.

8.8.1 Understanding the role of the NMHS in addressing environmental issues

This section concerns the role and relationship of NMHS 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 NMHS concerning atmospheric and related environmental issues, and environmental prediction;
- the organization, responsibilities, programs 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 programs 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, programs and working arrangements concerning relevant science activities taking place in government and non-governmental environmental organisations, especially in bordering states; also the World Meteorological Organisation and United Nations 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 programs.

The skills and knowledge, which relate to this section, are:

• explaining the role of government, national or international organisations and institutions;
• listing relevant legislation and regulations related to the issues;
• explaining the mandate of the NMHS 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.

8.8.2 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 utilised 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, characterisation, 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 visualisation/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, UVb, 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 characterisation 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;
  - NOx/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.

8.8.3 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 organisations, 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 customised 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 organisations, outlets and their environmental reporters.

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

- utilise appropriate methods, techniques and practices to determine user requirements for environmental services, products and customised investigations;
- collate, interpret, synthesise and prepare published reports and make oral presentations on the state of air issue knowledge and air issue impacts;
- utilise 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 optimises 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 summarise 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;
- prioritise 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.

8.8.4 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, synthesising 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 computerised databases of observed atmospheric data and analysed data results;
roles, responsibilities and operations within the office to facilitate and expedite the work program 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, co-ordination, implementation and evaluation of environmental services and products and their development;
conduct applied research studies and investigations, which could include field measurement programs:
  - applying theories and principles of project management;
  - demonstrating effective planning and organisational 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 organisational 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 organisations 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 organisations;
  - 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.
APPENDICES

Preface to the first edition
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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

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 (e) 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;
- 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 less-developed countries.

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

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

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

Two preliminary remarks should be made:

- 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 twofold:

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 national Meteorological Service 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 specialisation.

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).


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.

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

A.2.1 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 pre-requisite subjects and meteorology), supplemented by at least 6 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.

A.2.2 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 2 years, and a minimum of 9 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.

A.2.3 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 8-10 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.

A.2.4 Class IV

These personnel should have a basic education equivalent to 9 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 4 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.

A.3.1 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).

A.3.2 Member's 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% 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 % 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 % 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 specialisations' curricula should be revised on an ongoing basis.

(d) Divergent opinions - shared by (much) less than 50 % 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.
Appendix 4:
Glossary of terms

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, utilised 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 organised 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 co-ordination of concepts, processes and topics.

Branch of activity - an ensemble of technically related jobs, forming a relatively independent operational structure or unit of a national Meteorological Service (NMS), and performing an aggregate of specialised 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 8).

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'. 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 specialised 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 science), consistent with the requirements set forth in the 'Basic Instruction Package for Meteorologists'. 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 science' may be used with the same meaning) belongs to the applied physical sciences and its main disciplines are dynamical, 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 - 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 World Meteorological Organization.

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 eventually are 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.
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