Manual on the Implementation of Education and Training Standards in Meteorology and Hydrology

Volume I – Meteorology

2012 edition

World Meteorological Organization

WMO-No. 1083

Weather • Climate • Water

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Volume I

(Annex VIII to WMO Technical Regulations)

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EDITORIAL NOTE

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In the present publication, the use of one gender shall be considered as including a reference to the other unless the context otherwise requires.

METEOTERM, the WMO terminology database, may be consulted at: http://www.wmo.int/pages/prog/lsp/meteoterm_wmo_en.html. Acronyms may also be found at: http://www.wmo.int/pages/themes/acronyms/index_en.html.

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Chair, Publications Board
World Meteorological Organization (WMO)
7 bis, avenue de la Paix
P.O. Box 2300
CH-1211 Geneva 2, Switzerland

Tel.: +41 (0) 22 730 84 03
Fax: +41 (0) 22 730 80 40
E-mail: publications@wmo.int

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PREFACE

The present publication is intended to facilitate a common understanding of the basic qualifications being required of individuals who are to be recognized either as Meteorologists or as Meteorological Technicians, as defined by World Meteorological Organization (WMO), while also assisting National Meteorological and Hydrological Services (NMHSs) in establishing their respective personnel classification systems and training programmes to satisfactorily meet international standards.

In this context, the Sixteenth World Meteorological Congress adopted Resolution 32 (Cg-XVI) calling for the replacement of the traditional WMO publication *Guidelines for the education and training of personnel in meteorology and operational hydrology* (WMO-No. 258), Volume I: Meteorology, with the present *Manual on the implementation of education and training standards in Meteorology and Hydrology*, Volume I – Meteorology. This Manual is a companion publication to Chapter B.4 of the WMO *Technical Regulations* (WMO-No. 49), Volume I – General meteorological standards and recommended practices and constitutes Annex VIII to the WMO Technical Regulations. It is designed to assist Members in their implementation of the Standards contained in the WMO Technical Regulations. While some of the Standards material is reproduced in this Manual, users are advised to always refer to the Standards for any regulatory purposes.

The availability of qualified personnel is a key consideration for all scientific and technical institutions. As laid out in its Convention, one of the purposes of WMO is to encourage training in meteorology and related fields and to assist in coordinating the international aspects of such training. Accordingly, since its inception in 1950, WMO has contributed significantly to the promotion of education and training activities in meteorology and, once it had expanded its mandate accordingly, also in hydrology.

Through its Education and Training Programme (ETRP), WMO has traditionally strengthened the NMHSs of its Members, especially in the developing world, where the promotion of capacity-development and human resources development has progressively bridged the gap between the levels of services which can be provided by developed and developing NMHSs.

Moreover, in response to rapidly evolving needs, WMO has, over the last years, redefined the classification of its meteorological and hydrological personnel, while at the same time strengthening the role of WMO Regional Training Centres, upgrading trainers' capabilities, encouraging the use of novel technologies, facilitating fellowships, organizing training events and updating guidance publications.

In the process of developing this Manual, WMO has taken advantage of the experience generously shared by a number of WMO Members. The Organization would also like to seize the opportunity to express its gratitude to the members of the Executive Council Panel of Experts on Education and Training, and especially to its Chair, Mr Alexander Bedritskiy, who also guided the work of the editorial panel, consisting of Messrs Robert Riddaway, Christopher Webster, LeRoy Spayd and Jeff Wilson, for this publication.

PART I

WMO CLASSIFICATION OF PERSONNEL

The first sections of Part I present an overview of the WMO classification of personnel in meteorology. The following sections are devoted to meteorological personnel – their initial qualification requirements and subsequent career progression. In addition, a brief description is given of career progression, collective abilities and transferrable skills, and the foundation subjects that support development of meteorological understanding. Finally, some general advice is given about the implementation of the required programmes of study.

1.1 INTRODUCTION

> *'There is no doubt that meteorological personnel can be graded in a number of ways, each with its own particular merit and convenience. It is equally certain, however, that no one system will adequately define all types of personnel required. It is therefore necessary to accept a compromise classification, all the while recognizing its deficiencies and limitations. With this in mind, one can develop a system of classification which can be usefully employed as a basis for establishing syllabi for the education and training of meteorological personnel.'*
>
> *(WMO-No. 258, first edition, page 11)*

The above quote from the first edition (July 1969) of WMO Publication 258 "*Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology*" still captures the challenges and opportunities of such a publication as this. The challenge is to provide an international framework that is flexible enough to adapt to the needs of Members, while being robust enough to ensure the quality of personnel successfully completing courses built around the framework. Many Members are already educating and training their personnel above this minimum level to meet stricter national requirements, in response to evolving technology and user needs.

This publication addresses the two issues raised in the quote above: a generic classification system for personnel involved in meteorology, and recommended qualifications for personnel in each of these classifications. These generic classifications and qualifications are intended to provide an international framework that Members can implement, adapt to meet their own specific needs or use as a benchmark against which they can assess their own national schemes.

Throughout the publication, a clear distinction is made between classification of personnel and job tasks carried out within National Meteorological and Hydrological Services (NMHSs). Classification is related to qualifications, while job tasks are related to competencies. It is the responsibility of individual Members to decide how they allocate particular tasks to the different classifications.

The focus of this publication is on the initial education and training required for personnel to qualify for the various classification categories. The additional education and training required to meet the competencies associated with a wide range of common job tasks performed by meteorological and hydrological personnel are outlined in separate publications overseen by the appropriate WMO technical commissions – see http://www.wmo.int/pages/prog/dra/etrp/competencies.php for the latest listing of such publications.

The implementation of education and training standards will be supported by a companion publication, "*Guidelines for Educators and Trainers in Meteorology and Hydrology*", prepared by the EC Panel of Experts on Education and Training. It will contain guidance about the education and training process (including how to specify and assess learning outcomes and job competencies) as well as identifying the competency requirements for instructors.

1.2 BACKGROUND INFORMATION

This section outlines the basic assumptions on which the publication is based and why the classification system and the associated guidelines need to be kept under review.

1.2.1 Drivers for change

The guidelines and the classification system need to be kept under review for the following reasons:
(a) Important advances in meteorology, as an applied physical science, result from improved understanding of the coupled atmosphere-ocean-land system, improved prediction techniques and the ongoing revolution in Information and Communication Technology (ICT);
(b) Economic, social and political patterns continue to evolve in many parts of the world, resulting in new and changing demands for meteorological and hydrological services in a user-focussed, consistent and quality-controlled manner;
(c) Significant changes are taking place in the approach to professional instruction and specialization, particularly as a result of the increasing importance attached to continuing education and training and the specification of competencies (i.e., the knowledge, skills and behaviours required for a specific job).

1.2.2 Assumptions

The development of this publication is based on the following assumptions:
(a) The document should act as an international reference that is, as far as possible, adaptable to national and local needs;
(b) The key requirements to be classified as a Meteorological Technician or Meteorologist should be specified by the Basic Instruction Package for Meteorological Technicians (BIP-MT) and Basic Instruction Package for Meteorologists (BIP-M). These should be specified in terms of learning outcomes (defined as statements of what a learner is expected to be able to do as proof of knowledge, understanding or skill after completion of a process of learning, rather than content as described in a syllabus). Though the BIP-MT and BIP-M have some topics in common, the learning outcomes are different;
(c) Completion of a university-degree-level meteorology programme should be the key factor in differentiating between personnel classified as Meteorologists and those classified as Meteorological Technicians. 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. Also a Meteorological Technician could be re-categorized as a Meteorologist after satisfying the BIP-M requirements;
(e) The requirements to be classified as a Meteorological Technician or Meteorologist should be treated separately from the competencies required to perform a particular job;
(f) This publication should build upon the fourth edition of the *Guidelines to the Education and Training of Personnel in Meteorology and Operational Hydrology* (WMO-No 258), to maintain continuity, wherever possible;
(g) For the purpose of this Manual, the terms “atmospheric sciences” and “meteorology” should be treated as having the same meaning.

1.3 CLASSIFICATION OF PERSONNEL IN METEOROLOGY

This section describes the WMO classification scheme approved by the WMO Executive Council at its fiftieth session (Geneva, 1998), and endorsed by the Thirteenth World Meteorological Congress (Geneva, 1999). A modification to the definitions of a Meteorologist was recommended by the WMO Executive Council at its sixty second session (Geneva, 2010). This was approved by the Sixteenth World Meteorological Congress (Geneva, 2011).

1.3.1 Purpose of the classification

The purpose of the WMO system for classification of personnel in meteorology is to:
(a) Provide an international framework for the 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 learning outcomes and the associated syllabi for the education and training of personnel in meteorology;
(c) Assist the NMHSs of individual countries in:
   – Establishing personnel classification systems suited to their particular needs;
   – Developing education and training programmes applicable to their own structures and needs;
   – Ensuring that academic and vocational institutions are aware of and can respond to the education and training requirements for staff that are recruited to be Meteorologists or Meteorological Technicians.

1.3.2 Categories of personnel

Two broad categories of personnel are identified: professionals and technicians. For meteorological personnel, these categories are designated as follows.
– *Meteorologist*: a person who has successfully completed the Basic Instruction Package for Meteorologists (BIP-M) requirements at university-degree level;
– *Meteorological Technician*: a person who has successfully completed the Basic Instruction Package for Meteorological Technicians (BIP-MT) requirements.

Although the classification is focused on two main categories of personnel, users are expected to adapt it to their specific circumstances, such as their national regulations for civil service classification.

In many cases, being classified as a Meteorologist or Meteorological Technician will be a necessary condition for working as a meteorological specialist within an NMHS. However, further specialized education and training beyond the BIP-M and BIP-MT requirements will be needed to become competent to perform a specialized task such as observing, producing forecasts and warnings, or undertaking research.

1.3.3 Components of the BIP-M

The main components of the BIP-M are:
(a) Foundation topics in mathematics and physics plus complementary subjects dealing with other sciences and related topics, communications, and data analysis and utilization;
(b) Topics in atmospheric sciences:
   – Physical meteorology (i.e., atmospheric composition, radiation and optical/electrical phenomena; thermodynamics and cloud physics; boundary-layer meteorology and micrometeorology; conventional observations and instrumentation; remote sensing);
   – Dynamic meteorology (i.e., atmospheric dynamics; numerical weather prediction);
   – Synoptic and mesoscale meteorology (i.e., mid-latitude and polar weather systems; tropical weather systems; mesoscale weather systems; weather observing, analysis and diagnosis; weather forecasting; service delivery);
   – Climatology (i.e., global circulation, climates and climate services; climate variability and climate change).

Besides the basic requirement to successfully complete topics (a) and (b), individuals wishing to obtain a specialization may also study in greater depth such subjects as aeronautical meteorology, atmospheric chemistry, and climate monitoring and prediction.

1.3.4 Components of the BIP-MT

The main components of the BIP-MT are:
(a) Foundation topics in mathematics and physics plus complementary topics dealing with other sciences and related topics, communications, and data analysis and manipulation;

(b) Topics in general meteorology: basic physical and dynamic meteorology, basic synoptic and mesoscale meteorology, basic climatology, and meteorological instruments and methods of observation.

Besides the basic requirement to successfully complete topics (a) and (b), individuals wishing to obtain a specialization may also study in greater depth such subjects as specialized observations and measurements, data quality control and archiving, equipment calibration and maintenance, and communications and computing.

1.3.5 Beyond the BIPs

As well as developing the specializations that go beyond the BIP-M and BIP-MT (as referred to above), many Members will require that their staff have additional knowledge, understanding and skills that are broader and deeper than what is specified in the BIPs, to meet their specific national requirements. For example:

(a) Some NMHSs have responsibilities that go beyond the provision of services concerning weather and climate (for example, services dealing with earthquakes, tsunamis, volcanoes, land slides, water utilization and flooding), so their education and training requirements exceed those in the BIPs that are primarily based on meteorological expertise;
(b) For some NMHSs, the provision of specialized meteorological services is a key aspect of their activities (for example, provision of agrometeorological services). In that case their education and training programmes would need to address that specific area of expertise in depth, and this may require the acquisition of detailed knowledge about the activities and needs of users of the service;
(c) For NMHSs in tropical regions, the required knowledge of tropical weather systems will probably exceed that specified by the BIPs. The same applies to knowledge of mid-latitude and polar weather systems for NMHSs in extra-tropical regions.

In addition, for some NMHSs, having a degree may be a requirement for the recruitment or career progression of staff.

The approach taken is designed to allow Members to set national requirements beyond those specified by the BIPs.

1.3.6 Learning outcomes

The BIP-M and BIP-MT are specified in terms of learning outcomes rather than the content. Consequently, the emphasis is on the achievements of the learner rather than the intentions of the instructor or the subjects to be covered as specified in a syllabus. Specifying learning outcomes is beneficial both for the instructor and the students, as they provide clarity about the purpose of the programme of study. Also they provide a more robust basis for assessing whether the required learning has taken place.

There is a hierarchy of learning outcomes used in BIP-M and BIP-MT. The table below gives an overview of the various skill levels and some examples of the associated descriptors. The higher-order cognitive skills

Various skill levels and some examples of the associated descriptors of learning outcomes

Cognitive skill level	Examples of descriptors
Remembering. The learner recalls information.	describe, define, identify
Understanding. The learner explains ideas or concepts.	explain, interpret, discuss
Applying. The learner uses new knowledge in a familiar situation.	apply, use, relate
Analysing. The learner differentiates between constituent parts and relates the parts to the whole.	analyse, compare, investigate
Evaluating. The learner justifies a decision or course of action.	evaluate, argue, recommend
Creating. The learner generates new products, ideas or ways of looking at things.	create, organise, assess

Based on the classification of intellectual behaviour developed by Bloom et al. (1956) which was later modified by Anderson & Krathwohl (2001).

of analysing, evaluating and creating are built upon the lower-order skills of remembering, understanding and applying. The learning outcomes for the BIP-M and BIP-MT tend to be associated with remembering, understanding, applying and analysing.

1.4 RELATIONSHIP BETWEEN CLASSIFICATION, QUALIFICATIONS AND JOB COMPETENCIES

This section outlines the relationship between classifications, qualifications and job competencies, to enable the reader to better use this Manual.

The classification of personnel into Meteorologists or Meteorological Technicians is based on the fulfilment of either the BIP-M or BIP-MT requirements. Successful completion of these initial programmes of study does not mean that an individual is immediately able to competently perform a corresponding job.

It is anticipated that a particular job will have an associated set of competence standards that define the specialized knowledge, skills and behaviours required. Normally, acquiring these competencies will require job-specific education and training that goes beyond the BIP-M and BIP-MT requirements.

An NMHS or other agency may put in place an education and training programme that allows the classification and competency requirements to be satisfied as part of the same programme. For example, this approach could be taken for:

(a) Satisfying the BIP-MT requirements and acquiring the competencies to be an agrometeorological observer or a technician who installs and maintains meteorological equipment;
(b) Satisfying the BIP-M requirements and acquiring the competencies to be a public weather service forecaster.

An NMHS or other agency may also decide, based on national or local guidelines, that a particular job involving the responsibility for delivering professional services should only be filled by Meteorologists or Meteorological Technicians.

In 2010, the WMO Executive Council agreed that the technical commissions should be responsible for developing generic job competencies and the associated education and training requirements for personnel undertaking tasks in their areas of interest. Such requirements should appear in publications produced and maintained by the appropriate technical commissions. See http://www.wmo.int/pages/prog/dra/etrp/competencies.php for the latest listing of such publications.

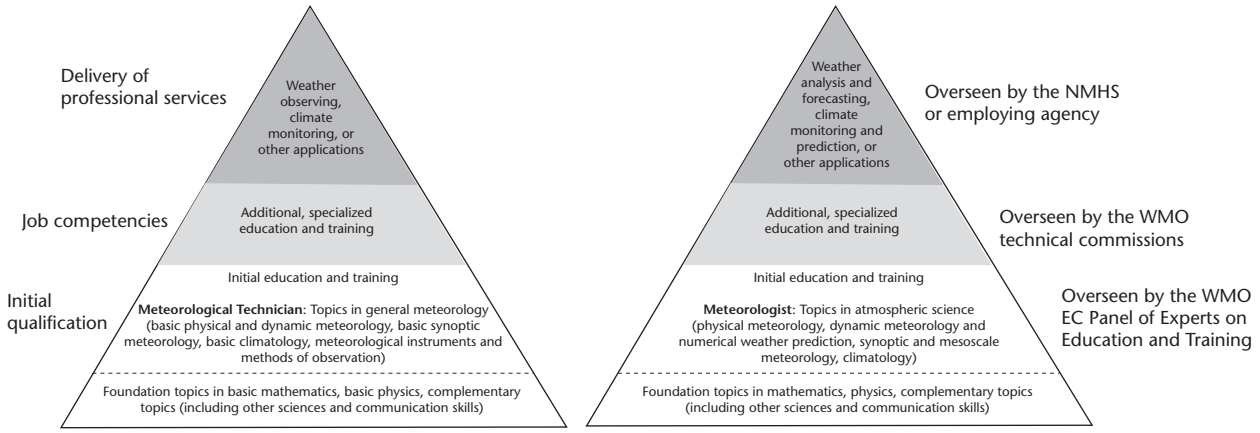
The relationship between initial qualifications, job competencies and delivery of professional services is summarized in the figure below.

Qualifications are awards issued by an approved authority, certifying that an individual has successfully completed a programme of study or has the expertise to perform a particular job effectively. A qualification signifies the range of knowledge, understanding and skills that has been acquired.

Qualifications fall into two broad categories:

– *Academic qualifications:* These are generally awarded by a college or university. They are often specified in terms of a set of learning outcomes that have to be satisfied;
– *Vocational (professional) qualifications:* These are generally awarded by a training institution or professional body. They are usually specified in terms of a set of competencies that have to be demonstrated.

Being classified as a Meteorologist or Meteorological Technician is in many ways similar to obtaining an academic qualification, in that the Basic Instruction Packages are based on satisfying a set of learning outcomes.



Schematic of the links between initial qualifications, job competencies and delivery of professional service along with the allocation of responsibilities. Note that if a technical commission does not specify the job competencies that responsibility falls to each NMHS.

1.5 METEOROLOGICAL PERSONNEL

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

1.5.1 Initial qualification of Meteorologists

The BIP-M requirements for Meteorologists will normally be satisfied through the successful completion of a university degree in meteorology or a postgraduate programme of study in meteorology (after acquiring a university degree that includes the foundation topics in mathematics and physics; such topics are typically covered in science, applied science, engineering or computational courses). In instances where this is not the case, educational institutions will need to demonstrate that their programme of study provides the characteristic learning outcomes associated with a university degree course and that nationally agreed academic qualification levels have also been met.

Permanent Representatives are expected to take the lead in consulting with the appropriate national and regional bodies to define the academic qualifications required by Meteorologists in their country. Permanent Representatives should also work with their national education and training establishments to ensure that meteorological graduates meet the BIP-M requirements (i.e., all the learning outcomes in the BIP-M are satisfied as part of the academic qualification).

The BIP-M should be delivered in such a way that individuals successfully completing the programme of study are able to:

– Demonstrate systematic understanding of their field of study;
– Accurately deploy established techniques of analysis and enquiry used in their field of study and apply the learnt methods and techniques to review, consolidate, extend and apply their knowledge and understanding;
– Use conceptual understanding that allows arguments to be devised and sustained and apply the understanding to the solving of problems in their field of study;
– Critically evaluate arguments, assumptions, abstract concepts and data while taking into account the uncertainty, ambiguity and limits of knowledge of their field of study;
– Communicate information, ideas, problems and solutions about their field of study to both specialist and non-specialist audiences.

In addition, they should acquire transferable skills relating to the importance of team-work, the management of their own learning, the exercise of initiative and personal responsibility, and the ability to make decisions in complex and unpredictable contexts.

1.5.1.1 University degree in meteorology

A university degree in meteorology that covers all the BIP-M is the optimum way to meet the requirements for classification as a Meteorologist. A meteorology degree will normally cover more than is required for the BIP-M. For example:

– Some topics will be covered in more depth than is necessary to meet the BIP-M requirements (for example, in tropical regions there will be more emphasis on tropical meteorology);
– Some topics not covered in the BIP-M will be included to allow the acquisition of specialized knowledge associated with (a) the specific economic needs of the country and/or requirements of the NMHS (for example, agricultural meteorology or hydrology) or (b) the research and development interests of the institution providing the programme of study.

Normally, a university degree programme satisfying the BIP-M requirements would require three or four academic years post secondary schooling, but the actual period may vary between academic institutions. Typically, the first half of the programme will be focused on fundamental science education, while the second half will be dedicated to the meteorological education.

1.5.1.2 Postgraduate programme of study in meteorology

A postgraduate programme of study in meteorology would normally be delivered via a university course leading to a postgraduate diploma or masters degree in meteorology. The entry requirement would normally be a university degree in a science, engineering or computational subject (for example, selected scientific or technical domains such as mathematics, physics, chemistry, electronic engineering or geo-sciences engineering), along with knowledge of mathematics and physics at the level of the BIP-M.

Certain education and training institutions (such as some of those run by NMHSs or Regional Training Centres) may provide a postgraduate programme of study that covers all of the BIP-M requirements but does not lead to a qualification such as a postgraduate diploma or masters degree. In such circumstances, the delivery of the programme of study should be as rigorous and intellectually demanding as a course of study at a university. The institutions are expected to be able to demonstrate that their programme is at the required level.

For a postgraduate programme of study the BIP-M requirements are the same as for those individuals completing the programme of study as part of a university degree in meteorology, but the pace of delivery may be considerably faster.

1.5.1.3 Non-degree education programme

Certain education and training institutions (such as some of those run by NMHSs or Regional Training Centres) may provide a programme of study that covers all of the BIP-M requirements but does not lead to a formal qualification such as a degree, postgraduate diploma or masters degree. These programmes are designed specifically to meet the BIP-M with little or no additional material. The BIP-M requirements are identical whether the programme concludes with a degree or not. In such circumstances the delivery of the programme of study should be as rigorous and intellectually demanding as a course of study at a university. Institutions are expected to be able to demonstrate that their programme is at the required level, especially in terms of its breadth and depth.

The admission requirements for such an institution could take into account the appropriate academic level of mathematics, physics, etc. already acquired by the prospective student, or the institution may provide these as part of their overall course structure. The key point is not how individuals enter the programme but whether by the end of the programme they meet the BIP-M requirements.

1.5.2 Initial qualification of Meteorological Technicians

Members have used various education and training approaches to qualify their Meteorological Technicians – from formal education in a technical school, college or university with specific training

programmes in meteorology, to vocational and/or on-the-job training in meteorological observations and measurements. Whichever approach is adopted, the BIP-MT requirements must be satisfied.

The BIP-MT requirements will normally be satisfied through the successful completion of a post-secondary programme of study at an institution such as an NMHS Training Institution or College of Further Education.

The BIP-MT should be delivered in such a way that individuals successfully completing the programme of study are able to:
- Demonstrate knowledge of the underlying concepts and principles associated with their field of study;
- Present, evaluate and interpret qualitative and quantitative data to make sound judgements in accordance with basic theories and concepts of their field of study;
- Evaluate different approaches to solving problems related to their field of study;
- Communicate the results of their studies accurately and reliably;
- Undertake further training and development of new skills within a structured and managed environment.

1.6 CAREER PROGRESSION

This section presents an overview of the career progression of Meteorologists and Meteorological Technicians.

Within both categories of personnel, depending on national circumstances, individuals will normally progress from positions of modest responsibility under close supervision, to positions with more responsibility and less supervision. Some individuals will advance to higher positions, with responsibilities for supervision and leadership. Any progression is based on increased experience, continuing education and training, and demonstration of the required job-specific competencies.

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.

1.6.1 Career levels for Meteorologists

Upon completion of the BIP-M programme, Meteorologists enter the professional world. After additional preparation aimed at developing competencies for a specific job (which should include an orientation period, on-the-job training and additional training courses), they gradually assume operational duties in weather analysis and forecasting, climate monitoring and prediction, or other relevant applications. Some Meteorologists will become involved in consulting, directing, decision-making and management; others will become involved in areas such as research and development, or teaching. Generic responsibilities for the three career levels may be summarized in Appendix A of Part I.

1.6.2 Career levels for Meteorological Technicians

Upon completion of the BIP-MT programme, Meteorological Technicians enter the professional world. While they have acquired a basic set of knowledge and skills, they then need to develop the competencies required for a specific job (which should include an orientation period, on-the-job training and additional training courses). They gradually assume operational duties that might involve carrying out weather, climate and other environmental observations or assisting weather forecasters in preparing and disseminating products and services. NMHSs typically employ many other types of technicians, such as mechanical, electrical and electronic technicians, to install and maintain equipment (for example, ground receivers for aeronautical meteorological observations, automatic weather stations, weather radar or telecommunication equipment). Generic responsibilities for the three career levels may be summarized as in Appendix A of Part I.

1.6.3 Changing classification mid-career

The requirements specified by the BIP-M and BIP-MT have been presented as if they are normally satisfied by an individual undergoing an initial programme of study at either a university or a training institution. This would normally happen before or shortly after taking up employment in an NMHS. In practice, however, satisfying the requirements to be a Meteorologist or Meteorological Technician might be achieved mid-career. For example, Meteorological Technicians who have acquired a substantial knowledge of meteorology based on their initial training, continuous professional development and operational experience, may want to undergo a programme of study that allows them to be classified as Meteorologists. In this case, many of the learning outcomes specified by the BIP-M will have already been satisfied. Provided that prior learning can be formally established and recorded (for example, by those responsible for training within an NMHS), the programme of study need only cover those learning outcomes that have not already been satisfied. The same approach applies to individuals whose initial training does not cover all the BIP-MT, but who later in their careers may want to be classified as Meteorological Technicians.

The specific national or institutional regulations and requirements will determine whether re-categorization that takes account of prior learning is accepted practice in any particular country.

1.7 COLLECTIVE ABILITIES AND TRANSFERABLE SKILLS

This section sets out the collective abilities and transferable skills of Meteorologists and Meteorological Technicians.

Meteorologists and Meteorological Technicians should undertake continuing education and training to update/upgrade their professional knowledge and skills and, where appropriate, acquire additional competencies. The continuing education and training can take many forms including coaching, self-study (for example, guided reading and computer-aided learning), secondment-/ temporary placement, on-the-job training and instructor-led refresher courses. The choice of method will depend upon factors such as the specific development needs, availability of training resources and preferred learning styles.

Meteorologists and Meteorological Technicians often act together as a team within their NMHSs. They must be competent in their jobs and be able to adapt to changing circumstances while also developing their careers. This will require a breadth and depth of relevant knowledge, understanding and experience, accompanied by an ability to be adaptable, flexible and independent when working.

Competence can be described as possessing – and being able to apply – appropriate basic knowledge and technical skills, but it is also necessary for both Meteorologists and Meteorological Technicians to display transferable behaviours such as the ability to:

– Communicate effectively through written and oral presentations;
– Share knowledge and work effectively with others;
– Apply initiative and take a problem-solving approach to non-routine tasks;
– Exhibit critical thinking when confronted with new information;
– Take responsibility for their own decisions and be prepared to explain the rationale for those decisions;
– Manage several tasks at any one time and prioritize accordingly;
– Manage their own learning and performance;
– Acquire new skills, knowledge and understanding demanded by changes in working practices.

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

1.8 FOUNDATION SUBJECTS AND ATMOSPHERIC SCIENCES

This section outlines the foundation subjects and identifies the basic meteorological disciplines.

As a physical science, meteorology deals essentially with the physics and dynamics of the atmosphere; it also deals with many direct effects of the atmosphere upon the Earth's surface, the oceans, and life in general. Its ultimate goals are the best possible understanding and prediction of atmospheric phenomena, from local to planetary scale, and from a few seconds, minutes and hours to several days, weeks and seasons (even decades and centuries). The establishment of the BIP-M and BIP-MT requirements is aimed at ensuring that individuals have a breadth and depth of knowledge to contribute towards attaining that ultimate goal.

1.8.1 Mathematics and physics

A thorough knowledge of mathematics and physics (and ideally a basic knowledge of chemistry) is required to enable students to understand the relationship between atmospheric phenomena and the nature of matter as expressed in the basic physical principles. Accordingly, when organizing basic instruction programmes in meteorology, provisions should be made for co-requisite/refresher courses in mathematics, with emphasis on basic concepts and methods required in studies of fluid dynamics and thermodynamics.

As with mathematics, there may be a need for co-requisite/refresher courses in physics. There is, however, a significant distinction between the study of atmospheric sciences and the common study of physics. In physics the focus tends to be on individual processes, but the study of atmospheric sciences concerns a large and complex system, where effects and interactions may not be fully understood if considered separately from their environment. The ultimate goal is to understand, not only qualitatively but also quantitatively, the coherent functioning of the whole system. Consequently the co-requisite/refresher courses in physics should provide the supporting knowledge necessary for an understanding of atmospheric sciences.

1.8.2 Complementary subjects

In addition to the knowledge of mathematics and physics as foundational requirements for studying the basic meteorological disciplines, it is also necessary to possess a basic knowledge of related sciences (particularly oceanography and hydrology). Further, having the ability to communicate effectively, and being adept at data analysis and manipulation, will underpin the development of meteorological expertise.

1.8.3 Basic meteorological disciplines

The basic meteorological disciplines – distinguished more by the function of the science than by the subject matter itself – may be designated as follows:
- Physical meteorology
- Dynamic meteorology
- Synoptic and mesoscale meteorology
- Climatology.

These are described in more detail in Appendix B of Part I.

1.8.4 Relationship between the basic meteorological disciplines and the BIPs

To some extent, there is overlap between the four basic meteorological disciplines. For example, synoptic meteorology could include some topics that might be considered to be part of dynamic meteorology or physical meteorology. Consequently the division into the four subject areas used here should not be considered the only way in which atmospheric sciences can be categorized.

For Meteorologists, it is convenient to describe the BIP-M learning outcomes in terms of the four meteorological disciplines. On the other hand, because of the kind of jobs that Meteorological Technicians might fill, it is reasonable to put more emphasis on meteorological instruments and methods of observation, with less emphasis on the theoretical aspects of physical and dynamic meteorology. This means that the BIP-MT learning outcomes have not been structured according to the four meteorological disciplines. Instead, the learning outcomes associated with physical and dynamic meteorology are combined, while those associated with meteorological instruments and methods of observation are treated separately.

1.9 IMPLEMENTATION

This section provides some general advice on implementing the BIP-M and BIP-MT programmes of study.

The learning outcomes as specified in the BIP-M and BIP-MT are still quite general. It is expected that an institution delivering a programme of study to satisfy the requirements of the BIP-M or BIP-MT will specify learning outcomes that are more detailed while at the same time being consistent with those specified. In doing that, consideration needs to be given to how the learning outcomes will be assessed.

The learning outcomes for both the BIP-M and BIP-MT have been put into broad categories of knowledge to help the users of this publication assimilate all the information. But the way the learning outcomes have been categorized is not intended to indicate how the programme of study should be structured. It is for the institution delivering the programme to decide on a structure that takes account of the prior knowledge and preferred learning styles of the participants, the availability of specialized facilities, and the particular needs of the associated NMHS.

A key aspect of classifying individuals as Meteorologists or Meteorological Technicians is to establish robust and transparent arrangements for assessing whether the learning outcomes specified within the BIP-M and BIP-MT have been satisfied. Responsibility for such arrangements lies with the NMHSs, in consultation with the institutions providing the programme of study. It is imperative that there be adequate documentation of the process and outcome for an external agency to be assured that an individual classified as a Meteorologist or Meteorological Technician has indeed satisfied the requirements specified in the BIP-M or BIP-MT.

APPENDIX A

CAREER LEVELS FOR METEOROLOGISTS AND METEOROLOGICAL TECHNICIANS

Career levels for Meteorologists

Entry level

Job-entry-level Meteorologists mainly carry out routine duties, to be performed under supervision and, most often, in collaboration with others. Individual autonomy within an established menu of responsibilities is expected.

Mid-level

Mid-level Meteorologists carry out a broad range of activities to be performed in a wide variety of contexts, some of which are complex and non-routine. These activities require the capacity to apply knowledge and skills in an integrated way, and an ability to solve problems. In addition, important personal autonomy and responsibility, including for the control or guidance of others, may also be expected (for example, directing and managing local operational services and devising creative and imaginative solutions for technical and administrative problems). Some services may require personnel wishing to enter this level to obtain additional qualifications.

Senior-level

Senior-level meteorologists need to be able to apply a significant range of fundamental principles and complex techniques across a wide and often unpredictable variety of contexts. Capacity to proficiently transfer knowledge and skills in a new task and situation and substantial personal autonomy are required. Often, significant responsibility for the work of others is required; this could be associated with analysis and diagnosis, planning and execution, control and evaluation, and training and retraining. Indeed the job might include responsibility for managing a service or branch. Some local services may require personnel wishing to enter this level to obtain additional qualifications.

Career levels for Meteorological Technicians

Entry-level

Job-entry-level Meteorological Technicians mainly carry out routine and predictable duties to be performed under supervision and, most often, in collaboration with others. Usually they specialize in a particular job (for example, surface observations, upper-air soundings, radiation measurements, operational data processing).

Mid-level

Mid-level Meteorological Technicians, besides performing standard duties, may also be required to carry out non-routine activities involving a degree of personal autonomy, in the context of explicit requirements and criteria. Responsibility for the guidance of others may also be assigned to some mid-level technicians. They generally work under the technical supervision of senior Meteorological Technicians or Meteorologists. Some local services may require personnel wishing to enter this level to obtain additional qualifications.

Senior-level

Senior-level Technicians require competencies in a wide range of complex technical-level and professional-level work activities, to be performed in a variety of contexts and with a substantial degree of personal responsibility, including responsibility for the work of other staff. They should be able to take technical decisions and capable of solving all technical problems in their specialized range of activity. Some local services may require personnel wishing to enter this level to obtain additional qualifications.

APPENDIX B

BASIC METEOROLOGICAL DISCIPLINES

Physical meteorology
Physical meteorology deals with the scientific explanation of the atmospheric phenomena. A thorough knowledge and understanding of the basic physical principles of thermodynamics and of the theory of electromagnetic radiation is essential. This will provide the necessary background for the study of topics such as: the structure and composition of the atmosphere, solar and terrestrial radiation, boundary-layer processes, microphysics of clouds and precipitation, atmospheric electricity, physical processes in small-scale dynamics (for example, turbulence), and observing technology, including remote-sensing methods.

Dynamic meteorology
Dynamic meteorology is concerned with the study of atmospheric motions as solutions of the fundamental equations of hydrodynamics and thermodynamics or other systems of equations appropriate to special situations, as in statistical theory of turbulence. A solid background in higher mathematics and fluid dynamics is required, since this provides the scientific basis for the understanding of the physical role of the atmospheric motions in determining the observed weather and climate on all scales – planetary, synoptic, mesoscale and microscale. Eventually, it is this understanding that enables the practical methodology for modern weather forecasting and climate prediction by dynamic methods.

Dynamic meteorology also includes a thorough knowledge and understanding of numerical weather prediction (NWP). This should include how forecast models work, their relative strengths, weaknesses and characteristics, post-processing of model output to create derived parameters and the way the output is used to derive guidance for specific applications.

Synoptic and mesoscale meteorology
Synoptic and mesoscale meteorology has traditionally been concerned with the study and analysis of weather information taken concurrently to identify synoptic-scale and mesoscale weather systems, diagnose their structure, and qualitatively anticipate their future evolution. Today this discipline deals with analysing and forecasting the weather from the mesoscale to planetary scale (for example, 'weather regimes'); and its sophisticated technical basis includes operational databases, standardized sets of automatically plotted diagnostic meteorological maps and diagrams, NWP outputs, as well as other products and auxiliary material. The traditional interpretation of the synoptic situation was empowered by modern diagnostic tools and new conceptual models. The sharp distinction between dynamic and synoptic/mesoscale meteorology has become rather diffuse.

With the ever-increasing application of objective methods, particularly the continued development of remote sensing, sophisticated data assimilation techniques, nowcasting techniques and operational application of ensemble forecasting, the human forecasters' contribution continues to evolve. Experienced forecasters are expected to have good understanding of the behaviours and performance characteristics of the numerical products and to be able to make useful subjective interpretations to add value (for example, utilize the ensemble forecasts' quantification of forecast uncertainty in conjunction with user-specific needs and constraints, including the risk-taking limitations). Good presentation and communication skills are required in the interaction with the users.

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

time period under consideration increases. Today's climatologists, while focusing on meteorological processes, increasingly study the role of physical and chemical processes within the oceans and across the multitude of land surface regimes. Integration of data and knowledge from meteorology, oceanography and hydrology becomes essential.

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

PART II

BASIC INSTRUCTION PACKAGE FOR METEOROLOGISTS

This Part starts with an outline of the aims of the BIP-M, then specifies the learning outcomes associated with foundation topics. The remainder of Part II deals with the learning outcomes concerning physical meteorology, dynamic meteorology, synoptic and mesoscale meteorology, and climatology.

2.1 INTRODUCTION

The overall aim of the BIP-M is to provide an individual with a robust and broad range of knowledge of atmospheric phenomena and processes, together with skills related to the application of this knowledge.

To satisfy the requirements of the BIP-M, it is necessary for an individual to achieve the learning outcomes that cover:

– The acquisition of knowledge concerning physical principles and atmospheric interactions, methods of measurement and data analysis, behaviour of weather systems (through the synthesis of current weather data with conceptual models), and the general circulation of the atmosphere and climate variations;
– The application of knowledge based on the use of scientific reasoning to solve problems in atmospheric science, and participation in the analysis, prediction and communication of the impacts of weather and climate on society.

It is intended that satisfying the BIP-M requirements will provide individuals with the knowledge, skills and confidence to carry on developing their expertise and provide a basis for further specialization. Individuals wishing to work in areas such as weather analysis and forecasting, climate modelling and prediction, and research and development will need to undertake further education and training to achieve the specialized job competencies in these areas. In addition, individuals are expected to continue enhancing their knowledge and skills by participating in continuous professional development throughout their careers.

2.2 FOUNDATION TOPICS IN MATHEMATICS, PHYSICS AND COMPLEMENTARY SUBJECTS

As an outcome of learning the foundation topics, an individual shall be able to:

– **Demonstrate the knowledge of mathematics and physics that is required to successfully complete the meteorological components of the BIP-M;**
– **Demonstrate the knowledge of other sciences and related topics that complements the development of the meteorological expertise covered in the BIP-M;**
– **Analyse and utilize data, and communicate and present information.**

It is expected that the supporting knowledge can be acquired using one or a combination of several approaches:

– Completion of a degree in mathematics or a physical science before studying the atmospheric science topics;
– An introductory programme of study, focussing on the learning outcomes for the foundation topics, that is completed before studying the topics in atmospheric science (this should be taught using practical applications related to atmospheric sciences.);
– Integrating the acquisition of the supporting knowledge into the studying of the topics in atmospheric science.

2.2.1 Mathematics

Learning outcomes – able to handle:
- *Differential and integral calculus*: Differentiate and integrate basic functions, find maxima and minima, and use a Taylor expansion based on an understanding of the fundamental concepts and methods in differential and integral calculus;
- *Vectors and matrices*: Solve simultaneous equations, find eigenvalues and eigenvectors of a matrix, and carry out calculations and transformations using complex numbers and vectors based on an understanding of the fundamental concepts and methods associated with matrices, vectors and complex numbers;
- *Differential equations*: Perform algebraic manipulation on basic first- and second-order ordinary differential and partial differential equations, including use of Fourier series and verification of solutions, and identify initial-value and boundary-value problems;
- *Statistics*: Select suitable ways of displaying statistical data, calculate basic statistical indicators (for example, mean, standard deviation and test of significance), and draw conclusions from statistical data based on an understanding of the fundamental concepts and methods associated with probability theory and statistics;
- *Numerical methods*: Use basic numerical schemes for time and space derivatives and perform a basic stability analysis based on an understanding of the fundamental concepts and methods associated with numerical modelling.

2.2.2 Physics

Learning outcomes– able to handle:
- *Mechanics*: Apply the fundamentals of mechanics to bodies in motion, including Newton's laws of motion, equilibrium conditions, conservation of momentum and angular momentum, conservation of energy, the effects of rotating systems, and the relationship between Eulerian and Lagrangian frames of reference;
- *Fluid motion*: Explain the basic kinematics of fluids, including the concepts of vorticity, divergence, deformation, streamfunction and velocity potential, and the relationship between streamlines and trajectories;
- *Heat transfer*: Explain the physical basis of heat transfer via conduction, convection and radiation;
- *Basic thermodynamics*: Apply the fundamentals of thermodynamics to gaseous systems, including the gas laws for dry and moist air, First and Second Laws of Thermodynamics, Dalton's Law and the kinetic theory of gases, and explain the physical basis of sensible heat, specific heat, latent heat, vapour pressure and saturation, reversible and irreversible processes, entropy and enthalpy, and the phases of water and the changes of phase;
- *Waves*: Explain the fundamentals of wave motion, including the concepts of reflection, refraction and diffraction, phase and group velocities, wave dispersion and wave breaking;
- *Optics*: Explain the concepts of reflection, refraction, diffraction and scattering of light;
- *Electromagnetic radiation*: Explain the fundamentals of electromagnetic radiation, including the electromagnetic spectrum, black body radiation, Planck's Law, Wien's Law and Stefan-Boltzmann Law, and scattering, absorption and emission of radiation.

2.2.3 Complementary subjects

Learning outcomes – able to handle:

(a) Other sciences and related topics
  - *Historical context*: Outline the scientific and technological advances that have contributed to the development of meteorology and its applications;
  - *Basic physical chemistry*: Explain, using chemical nomenclature where appropriate, the basic concepts used in physical chemistry (including elements, molecules, compounds, bonds, chemical reactions and reaction rates), and describe the properties of gases and the key chemical reactions and cycles affecting the chemistry of the troposphere and stratosphere;
  - *Basic oceanography*: Describe the general circulation and thermal structure of the oceans, explain the dynamical processes involved in producing ocean currents, tides and waves, and describe how measurements of temperature and salinity are taken;

- *Basic hydrology*: Describe the hydrological cycle, explain the factors determining runoff, groundwater and surface water resources and the water balance, describe how hydrological measurements are made (precipitation, evaporation, soil moisture, river flow, groundwater, etc.), and identify the causes of different types of flooding;
- *Basic geography*: Describe the main geographical characteristics of the region of responsibility, including local terrain and local demographics, and describe map projections commonly used in meteorology;
- *Basic ecology*: Describe the major cycles of the biosphere (with emphasis on the carbon and water cycle) and the influence of human activity on those cycles (for example, destruction of rain forests and melting of permafrost).

(b) Communications and teamwork
- *Written communications*: Prepare written communications within specified time limits in a concise, accurate and comprehensible way, including use of word processing and presentation programmes;
- *Oral presentations*: Make presentations within specified time limits, in which the content and style of delivery accurately conveys information in a way that can be understood by the audience;
- *Teamwork*: Demonstrate an understanding of the different roles and functions in a team.

(c) Data analysis and utilization
- *Programming*: Use basic computer programming principles, and construct a simple computer programme for analysing or displaying data;
- *Data processing*: Perform data processing and statistical analysis using spreadsheets and databases;
- *Accessing and obtaining information*: Find meteorological information using libraries, databases and internet searches;
- *Geographic Information Systems*: Discuss the components and functionality of a GIS, describe the potential uses of a GIS along with its benefits and shortcomings, and outline data quality issues involved in using a GIS;
- *Creating and publishing online material*: Create, publish and update a basic webpage.

2.3 TOPICS IN ATMOSPHERIC SCIENCES

In order to provide structure to the learning outcomes associated with atmospheric sciences, they have been organized into the following broad categories of knowledge:
- Physical meteorology
- Dynamic meteorology
- Synoptic and mesoscale meteorology
- Climatology.

It should be noted, however, that this is not intended to specify the structure of a programme of study. There are many ways of structuring a programme that will ensure all the learning outcomes are satisfied. For example:
- A single module of a programme of study could cover several topics (for example, conventional observations and instrumentation and remote sensing):
- The learning outcomes associated with several topics could be divided up differently (for example, some learning outcomes listed under atmospheric dynamics could be covered when dealing with mid-latitude and polar weather systems and vice versa);
- The learning outcomes for one topic could be covered in several modules of the programme of study that go into more detail than is required for the minimum qualification (for example, separate modules on thermodynamics and cloud physics);
- The learning outcomes could be covered in increasing detail as the programme of study progresses (for example, there could be an initial module on the introduction to meteorology, with topics then being covered in more detail at a later stage);
- The learning outcomes could be covered as part of a programme of study that is aimed at preparing participants for a particular role (for example, a course aimed primarily at training forecasters could cover all the required learning outcomes in the BIP-M, in addition to developing deeper and more practical skills);

The priority is for each institution to develop a programme of study that takes account of the prior knowledge of the participants, the best way to structure the programme to meet local requirements, and the purpose of the overall programme of study that may go beyond what is needed to satisfy the learning outcomes specified here.

2.3.1 Physical meteorology

An individual achieving the learning outcomes dealing with physical meteorology shall be able to:
- **Explain the structure and composition of the atmosphere, the processes affecting radiative transfer in the atmosphere and global energy balance, and the causes of optical phenomena in the atmosphere;**
- **Apply the Laws of Thermodynamics to atmospheric processes, use a thermodynamic diagram to assess the properties and stability of the atmosphere, identify the effect of water on thermodynamic processes and explain the processes leading to the formation of water droplets, clouds, precipitation and electrical phenomena;**
- **Use knowledge of turbulence and surface energy exchanges to explain the structure and characteristics of the atmospheric boundary layer and the behaviour of contaminants;**
- **Compare, contrast and explain the physical principles used in conventional instruments to make surface and upper-air measurements of atmospheric parameters, and explain the common sources of error and uncertainty and the importance of applying standards and using best practice;**
- **Describe the range of meteorological data obtained from remote-sensing systems, explain how radiation measurements are made and the processes by which atmospheric data is derived from those measurements, and outline the uses and limitations of remote-sensing data.**

2.3.1.1 Atmospheric composition, radiation and optical phenomena

Learning outcomes – able to handle:
- *Atmospheric structure*: Describe the vertical structure of the atmosphere in terms of its constituents, temperature and moisture content;
- *Atmospheric composition*: Explain the composition of the atmosphere, including trace gases, aerosols, dust and volcanic ash, and pollutants;
- *Radiation in the atmosphere*: Use a basic knowledge of radiative transfer theory to explain the effect of surface conditions (including snow and ice) and atmospheric constituents (including aerosols, water vapour, clouds, greenhouse gases and reactive gases) on the incoming and outgoing radiation;
- *Global energy balance*: Relate the Earth's climate and its latitudinal and temporal variation to the energy balance at the Earth's surface, variations in the solar flux and the Earth's orbital characteristics;
- *Optical phenomena*: Explain the transparency of the atmosphere and the origins of common optical phenomena (rainbows, haloes, coronas, sky colour, cloud colour, etc.) and describe the meteorological conditions favourable for their occurrence.

2.3.1.2 Thermodynamics and cloud physics

Learning outcomes – able to handle:
- *Applied thermodynamics*: Apply the Laws of Thermodynamics, with emphasis on understanding the concept of an air parcel, describing adiabatic processes and deriving dry and saturated adiabatic lapse rates and the associated conserved quantities;
- *Atmospheric moisture*: Define the parameters used to represent the amount of moisture in the atmosphere, explain their physical meaning, how they are related and how they are measured, explain the change of phase process, and determine the effect of water on the thermodynamic processes within the atmosphere;
- *Atmospheric stability*: Explain the basic features of a stable, neutral, conditionally unstable, potentially unstable and unstable atmosphere, identify the environmental conditions that can produce various stabilities, and explain the physical basis of commonly used stability parameters;

– *Thermodynamic diagrams*: Use a thermodynamic diagram to analyse atmospheric processes, including assessing atmospheric stability, determining common parameters used to describe the state of the atmosphere (including cloud parameters), and interpreting the key features of a sounding;
– *Clouds and precipitation*: Describe and explain the microphysical processes leading to the formation and dissipation of cloud droplets, the growth and dissipation of warm and cold clouds, and the formation and growth of rain and solid precipitation particles, and describe the macroscopic structure of warm and cold clouds;
– *Electrical phenomena*: Explain the mechanisms causing electrical phenomena that occur in the atmosphere (for example, cloud-to-ground and cloud-to-cloud lightning), and describe the meteorological conditions favourable for their occurrence;
– *Formation of atmospheric hydrometeors*: Describe the synoptic and mesoscale conditions and local processes that produce the various cloud types, precipitation types, icing, dew, frost and the various types of fog.

2.3.1.3 Boundary-layer meteorology and micrometeorology

Learning outcomes – able to handle:
– *Turbulent processes*: Describe the fundamental turbulent processes in the atmospheric boundary, including laminar and turbulent flows, mechanisms for generating turbulence, dissipation, decomposition of the fields into mean and fluctuating parts, statistical description of turbulence, and turbulent transport of mass, heat, moisture and momentum;
– *Surface energy exchanges*: Describe the energy budget near the Earth's surface and explain the energy exchange processes in the surface layer;
– *Boundary layer variations*: Use knowledge of turbulence and surface energy exchanges to explain the evolution and diurnal variation of the boundary layer, with emphasis on the conductive transfer from the underlying surface and the role of radiative transfer in determining the behaviour of the boundary layer;
– *Boundary layer profiles*: Use knowledge of turbulence and surface energy exchanges to explain the typical profiles of meteorological variables in stable, neutral and unstable conditions;
– *Local winds*: Explain the impact on boundary layer flows of the terrain, coastline and urban areas, including thermally induced circulations (for example, sea and land breezes, lake effects and valley winds);
– *K theory*: Explain how K theory is used to modify the equations of motion to take account of turbulence, explain the origin and significance of the Ekman spiral, and derive an expression for the vertical structure of the wind in the surface layer using the mixing-length hypothesis;
– *Measuring techniques*: Describe the techniques used to measure boundary-layer properties, including air quality;
– *Air contaminants*: Describe the common contaminants and pollutants affecting air quality and their major sources and sinks, along with their measurement, behaviour (including chemical and photochemical reactions and dry and wet deposition), and dispersion in the boundary layer, and explain how meteorological conditions, including stability, affect air quality, visibility and the dispersion of plumes.

2.3.1.4 Conventional observations and instrumentation

Learning outcomes – able to handle:
– *Surface measurements*: Explain the physical principles used in instruments to make surface measurements of temperature, moisture, pressure, precipitation, wind, cloud height, visibility, sunshine and radiation, and wave height, and the limitations and sensitivities of those instruments, and describe the way cloud and weather types are classified;
– *Upper-air measurements*: Explain the physical principles used in instruments to make upper-air measurements of geographical position, pressure, temperature, moisture and wind as well as ozone and other atmospheric constituents (for example, dust and volcanic ash);
– *Characteristics of instruments*: Describe, compare and contrast the characteristics of various instruments used to make surface and upper-air measurements of atmospheric parameters;
– *Instrument errors and uncertainty*: Explain the common sources of error and uncertainty in standard instruments and observing techniques, the methods of estimating the confidence in a particular measurement, and the need to take account of the representativeness of an observation;

– *Standards of instrumentation*: Explain the importance of national and international standards of measurement, and compliance with best practice for the accurate calibration of instruments;
– *Use and limitation of observations*: Describe the uses of conventional observations and their limitations;

2.3.1.5 Remote sensing

Learning outcomes – able to handle:
– *Radiation measurements*: Describe the principles behind the radiation measurements used for passive and active remote sensing, and how usable information can be derived from remote-sensing data, including the limitations and sources of errors/uncertainty;
– *Passive sensing systems*: Explain how passive sensing systems are used to provide digital data (such as visible, near infrared, infrared and water vapour imagery channels) and derived information about surface temperature and lightning, and atmospheric properties (including temperature, humidity, wind and atmospheric constituents);
– *Active sensing systems*: Explain how active sensing systems, such as radar, LIDAR and SODAR, are used to provide quantitative and qualitative information about atmospheric parameters such as temperature, humidity, cloud, precipitation (rate and type), wind speed and direction, turbulence and phenomena such as thunderstorms, microburst and tornadoes;
– *Satellite sounding systems*: Describe the orbital characteristics, accuracy, sampling limitations, use and limitations of various satellite sounding systems;
– *Radar measurements*: Explain the physical principles behind weather radar, including pulsed-Doppler radar, signal characteristics, how the radar information is processed, and the effect of meteorological factors on the propagation and attenuation of radar waves in the atmosphere;
– *Aircraft and marine systems*: Explain how aircraft, ships and buoys can be used to obtain atmospheric and oceanic information using remote-sensing systems.

2.3.2 Dynamic meteorology

An individual achieving the learning outcomes dealing with dynamic meteorology shall be able to:
– **Explain the physical basis of the equations of motion in terms of forces and frames of reference, apply scale analysis to identify the dynamic processes in balanced flows, describe the characteristics of balanced flows, and use the equations of motion to explain quasi-geostrophy, ageostrophy, and the structure and propagation of waves in the atmosphere;**
– **Describe and explain the scientific basis, characteristics and limitations of numerical weather prediction (NWP) for short-, medium- and long-range forecasting, and explain the applications of NWP.**

2.3.2.1 Atmospheric dynamics

Learning outcomes – able to handle:
– *Equations describing large-scale atmospheric flows*: Explain the physical principles underlying the equations that describe large-scale atmospheric flows (i.e., the primitive equations), including deriving the apparent and real forces acting on a fluid in a rotating frame of reference, and formulating the horizontal equation of motion;
– *Pressure coordinates*: Cast in pressure coordinates the primitive equations that govern the evolution of large-scale atmospheric flows, and state the advantages of using this coordinate system;
– *Scale analysis and balanced flows*: Apply scale analysis to determine the dominant processes operating in various examples of fluid flows, and derive the equations describing balanced flows (including inertial, cyclostrophic, geostrophic and gradient flows), hydrostatic equilibrium and thermal wind balance;
– *Ageostrophic motion*: Use the equations of motion to explain the causes and implications of ageostrophic flow, including the effect of friction;
– *Vorticity and divergence*: Explain the concepts of divergence, vorticity and potential vorticity, describe the mechanisms for generating changes in these parameters, and determine the relationship between divergence in the horizontal wind and vertical motion;

– *Quasi-geostrophic flow*: Explain the approximations and assumptions involved in deriving the quasi-geostrophic system of equations, outline the derivation of the geopotential tendency and omega equations, provide a physical interpretation of the forcing terms in these equations, and use these equations to explain the distribution of vertical motion and geopotential tendency in a developing baroclinic system;
– *Waves in the atmosphere*: Use approximate forms of the equations describing fluid flows to describe the structure and propagation of sound waves, gravity waves and Rossby waves;
– *Baroclinic and barotropic instability*: Explain the conceptual model used to describe baroclinic and barotropic instability.

2.3.2.2 Numerical weather prediction (NWP)

Learning outcomes – able to handle:
– *NWP data assimilation*: Explain how information from observing networks and systems is obtained and prepared for use in an NWP model, and explain the principles behind objective analysis, data assimilation (including 3D-Var and 4D-Var) and initialization;
– *NWP forecast models*: Describe the key components of an NWP model (including the prognostic variables, physical laws, and how physical processes are parameterized), and explain the difference between types of models (for example, spectral versus grid-point and hydrostatic versus non-hydrostatic models);
– *Strengths and weaknesses of NWP*: Assess the strengths and weaknesses of NWP and the reasons why there are limits to atmospheric predictability;
– *Ensemble forecasting*: Describe the principles behind ensemble forecasting and how such an approach can be used for short-, medium- and long-range forecasting;
– *Monthly to seasonal forecasting*: Explain the scientific basis of monthly, seasonal and intra-annual forecasting;
– *Downscaling*: Describe the techniques used to provide detailed regional atmospheric information based on the output from global models;
– *Post-processing and applications*: Describe the techniques used for post-processing NWP output (for example, use of model output statistics) and some of the applications driven by NWP output (for example, wave and crop yield models).

2.3.3 Synoptic and mesoscale meteorology

An individual achieving the learning outcomes dealing with synoptic and mesoscale meteorology shall be able to:
– **Use physical and dynamical reasoning to describe and explain the formation, evolution and characteristics (including extreme or hazardous weather conditions) of synoptic-scale weather systems in (a) mid-latitude and polar regions and (b) tropical regions, and assess the limitations of theories and conceptual models concerning these weather systems;**
– **Use physical and dynamical reasoning to describe and explain the formation, evolution and characteristics (including extreme or hazardous weather conditions) of convective and mesoscale phenomena, and assess the limitations of theories and conceptual models about these phenomena;**
– **Monitor and observe the weather situation, and use real-time or historic data, including satellite and radar data, to prepare analyses and basic forecasts;**
– **Describe service delivery in terms of the nature, use and benefits of the key products and services, including warnings and assessment of weather-related risks.**

2.3.3.1 Mid-latitude and polar weather systems

Learning outcomes – able to handle:
– *Weather systems*: Explain how mid-latitude and polar weather systems differ from those in the tropics;
– *Modification of bodies of air*: Explain how bodies of air can be modified by the environment, the resulting characteristics of the air, and the ways in which the modifications can affect weather at distant locations through air movement;

- *Fronts*: Use knowledge of physical processes to describe the characteristics of warm, cold and stationary and occluded fronts, how these fronts are related to synoptic fields, and the three-dimensional nature of frontal boundaries;
- *Mid-latitude depressions*: Apply physical and dynamical reasoning to explain the life cycle of mid-latitude depressions in terms of the Norwegian cyclone model, including the three-dimensional structure of a developing depression and the air flow through the depression;
- *Jet streaks and jet stream*: Apply physical and dynamical reasoning to explain the development, structure and impact of jet streaks and the relationship between the jet stream and the development of mid-latitude depressions;
- *Synoptic-scale vertical motion*: Diagnose synoptic-scale vertical motion in mid-latitude weather systems (for example, by considering ageostrophic motion, using the Petterssen or Sutcliffe Development Theory or applying the omega equation);
- *Cyclogenesis*: Apply knowledge of dynamical processes to explain cyclogenesis and the factors contributing to explosive cyclogenesis;
- *Frontal structure and frontogenesis*: Explain the structure and dynamical characteristics of fronts, the relationship between frontogenesis and vertical motion, and the processes causing upper-level frontogenesis;
- *Polar weather systems*: Explain the characteristics and formation of polar weather systems, including katabatic winds, barrier winds and polar lows;
- *Extreme weather*: Describe the weather, with emphasis on any extreme or hazardous conditions, that might be associated with mid-latitude and polar weather systems and the likely impact of such conditions;
- *Limitation of conceptual models*: Analyse recent and/or historic weather events to assess the extent to which theories and conceptual models of mid-latitude and polar weather systems resemble reality.

2.3.3.2 Tropical weather systems

Learning outcomes – able to handle:

- *General circulation in the tropics*: Describe the general circulation in the tropics and its seasonal variation in terms of the temperature, zonal wind, meridional motions, humidity and sea-level pressure;
- *Main tropical disturbances*: Describe the main tropical disturbances and their temporal variability, including the ITCZ, tropical waves, trade inversions, trade winds, tropical/sub-tropical jet streams, cloud clusters, squall lines, tropical depressions, sub-tropical ridges and upper-level anticyclones;
- *Analysis of tropical flows*: Describe the techniques used to analyse tropical flows, including the depiction of streamlines and isotachs, and the identification of areas of convergence/divergence;
- *Weather systems*: Explain how tropical weather systems differ from those in mid-latitudes and polar regions;
- *Tropical waves*: Describe the various types of tropical wave (including Kelvin waves, equatorial Rossby waves and Madden-Julian Oscillation) and their relationship to organized convection and cyclogenesis;
- *Tropical cyclones*: Apply physical and dynamical reasoning to explain the structure and characteristics of tropical cyclones, the main dynamical processes involved in their development, and the techniques used to forecast the development and evolution of tropical storms;
- *Monsoon*: Apply physical and dynamical reasoning to explain the structure and characteristics of monsoons and the main dynamical processes involved in their development;
- *Ocean-atmosphere coupling*: Describe the role of ocean-atmosphere coupling with emphasis on the theoretical basis and impact of El Niño-Southern Oscillation (ENSO);
- *Extreme weather*: Describe the weather, with emphasis on any extreme or hazardous conditions that might be associated with tropical weather systems (including tropical cyclones and monsoons) and the likely impact of such conditions;
- *Limitation of conceptual models*: Analyse recent and/or historic weather events to assess the extent to which theories and conceptual models of tropical systems resemble reality.

2.3.3.3 Mesoscale weather systems

Learning outcomes – able to handle:
- *Mesoscale systems*: Describe the space and time scales associated with mesoscale phenomena, and the differences in the dynamical processes that drive mesoscale and synoptic scale systems;
- *Mesoscale features associated with depressions*: Explain the mesoscale features associated with depressions (rainbands, drylines, gust fronts, squall lines, etc.);
- *Gravity waves*: Apply physical and dynamical reasoning to explain the structure and formation of mesoscale gravity waves;
- *Convective system*s: Apply physical and dynamical reasoning to explain the structure and formation of isolated convective systems such as thunderstorms and convective storms (including single cell, multicell and supercell storms);
- *Mesoscale convective systems*: Apply physical and dynamical reasoning to explain the structure and formation of mesoscale convective systems;
- *Orographic mesoscale phenomena*: Apply physical and dynamical reasoning to explain the structure and formation of orographic mesoscale phenomena (lee waves, rotors, up-slope and down-slope winds, valley winds, gap flows, lee lows, etc.);
- *Extreme weather*: Describe the weather, with emphasis on any extreme or hazardous conditions that might be associated with convective and mesoscale phenomena, and the likely impact of such conditions;
- *Limitation of conceptual models*: Analyse recent and/or historic weather events to assess the extent to which theories and conceptual models of convective and mesoscale phenomena resemble reality.

2.3.3.4 Weather observing, analysis and diagnosis

Learning outcomes – able to handle:
- *Monitoring and observing the weather*: Monitor the weather, make a basic surface observation using remote and directly-read instruments and visual assessments (including identifying cloud types, cloud amount and weather type), explain the reasons for the visual assessments, and explain the underlying causes of a variety of weather phenomena that are visible from the Earth's surface;
- *Processing observations*: Describe how observations are quality-controlled, coded and distributed.
- *Synoptic analysis and interpretation*: Analyse and interpret synoptic charts and soundings plotted on a thermodynamic diagram, and describe the limitations of the observations used in the analyses;
- *Interpreting radar data*: Interpret common radar displays, including use of enhancements and animated imagery, to identify features associated with convective and mesoscale processes;
- *Interpreting satellite imagery*: Interpret satellite images, including use of common wavelengths (infrared, visible, water vapour and near infrared) and enhancements and animated imagery, to identify cloud types and patterns, synoptic and mesoscale systems, and special features (fog, sand, volcanic ash, dust, fires, etc.);
- *Integrating conventional and remote-sensing data*: Integrate remote-sensing data and synoptic observations to identify synoptic and mesoscale systems and diagnose the weather situation through relating features found in radar and satellite imagery to features observed from other data sources;
- *International collaboration*: Describe the role of international collaboration in the making and sharing of observations, with emphasis on the World Weather Watch, WMO Global Observing System and WMO Information System (including the Global Telecommunications System).

2.3.3.5 Weather forecasting

Learning outcomes – able to handle:
- *Local weather*: Describe factors affecting local weather (for example, the effect of orography and large bodies of water on cloud and precipitation, or the effect of land surface types);
- *Forecast process*: Describe the main components of the forecast process, including observation, analysis, diagnosis, prognosis, product preparation, product delivery and product verification;
- *Types of forecasting methods*: Explain the advantages and disadvantages of preparing forecasts based on persistence, extrapolation and numerical weather prediction (NWP), and describe the role of the forecaster;

– *Conceptual models*: Apply conceptual models in making short-range forecasts and interpreting longer-range forecasts;
– *Practical forecasting*: Combine information from various sources to explain the current weather conditions, and use basic forecasting techniques, including the interpretation of NWP output, to forecast atmospheric variables (for example, maximum and minimum temperature, wind, and precipitation type and intensity) at a specific location.

2.3.3.6 Service delivery

Learning outcomes – able to handle:
– *Function of National Meteorological Services*: Describe the function of National Meteorological Services in monitoring and forecasting the weather and the role of other service providers;
– *Service provision*: Communicate weather information, orally or in written form using deterministic and probabilistic approaches, that meets user requirements;
– *Key products and service*s: Describe the key products and services, including warnings of hazardous weather conditions, based on current and forecast weather information, that are provided to the public and other users, and describe how the products and services are used (for example, for decision-making and managing risk);
– *Hazardous weather*: Describe the extent to which hazardous weather systems affecting the region of responsibility can be forecast, and explain the importance of assessing the risk of hazardous weather, issuing prompt and accurate warnings, and of understanding the potential impact of hazardous weather on society;
– *Quality of products and services*: Explain the basic techniques used to assess the quality of products and services;
– *Benefits and costs of meteorological services*: Identify the economic and social impacts of meteorological services upon a country and their key user sectors.

2.3.4 Climatology

An individual achieving the learning outcomes dealing with climatology shall be able to:
– **Describe and explain the Earth's general circulation and climate system in terms of the physical and dynamical processes that are involved, and describe the key products and services based on climate information and their inherent uncertainty and use;**
– **Apply physical and dynamical reasoning to explain the mechanisms responsible for climate variability and climate change (including the influence of human activity), describe the impacts in terms of possible changes to the global circulation, primary weather elements and potential effects on society, outline the adaptation and mitigation strategies that might be applied, and describe the application of climate models.**

2.3.4.1 Global circulation, climates and climate services

Learning outcomes – able to handle:
– *Components of the Earth system*: Describe the key components of the Earth system (i.e., atmosphere, oceans, land, cryosphere and solid earth);
– *Climate and weather*: Describe climate and how it differs from weather;
– *Climate data*: Describe how climate is measured and the uncertainty inherent in climate data, how climate data is analysed using statistics, and how climate can be measured using remote sensing;
– *Cycling of material*: Describe the main features of the energy cycle, hydrological cycle, carbon cycle and nitrogen cycle;
– *Features of the global circulation*: Explain the main features of the global circulation of the atmosphere and oceans based on an understanding of the physical and dynamical process that are involved, and describe the global energy balance and the role of the atmosphere and oceans in balancing the radiative heating differences between the equator and pole;
– *Regional and local climate*s: Assess the factors that determine regional and local climates;

– *Classifying and describing climates*: Describe the techniques for classifying the climate, the principles behind these techniques, and the meaning and use of standard statistical variables used to describe climate;
– *Local climate*: Describe the climatology and seasonal changes of the region of responsibility and the way climatological information can be obtained and displayed;
– *Key products and services*: Describe the key products and services based on climate information that are provided to the public and other users, describe their inherent uncertainties and how the products and services are used (for example, for decision-making and managing risk).

2.3.4.2 Climate variability and climate change

Learning outcomes – able to handle:
– *Data to assess climate variations*: Describe the source and processing of data that is used to reconstruct past climates and assess changes in climate and atmospheric composition;
– *Observed climate variations*: Describe how the climate has changed in the recent past in the context of changes that have occurred more generally in the past and the techniques used for attributing the causes;
– *Atmosphere-ocean interactio*n: Describe the various ways in which the atmosphere influences the oceans and the oceans influence the atmosphere;
– *Climate variability*: Apply physical and dynamical reasoning to explain the causes of internally-generated climate variability (including examples of teleconnections, anomalies, and the climatic effects of major regimes such as the Madden-Julian Oscillation, North Atlantic Oscillation, and El Niño-Southern Oscillation);
– *Climate change*: Apply physical and dynamical reasoning to explain the causes of externally-forced climate change (including the influence of human activity), and the source of uncertainty in understanding these causes;
– *Impact, adaptation and mitigation*: Assess the major impacts of climate variability and change, and outline the adaptation and mitigation strategies that are applied in response to current and projected changes in the climate;
– *Climate models*: Explain the differences between climate models and those used for weather prediction, explain why there are uncertainties in climate predictions, describe how climate predictions can be verified, and explain why there are differences between statistical intra-annual forecasts and climate model predictions.

PART III

BASIC INSTRUCTION PACKAGE FOR METEOROLOGICAL TECHNICIANS

This Part starts with an outline of the aims of the BIP-MT and then specifies the learning outcomes associated with foundation topics. The remainder of Part III deals with the learning outcomes concerning basic physical and dynamic meteorology, basic synoptic meteorology, basic climatology, and meteorological instruments and methods of observation.

3.1 INTRODUCTION

The overall aim of the BIP-MT is to provide an individual with a basic knowledge of atmospheric phenomena and processes, together with skills related to the application of this knowledge.

To satisfy the requirements of the BIP-MT, it is necessary for an individual to achieve the learning outcomes that cover:
- The acquisition of basic knowledge concerning physical principles and atmospheric interactions, methods of measurement and data analysis, a basic description of weather systems, and a basic description of the general circulation of the atmosphere and climate variations;
- The application of basic knowledge to observe and monitor the atmosphere and interpret commonly used meteorological diagrams and products;

The intent in satisfying the BIP-MT requirements is to provide individuals with the knowledge, skills and confidence to carry on developing their expertise and provide a basis for further specialization.

Individuals wishing to work in areas such as weather observing, climate monitoring, network management, and provision of meteorological information and products to users will need to undertake further education and training to meet the specialized job competencies in these areas. In addition, individuals are expected to continue enhancing their knowledge and skills by participating in continuous professional development throughout their careers.

3.2 FOUNDATION TOPICS IN MATHEMATICS, PHYSICS AND COMPLEMENTARY SUBJECTS

An individual achieving the learning outcomes dealing with the foundation topics shall be able to:
- **Demonstrate the knowledge of mathematics and physics that is required to successfully complete the meteorological components of the BIP-MT;**
- **Demonstrate the knowledge of other sciences and related topics that complements the development of the meteorological expertise covered in the BIP-MT;**
- **Analyse and utilize data, and communicate and present information.**

It is expected that the supporting knowledge can be acquired using several approaches or a combination of them, as follows:
- Completion of a programme of study in the foundation topics at a school or college before attending an institution to study the topics in atmospheric science;
- Taking an introductory programme of study in the foundation subjects at the same institution where the topics in general meteorology are to be studied;
- Integrating the acquisition of the supporting knowledge associated with the foundation topics into the studying of the topics in general meteorology.

3.2.1 Mathematics

Learning outcomes – able to handle:
- *Trigonometry*: Define sine, cosine and tangent, describe their relationship with their inverse functions, and manipulate basic trigonometrical equations;
- *Logarithms and exponentials*: Manipulate logarithms and exponentials;
- *Vectors*: Add and subtract vectors, and multiply a vector by a scalar;
- *Algebra*: Manipulate polynomial equations and solve basic algebraic equations, including quadratic equations;
- *Geometry*: Calculate the areas of right-angled and isosceles triangles, circumference and area of circles, and areas and volumes of rectangular blocks, cylinders and spheres, and describe the relationship between radians and degrees;
- *Coordinate geometry*: Interpret the slope and intercept of a linear graph, recognize standard curves such as the parabola, ellipse and hyperbola, and convert between cartesian and polar coordinate systems;
- *Statistics*: Select suitable ways of displaying statistical data and interpret the results, use different measures of central tendency (mean, median and mode) and variation (range, interquartile range and standard deviation), and explain the concepts of sampling, linear regression by least squares, correlation, normal distribution, percentiles and hypothesis testing.

3.2.2 Physics

Learning outcomes – able to handle:
- *Kinematics*: Solve problems using the equations describing the relationship between distance, speed, acceleration and time for uniformly accelerated motion in a straight line;
- *Dynamics*: Solve basic problems when a system is in equilibrium, solve basic problems using Newton's Second Law of Motion, and solve basic problems using the principle of the conservation of momentum;
- *Work, energy and power*: Explain the concepts of work, kinetic energy, potential energy, internal energy, and solve problems using the principle of the conservation of energy and the relationship between power, work and force;
- *Motion in a circle*: Explain the concept of centripetal acceleration and describe circular orbits by relating the gravitational force to the centripetal acceleration;
- *Phases of matter*: Describe the physical differences between solids, liquids and gases, explain the concept of latent heat associated with a phase change, and describe the processes associated with changes of phase with emphasis on condensation and evaporation;
- *Temperature and heat*: Explain the concepts of temperature and heat, describe how physical properties of a substance that varies with temperature can be used to measure temperature, and describe how heat is transferred by conduction, convection and radiation;
- *Thermodynamics and kinetic theory of gases*: Solve problems using the equation of state for an ideal gas, give a qualitative description of the First Law of Thermodynamics, explain what is meant by an adiabatic process with emphasis on the adiabatic expansion of a gas, and describe the concepts behind the kinetic theory of gases;
- *Oscillations and waves*: Describe the properties of oscillations and waves, describe simple harmonic motion, solve problems using the relationship between speed, frequency and wavelength for waves, explain the difference between longitudinal and transverse waves, and explain the concepts of reflection, refraction, diffraction and interference;
- *Electromagnetic radiation*: Describe the characteristics of electromagnetic radiation and the key features of the electromagnetic spectrum, describe the processes of reflection, absorption and scattering of radiation (including reflection and refraction of light), describe what is meant by a black body, and outline the implications of the Stefan-Boltzmann Law and Wien Law;
- *Electricity and electromagnetic induction*: Describe the physical basis of current, voltage and resistance and how these quantities are measured, solve circuit problems (including those with two or more resistors) using Ohm's Law and Kirchhoff's Laws, and describe the process of electromagnetic induction.

3.2.3 Complementary subjects

Learning outcomes – able to handle:

(a) Other sciences and related topics
- *Historical context*: Outline the scientific and technological advances that have contributed to the development of meteorology and its applications;
- *Basic oceanograph*: Describe the general circulation and thermal structure of the oceans, and describe how measurements of temperature, salinity and sea state are made;
- *Basic hydrology*: Describe the hydrological cycle, identifying the key factors determining runoff, groundwater and surface water resources and the water balance, and describe how hydrological measurements are made (precipitation, evaporation, soil moisture, river flow, groundwater, etc.);
- *Basic geography*: Describe the main geographical characteristics of the region of responsibility, including a description of the local terrain.

(b) Communications
- *Written communications*: Prepare written communications within specified time limits in a concise, accurate and comprehensible way, including use of word processing and presentation programmes;
- *Oral presentations*: Make presentations within stated time limits in which the content and style of delivery accurately conveys information in a way that can be understood by the audience.

(c) Data analysis and utilization
- *Programming*: Use basic computer programming principles, and construct a basic computer programme;
- *Data processing*: Perform data processing and statistical analysis using spreadsheets and databases;
- *Accessing and obtaining information*: Find meteorological information using libraries, databases and internet searches;
- *Creating and publishing online material*: Create, publish and update a basic webpage.

3.3 TOPICS IN GENERAL METEOROLOGY

In order to provide structure to the learning outcomes associated with general meteorology, they have been organized into the following broad categories of knowledge:
- Basic physical and dynamic meteorology
- Basic synoptic and mesoscale meteorology
- Basic climatology
- Meteorological instruments and methods of observation.

It should be noted, however, that this is not intended to specify the structure of a programme of study. There are many ways of structuring a programme that will ensure all the learning outcomes are satisfied. For example:
- The learning outcomes associated with several topics could be divided up differently (for example, some learning outcomes listed under basic physical and dynamic meteorology could be covered when dealing with basic synoptic meteorology and vice versa);
- The learning outcomes for one topic could be covered in several modules of the programme of study that go into more detail than is required for the minimum qualification (for example, separate modules on thermodynamics and dynamics);
- The learning outcomes could be covered in increasing detail as the programme of study progresses (for example, there could be an initial module on the introduction to meteorology, with topics then being covered in more detail at a later stage);
- The learning outcomes could be covered as part of a programme of study that is aimed at preparing participants for a particular role (for example, a course aimed primarily at training observers could cover all the required learning outcomes in the BIP-MT, in addition to developing more practical skills);

The priority is for each institution to develop a programme of study that takes account of the prior knowledge of the participants, the best way to structure the programme to meet local requirements, and

the purpose of the overall programme of study that may go beyond what is needed to satisfy the learning outcomes specified here.

3.3.1 Basic physical and dynamic meteorology

An individual achieving the learning outcomes dealing with basic physical and dynamic meteorology shall be able to:
- **Explain the basic physical and dynamical processes that take place in the atmosphere;**
- **Explain the physical principles used in instruments to measure atmospheric parameters.**

Learning outcomes – able to handle:
- *Atmospheric composition and structure*: Describe the composition of the atmosphere and explain its vertical structure;
- *Radiation*: Explain the diurnal, latitudinal and seasonal variations in the radiation reaching the Earth's surface, describe the differences between short- (solar) and long-wave (terrestrial) radiation, describe the processes affecting short- and long-wave radiation (i.e., reflection, scattering and absorption of radiation), outline the heat budget of the Earth's atmosphere, explain the greenhouse effect, explain the role of ozone in affecting ultraviolet radiation, and describe the heat balance at the surface and how it varies with latitude;
- *Atmospheric pressure*: Explain why pressure varies with height, explain the effect of temperature and humidity on the variation of pressure with height, and explain why pressure is often reduced to mean sea level;
- *Atmospheric temperature*: Describe the heating and cooling effect of convection, advection, turbulence and evaporation/condensation, explain the effect of water vapour, cloud and wind on the surface air temperature, explain the diurnal variation in surface air temperature, and describe the main factors that affect the global distribution of surface air temperature;
- *Atmospheric humidity*: Explain why humidity is important, explain the concepts of vapour pressure, saturated vapour pressure, wet-bulb temperature, dew point and relative humidity, and describe the factors that affect the rate of evaporation;
- *Atmospheric stability*: Describe the causes of variations in atmospheric stability, explain the concepts of dry adiabatic lapse rate, saturated adiabatic lapse rate and environmental lapse rate, explain various types of stability (for example, absolute, conditional, neutral), explain the role of temperature inversions, and describe how stability and instability develop;
- *Wind*: Explain why winds occur, describe the pressure gradient force and Coriolis force, and explain concepts of the geostrophic and gradient winds, describe the effect of friction on the wind, and explain the causes of common local winds caused by topography (for example, sea/land breezes, foehn winds and katabatic/anabatic winds);
- *Clouds, precipitation and thunderstorms*: Explain why rising motion leads to the formation of clouds, describe the main mechanisms for the formation of clouds, describe the processes that produce precipitation, and describe the triggering processes for thunderstorms and their life cycle;
- *Dew, frost and fog*: Describe the factors affecting visibility, explain the formation of dew and frost, and explain the causes of fog, with emphasis on radiation and advection fog;
- *Atmospheric optics and electricity*: Explain the formation of rainbows, haloes, blue skies and lightning.

3.3.2 Basic synoptic and mesoscale meteorology

An individual achieving the learning outcomes dealing with basic synoptic and mesoscale meteorology shall be able to:
- **Describe the formation, evolution and characteristics of synoptic-scale and mesoscale tropical, mid-latitude and polar weather systems, and analyse weather observations;**
- **Describe the forecast process and the use made of the associated products and services.**

Learning outcomes – able to handle:
- *Weather at a specific location*: Explain how the weather experienced at a specific location is a combination of effects acting on different time and space scales;

- *Bodies of airs*: Describe and explain the origin, characteristics, movement and modification of bodies of air;
- *Mid-latitude and polar weather systems*: Describe the characteristics of depressions, anticyclones, troughs and ridges and their associated weather, with emphasis on those affecting the region of responsibility, describe the characteristics of warm, cold and occluded fronts and the weather associated with their passage, and describe the relationship between jet streams and weather systems;
- *Main tropical disturbances*: Describe the main tropical disturbances and their associated weather, including the ITCZ, tropical depressions, monsoons and El Niño-Southern Oscillation (ENSO);
- *Mesoscale systems*: Describe the formation and characteristics of important mesoscale features affecting the region of responsibility;
- *Hazardous weather*: Describe the formation and characteristics of hazardous weather systems (for example, thunderstorms, and tropical cyclones) affecting the region of responsibility, the extent to which they can be forecast, and their impact on society;
- *Surface pressure diagrams*: Identify the main synoptic features on surface pressure diagrams and the associated satellite and radar imagery, and describe the typical weather associated with those features;
- *Upper-air diagrams*: Describe different types of upper-air diagrams, including height charts on constant pressure surfaces, identify the main synoptic features on the diagram and the associated satellite and radar imagery, and describe the typical weather associated with those features;
- *Aerological diagrams*: Describe the physical ideas that form the basis of aerological diagrams and perform basic operations on the diagram;
- *Display and mapping systems*: Discuss the common systems used within Meteorological Services to (a) display and map data and (b) prepare products and services for users, along with the benefits and shortcomings of the systems;
- *Forecast process*: Describe the forecasting process, describe the principles behind numerical weather prediction (NWP), and interpret basic operational NWP output;
- *Key products and services*: Describe the key products and services, including warnings of hazardous weather conditions, based on current and forecast weather information, that are provided to the public and other users;
- *Function of National Meteorological Services*: Describe the function of National Meteorological Services in monitoring and forecasting the weather and the role of other service providers.

3.3.3 Basic climatology

An individual achieving the learning outcomes dealing with basic climatology shall be able to:
- **Describe the general circulation of the atmosphere and the processes leading to climate variability and change;**
- **Describe the use made of products and services based on climate information.**

Learning outcomes – able to handle:
- *Features of the global circulation*: Explain the main features of the global circulation of the atmosphere and oceans and their temporal (diurnal, seasonal, annual) variability;
- *Regional and local climates*: Explain the factors that determine regional and local climates;
- *Classifying and describing climates*: Describe the techniques for classifying the climate, including the Köppen method;
- *Local climate*: Describe the climatology and seasonal changes of the region of responsibility and the climatic trend in that region;
- *Climate variability and climate change*: Describe the difference between climate variability and climate change, describe the basic concepts behind the greenhouse effect and the basic science involved in human-induced climate change, and describe the basis for climate predictions;
- *Seasonal forecasts*: Outline the process and scientific basis for making seasonal forecasts;
- *Climate data*: Describe how climate data is captured, collected and quality-controlled in the meteorological service;
- *Climate statistics*: Describe how climate data is analysed in terms of its distribution (for example, frequency and cumulative frequency), central tendency and variation;
- *Key products and services*: Describe the key products and services based on climate information that are provided to the public and other users.

3.3.4 Meteorological instruments and methods of observation

An individual achieving the learning outcomes dealing with meteorological instruments and methods of observation shall be able to:
- **Explain the physical principles used in instruments to measure atmospheric parameters;**
- **Make basic weather observations.**

Learning outcomes – able to handle:
- *WMO Integrated Global Observing System*: Describe the main components of the WMO Global Observing System and WMO Information System (including the Global Telecommunications System) that are used for making and transmitting meteorological and other environmental observations on a global scale using surface-based and space-based systems;
- *Siting of instruments*: Describe the factors that need to be taken into account when siting surface instrumentation;
- *Surface instrumentation*: Explain the physical principles used in instruments to make surface measurements of temperature, moisture, pressure, precipitation, wind, cloud height, visibility, sunshine and radiation (including instruments used in automatic weather stations), describe how these instruments operate, and outline the kinds of errors that might occur;
- *Hydrometeors*: Describe the various hydrometeors and how they are observed;
- *Clouds*: Describe the main cloud types, their characteristics, usual height range, and associated weather phenomena;
- *Weather phenomena*: Describe the various weather phenomena considered when taking a visual surface observation, describe their characteristics and explain their formation;
- *Monitoring and observing the weather*: Monitor the weather, make surface observations using remote and directly-read instruments and visual assessments (including identifying cloud types, cloud amount and weather type), and explain the reasons for the visual assessments;
- *Standards, quality control, calibration and intercomparison*: Describe national and international measurement standards and best practice for the quality control of observations and calibration and intercomparison of instruments;
- *Upper-air observations*: Explain the physical principles and the limitations of instruments used to make upper-air measurements;
- *Remote-sensing systems*: Describe the means by which remote sensing from ground and space (including use of satellites, radars, wind profilers, and aircraft, marine and lightning-detection systems) provides information about the atmosphere;
- *Coding*: Outline how observations are coded and transmitted, and describe the differences between different types of messages (SYNOP, SHIP, CLIMAT, METAR, etc.);
- *Use of observations*: Describe the main uses of observations from the WMO Integrated Global Observing System and other sources of information.

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