The Basic Instruction Package for Meteorologists (BIP-M)

Review team proposal

Draft version 2

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Contents

Figures

Tables

Preface

This document sets out the form of the next edition of the BIP-M, as developed by the review team, for discussion among the global community and seek feedback. This document is the result of a two year process, starting with a meeting held in Geneva during November 2018 which discussed the results of a survey and position papers from several stakeholder groups and which formed a review team to consider how to implement the changes identified.

The review team expresses its thanks to those who contributed to the development of this document, particularly those who reviewed the first draft and whose valuable input has made this second draft a far better product.

To those reviewing this second draft of the new BIP-M, firstly thank you for agreeing to spend your valuable time to help. All feedback is welcome, but in particular we would like to know if the overall package is understandable and whether or not it helps solve problems which your institution or country may have encountered with the previous edition.

Chapter 1 Introduction

The Basic Instruction Package for Meteorologists (hereafter referred to as the BIP-M) defines the educational requirements of those studying to become a meteorologist, and it is the attainment of those outcomes contained in the BIP-M which qualifies somebody as a meteorologist according to the definition in WMO Technical Regulations[1]. A new meteorologist on completion of the BIP-M will, through the study and application of the atmospheric sciences, have demonstrated their ability to professionally apply, develop, and communicate that science for the benefit of society.

The competencies and skills required of meteorologists working in diverse fields including research, consultancy, operational forecasting and more will often be highly localised to a region, country, service, etc. These competencies and skills will evolve quickly as science, technology, and service provision change. The role of the BIP-M is to provide the underlying knowledge and skills common to all meteorologists upon which they can develop the necessary skills and competencies needed for specific roles and continue to learn through their career.

This edition of the BIP-M remains focussed on specifying the learning outcomes required by meteorologists of all types, including underlying knowledge and skills common to the WMO competency frameworks. At the same time, it explicitly provides latitude for institutions, member states, and employers to tailor learning outcomes to the nature of the course of study or national needs. This creates a seemingly contradictory set of requirements: how to maintain an international standard while supporting the pragmatism and flexibility demanded?

The last major review of the BIP-M, when WMO 258 was replaced by WMO 1083[2], had at its core a move from a system of personnel classification and associated syllabi to a system based on learning outcomes, in other words a move to a system in which the attainment of the learner was central. This edition goes further, abstracting the essence of what all meteorologists must be able to do into a set of overarching learning outcomes, while making explicit the role of the more detailed outcomes as being to guide rather than restrict institutions.

1.1 The BIP-M in context

Since the publication of the previous edition of these guidelines, attainment of the BIP-M[3] has been mandated for those meteorologists providing services to civil aviation (as Aeronautical Meteorological Forecasters or AMF), naturally putting more focus on the contents of the BIP-M itself. At the same time, much work has been done to define the role of job competencies and competency frameworks, notably in aviation and other forecasting contexts. The community has also started to develop skills frameworks such as in satellite and radar meteorology. A compendium of these frameworks has been published as WMO 1209[4].

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[1] (World Meteorological Organization, 2019c)
[2] (World Meteorological Organization, 2015)
[3] Or at least those elements directly relevant to the work of the AMF
[4] (World Meteorological Organization, 2019b)

It is the acquisition of the skills and competencies, either as described in these frameworks or as defined by employers or universities, which mark somebody as being a competent professional meteorologist. Achieving the learning outcomes as specified in the BIP-M are an essential pre-requisite to gaining workplace competence, being insufficient for this purpose in and of themselves.

It is recognised that there are a number of pathways by which meteorological education and training lead someone to becoming a professional meteorologist. Many education or training programmes will contain a combination of the underpinning atmospheric science and other outcomes (from BIP-M) and skills (from the skills frameworks). Programmes will likely also include other complementary academic subjects, often related to the research interests of the institution, or even significant portions of the competencies needed for certain jobs (from the competency frameworks).

Institutions or employers must define an overall set of learning outcomes which meet national needs, using the BIP-M as the foundation. Member states are encouraged to work with educational institutions to ensure programmes of education are designed with the employability of graduates and the HR needs of NMHSs in mind by considering the need to include the application of the science as described in the competency frameworks.

Key aims for this edition of the BIP-M, included after wide consultation, are given below, with brief details on how these have been met given in the following sections.

- Place the BIP-M in context of an overall framework for education and training, encompassing educational foundations, skills, and competency frameworks.
- Ensure the BIP-M meets the needs of diverse and evolving job roles and provides clarity and guidance on how to apply the BIP to these roles, with standard skill and competency frameworks being central for many of them.
- Meet the needs of the entire global meteorological community, regardless of size or level of development. In particular to remove barriers to the education and training of meteorologists who are vital to the delivery of operational services to key industries such as aviation.
- Be flexible enough to meet future needs in a rapidly evolving world.
- Maintain the intellectual rigour of the BIP-M and so, while being designed for those to become a meteorologist in research or operational roles, continue to offer an attractive option for those wanting a grounding in a numerate, physically based, earth science subject.
- Minimise work needed to validate or change existing programmes, while at the same time clearly highlighting the necessary changes.

1.2 Main changes to this edition

1.2.1 A hierarchy of learning outcomes

To avoid any misinterpretation of the BIP-M as being made up of a series of related but disconnected topics, a set of “overarching[5] learning outcomes” has been developed which summarise the demonstrable abilities of meteorologists. These overarching outcomes are intended both to provide the ‘glue’ which connect the educational learning outcomes, and to encourage holistic education and training programmes in which interconnections between

[5] The phrase ‘overarching learning outcomes’ is defined in section **Error! Reference source not found.**

the various components are made explicit and the application of our science to solving real-world problems is central.

The value to students in contextualising and applying their learning as they go, in terms of retention and transfer, are well known[6]. Through the overarching learning outcomes the BIP-M will encourage this in the spirit of the thinking of C-G Rossby, who in 1934 (Rossby, 1934) wrote:

> *"It would seem, then, that the principal task of any meteorological institution of education and research must be to bridge the gap between the mathematician and the practical man (sic), that is, to make the weather man realize the value of a modest theoretical education and to induce the theoretical man to take an occasional glance at the weather map."*

The changes made during the last major revision of the BIP included a change from a list of topics to a system of learning outcomes. We have continued and extended this work and have tried to word the learning outcomes to be explicitly clear on what is expected of a meteorologist at the end of a BIP-M programme of education, rather than on how topics might be taught. Part of this work has been a focus on higher-order cognitive processes so that the minds of students and instructors alike is on the application of the science to real-world problems across domains and spatial and temporal scales.

To support the change in emphasis of some of the learning outcomes, a short section is added explaining both the philosophy used and the intended meaning of certain verbs used in the outcomes.

1.2.2 Reducing barriers to access

Among the messages from member states in the survey was the need to minimise the burden – real or perceived – that the BIP-M places upon educators, learners, and employers. By reducing any burden or barriers to accessing learning, opportunities to obtain meteorological education might be opened up to demographics who are currently excluded.

Some members also highlighted what was for them an overly-theoretical tone in places out of touch with the human resource needs of NMHSs. Comments touched upon both the overall size of the BIP and on the relevance and nature of specific sections.

Rather than remove topics wholesale (there was no consensus as to topics which were unnecessary), we have taken a number of approaches:

- Be more specific about the knowledge and thinking skills required of meteorologists.
- Taking care to ensure learning outcomes can be taught and assessed in range of methods without being inadvertently prescriptive.
- Illustrate alternative approaches to meeting the learning outcomes, such as through WMO Global Campus, which may open up meteorological education to those for who access is currently denied due to location, financial considerations, or having work and family commitments which make attending a full-time course impossible.

[6] See e.g. (Hoffman, et al., 2017)

Another aspect of reducing barriers to accessing careers in meteorology is making programmes themselves accessible and inclusive to all members of society. A discussion of this is given is section 2.6.

1.2.3 Making the BIP-M meet national needs

Chapter 2 contains a discussion on the application of the learning outcomes to build a programme of study, including restating the fact that how outcomes are achieved is a decision for institutions and individual instructors, given their specific national or regional needs. This structure allows for a spectrum of implementations of the BIP-M, from highly mathematical or theoretical approaches suited to those destined for research careers to more qualitative but still rigorous approaches which meet the stated needs of NMHSs for people able to apply meteorology to support customers in an operational setting.

A new section briefly explains a process which can be used for mapping the BIP-M into a curriculum suited to national needs.

1.2.4 Influencing best practice in teaching, learning, and assessment

A short section has been added to highlight the continuing need to embed evidence-based teaching and assessment practices into meteorological education and training.

1.2.5 Future-proofing the BIP-M

Included in section 3.8 are a set of *professional* learning outcomes to give institutions guidance on communication skills, information technology, etc learning aspects of which is required to achieve the overarching outcomes.

Also included in this section are outcomes associated with current or future meteorologist skills which do not have their own competency framework. These include research skills and data science. These sections are intended to act as the basis for discussion and course development to meet the needs of these roles. Institutions are encouraged to provide opportunities to students to learn these and other complementary topics such as business and management which will aid in future career progression.

1.2.6 A BIP-M review process

A formal review process has been devised to ensure the continued relevance and usefulness of the BIP-M and the related implementation guidance. This process accommodates both the need for small-scale corrections and amendments, as well as larger scale periodic reviews.

The details of this review process are given: in Appendix 1 – Review process on page 50.

1.3 Transitioning to this edition

In preparing this edition of the BIP-M consideration was given to additional work which might be required by institutions to ensure their programmes remain compliant. For many the adoption of the previous edition was a significant undertaking and only happened relatively recently.

Chapter 2 Education and Training of Meteorologists

2.1 Purpose and nature of the BIP-M

The BIP-M defines both the essential knowledge that all professional meteorologists must acquire and how those meteorologists need to be able to think and act using that knowledge. As such it must reflect the role of meteorologists of all sorts in developing the science of meteorology and applying that science to the benefit of society.

Professionals in any field are identified not necessarily by *what* they do, but on their basis for doing it, which is by having deliberated about it and made an informed decision to do it that way and not another, based upon their body of domain knowledge and the critical thinking skills they have developed[7]. For this reason, the BIP-M mandates not only learning of atmospheric science but an array of applied professional knowledge; it also focuses on higher order cognitive skills rather than specifying declarative knowledge to be covered in a syllabus.

People arriving at a university, NMHS, RTC, or other institution to learn meteorology will have a wide range of prior education, exposure to weather and climate science, and motivation to have chosen their path. They will also go on to embark on a wide spectrum of careers both in meteorology and other fields, including research, consultancy, forecasting, and more. The BIP-M cannot define learning which meets the individual needs of all these learners, or the requirements of all career paths. By necessity we must make some assumptions here about the general level of prior education, while providing guidance as to those areas such as mathematics and physics which are essential to gain an understanding of atmospheric science.

We also cannot, and do not attempt, to define the detailed skills and competencies needed in particular branches of professional practice such as forecasting or research. It is expected that further, more specific, education and training is needed beyond or alongside the BIP-M for somebody to be able to take up a professional role unsupervised. More details on how to achieve this for some of these contexts is contained in other WMO publications as detailed in the section.

2.2 Meeting the needs of the meteorological community

A key driver for the current revision of the BIP-M included, *inter alia*, removing obstacles – real or perceived – to the education and training of sufficient meteorologists to meet the needs of society. One of those obstacles identified by WMO member states was the range of learning outcomes contained within the BIP-M. Some said there were too many outcomes, or that they were too academic in nature; others lamented the exclusion of certain topics or that they did go into enough depth.

Given the finite amount of time available for programmes of education and training, considerations of breadth vs depth in curriculum design become critical. Not only would covering the whole of a broad syllabus in a robust fashion be expensive, but much of the

[7] See, e.g. (Biggs & Tang, 2011, pp. 160-161)

knowledge intended to be learnt would only be done so in a shallow way and would soon be forgotten. As the developmental psychologist Howard Gardner has said (Brandt, 1993):

> *"The greatest enemy of understanding is coverage. As long as you are determined to cover everything, you actually ensure that most … are not going to understand."*

One of the pressing needs of the WMO community today is the shortage of BIP-M qualified forecasters[8], particularly in the aviation sector. In many countries, particularly but by no means limited to the least developed, there is a reliance on university courses in more developed countries to educate and train people to meet their urgent needs for forecasters. Of course, the study of meteorology as an academic discipline remains extremely valuable, indeed essential to maintain the vigour of meteorological research and development of meteorological practice, so the global education and training system must be flexible enough to meet both human resources needs both research and operations.

This edition of the BIP-M has been designed to be applied flexibly to meet exactly this conundrum. Some overarching learning outcomes applicable to all are mandatory; WMO member states and their education institutions are explicitly required to apply the more specific outcomes in a flexible manner to meet their particular needs; detailed guidance on how to do this is provided below.

It is incumbent on the global education and training community to ensure programmes of study meet the needs of those people destined to apply meteorological science to the needs of people, businesses, and society in the many service delivery roles including what is traditionally thought of as the forecaster role. Few universities offer courses in forecasting or other applied areas of meteorology (Hoffman, et al., 2017, p. 55), leaving this to be provided by post-employment training if employers have the capability to provide this. By having a more flexible BIP-M it is hoped that more programmes will bridge the divide between academic study and on-the-job competencies.

2.3 Structure of the BIP-M

A new set of overarching learning outcomes[9] have been developed which lay out in broad terms the philosophy of the BIP-M by defining that knowledge and set of abilities which are common to all meteorologists. These outcomes will be achieved through the learning and assessment of atmospheric science and related topics.

The previous edition of BIP-M grouped learning outcomes under five headings: foundation topics in mathematics, physics, and complementary subjects; physical meteorology; dynamic meteorology; synoptic and mesoscale meteorology; and climatology. This remains a logical and useful division of the main learning outcomes and is largely retained for convenience (with a slight change of emphasis): there are, however, changes to the outcomes within these sections in terms of content and cognitive level.

[8] The words 'Forecaster' and 'Operational meteorologist' are considered as synonyms here, and we use 'forecaster' or 'forecasting' for brevity. It is recognised that forecasting roles have evolved and undertake a wider range of tasks than those traditionally thought of as forecasting tasks.
[9] The phrase 'overarching learning outcome' is defined in sub-section 2.3.2.

The hierarchy of outcomes is presented graphically in Figure 1. At the top of the hierarchy sit the competency frameworks as defined in WMO 1209[10]. WMO 1205[11] describes more fully the relationships between *competencies* required for a given job role and *qualifications* required to enter a profession. It is the competency frameworks which should be the primary guide to assess whether an individual is competent for any given role, and WMO 1205 should be consulted for guidance in using these frameworks.

Although the learning outcomes are presented in several distinct sections, there exists connections within and between these sections; meteorologists must be able to synthesise knowledge across these boundaries to solve problems and create solutions. Care must be taken, therefore, not to consider the division of learning outcomes into distinct sections as meaning they should be taught in isolation or that cross-disciplinary thinking should not be encouraged or explicitly included in curricula.

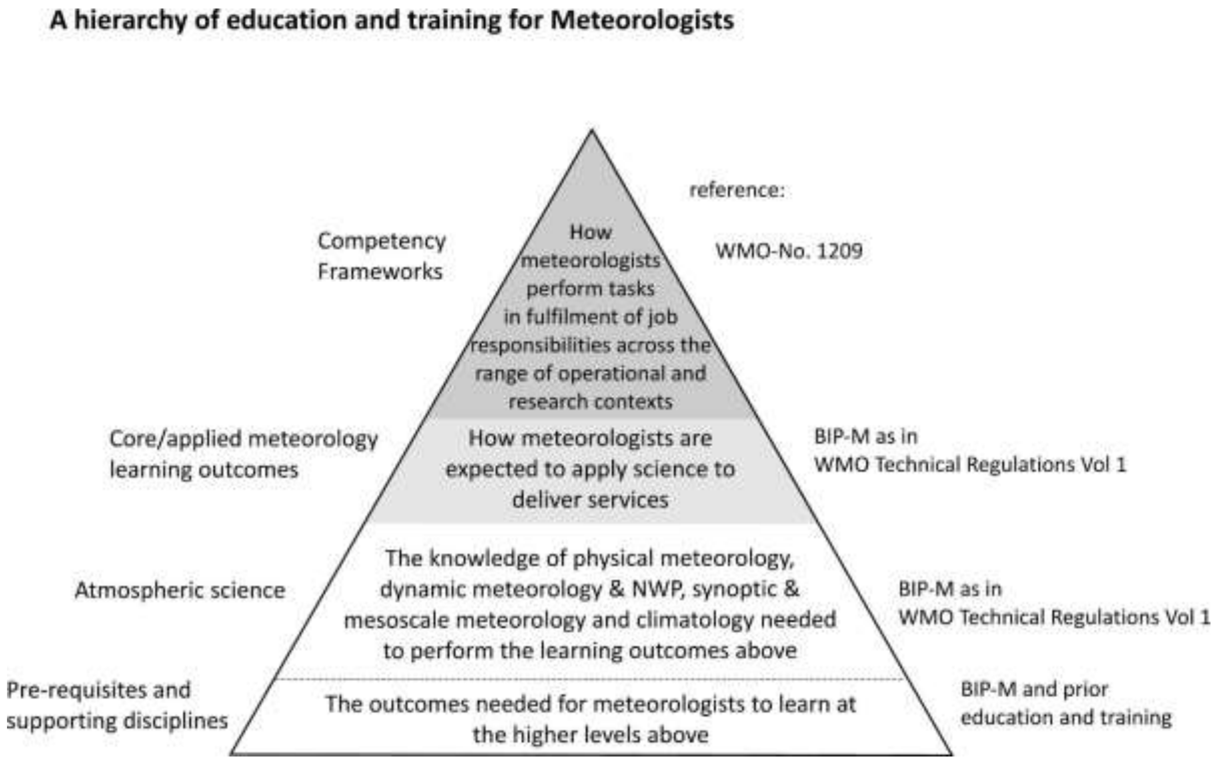

Figure 1 - A hierarchy of education and training for meteorologists

[10] (World Meteorological Organization, 2019b)
[11] (World Meteorological Organization, 2018)

2.3.1 The learning outcomes-based approach

The main innovation introduced in the last edition of the BIP-M was a change from an outline syllabus to a system of learning outcomes. The reasons for this change are still very much valid today:

> *"…. 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. Specific learning outcomes are beneficial both for the instructor and for the students, as they provide clarity about the purpose of the programme of study. They also provide a more robust basis for assessing whether the required learning has taken place."*[12]

This change benefitted the BIP-M by making it better able to describe how knowledge should be demonstrated by those students undertaking meteorology programmes. This current version of the BIP-M goes further, using the learning outcome based approach to define the overall aims of the BIP-M, and making explicit the need both for institutions to map the BIP-M outcomes to their own programme and course outcomes and to map teaching and assessment activities to the course and BIP outcomes.

Learning outcomes have been usefully be categorised, e.g. by (Krathwohl & Payne, 1971), into three levels of specificity as described below, bearing in mind that in reality they lay on a continuum:

- Overarching outcomes[13].
- Educational outcomes
- Instructional outcomes

The BIP-M comprises a set of overarching outcomes which as an ensemble specify the philosophy and the vision of the BIP. These overarching outcomes are the desired end; the means to achieve them should be through the study and assessment of the educational outcomes in atmospheric science. For convenience and continuity with previous editions are grouped into the broad themes of physical, dynamic, weather systems and services[14] and climate variability, change, and services[15].

It is the overarching and educational learning outcomes (as set out in WMO Technical Regulations[16]) which define the Basic Instruction Package. Extracts from these regulations are included in Chapter 3, where they are clearly differentiated from indicative instructional outcomes and explanatory narrative included as guidance.

The BIP-M does not include instructional outcomes as such, but some are presented in the tables within Chapter 3 of this guidance to suggest the breadth and depth of outcomes which institutions might develop. Instructional learning outcomes are the detailed pieces of learning which are defined on the per module or learning activity basis, as part of the process of designing those learning activities to help students meet the course/module level outcomes. They will expand on the educational outcomes to include declarative knowledge and lower-

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[12] (World Meteorological Organization, 2015)
[13] Termed "global outcomes" by Krathwohl & Payne. Here the phrase "overarching outcomes" is substituted to prevent any confusion as the word "global" is used in another context.
[14] Previously "synoptic and mesoscale meteorology"
[15] Previously "climatology"
[16] (World Meteorological Organization, 2019c)

level procedural knowledge required to demonstrate the higher-level educational outcomes (see next section for definitions).

The relationships between overarching, educational, and instructional learning outcomes are summarised in Table 1 below.

Table 1- The specificity level of learning outcomes. Adapted from (Anderson, et al., 2001).

	Level of outcome		
	Overarching	**Educational**	**Instructional**
Scope	Broad	Moderate	Narrow
Time needed to learn	One or more years	Weeks or months	Hours or days
Purpose or function	Provide vision	Design local curriculum	Prepare lesson/assessment plans
Example of use	Plan an overall programme of study and training	Plan modules or units of instruction	Plan daily activities, lessons, exercises.
Included in BIP-M?	Yes	Yes	No (but guidance given)

2.3.2 Defining learning outcomes

As previously noted, modern theories of how learning takes place have shifted our focus away from the intent of the instructor towards the role and active participation of the learner. Learners are not passive recipients of knowledge given to them via lecture, textbook, etc but are active agents who engage with learning activities by various cognitive and metacognitive[17] processes, building meaning from them in the context of their prior learning and experience.

We must, therefore, be explicit both in our identification and specification of that body of knowledge which we expect a meteorologist to learn and in what types of cognitive process we expect them to use to make use of that knowledge. To ensure a common language to describe learning outcomes in this explicit fashion, and for continuity with the previous edition, we make use of the revision to Bloom's taxonomy which has widespread use (Anderson, et al., 2001).

The taxonomy consists of two dimensions: the cognitive process dimension and the knowledge dimension. Both are required to fully describe what we expect a student to know and how we expect them to demonstrate that knowledge. Here we briefly discuss these dimensions and how we apply these to the BIP-M.

When using the taxonomy care must be taken not to interpret it hierarchically. Acquisition of both declarative and procedural knowledge are equally important. Equally, cognitive

[17] Where 'metacognition' can be interpreted to mean 'thinking about thinking'. It is that knowledge somebody have has about themselves as a learner, the processes and techniques they are able to use to learn, and when to use those techniques. It is regulated by conscious planning, monitoring, and evaluation of the learning process (Schraw, 1998).

processes such as remembering or understanding should not be seen as being less valuable than applying or evaluating, indeed they are often complementary as a body of declarative domain knowledge in memory is necessary for the higher-order processes.

The knowledge dimension

The earliest versions of these guidelines were largely outline syllabi – that is, a high-level list of the topics which it was deemed a meteorologist should learn during their initial education. Since those times, while the fundamentals of the atmospheric sciences have indeed evolved, transformational change has taken place within the technological domains of pervasive computing, radar and satellite observations, numerical modelling and more. The societal and economic context within which meteorologists operate has also changed radically.

At the same time that the domain of meteorological expertise has grown, cognitive science has transformed our knowledge of the processes through which humans learn, that is how we organise and structure knowledge.

Declarative knowledge can be broken down into knowledge of facts and knowledge of concepts.

> *Factual knowledge* consists of those basic pieces of terminology and facts that meteorologists use to communicate about the discipline. This form of knowledge is very specific, in that pieces of factual knowledge can be isolated as atomic 'bits' of information. The learning of factual knowledge is vital both for learning the more general types of knowledge necessary and for applying these in a workplace, however care needs to be taken to ensure that students (or instructors) do not place undue emphasis on it. Students must learn to make the connections between and among the various facts, building the schemata which characterise an 'experts' knowledge of the science. A problem which both students and their instructors must address is that of being able to transfer or apply facts to the more complex situations a professional will encounter, rather than simply acquiring a body of so-called 'inert' factual knowledge.
>
> *Conceptual knowledge* consists of those more general schemata, theories, mental or conceptual models which include the inter-relationships between and among the facts of the subject matter. A deep understanding of the subject with clear mental organisation of the myriad facts is a hallmark of an expert in a field and is helpful in the transfer of knowledge to new situations. The bulk of the learning outcomes specified in the BIP-M include as their subject forms of conceptual knowledge.

Procedural knowledge consists of our knowledge of how to accomplish something, such as solve a quadratic equation, interpret a synoptic chart, plot a timeseries of data using Python, etc.

The cognitive process dimension

While it is true that retention of knowledge is an important educational goal, the transfer of that knowledge, i.e. having both a deep understanding of that knowledge and the ability to apply it in different ways to a range of tasks and problems, including in novel situations is important for a professional qualification such as the BIP-M.

A brief explanation of each of the cognitive processes in the taxonomy is given below, including the definition of the process (Anderson, et al., 2001), simple examples, and notes on how we have represented the process in the BIP-M learning outcomes. As already noted, there is no hierarchy inherent in this list of processes – *remembering* complex material is mentally more demanding than *creating* something simple – and we have tried to select the verbs in the outcomes which describe the most common application of the subject knowledge.

1. **Remember**. "Retrieve relevant knowledge from long-term memory", such as being able to recognise presented information as being prior knowledge or recalling relevant information. Learning outcomes commonly pair the remember cognitive process with factual knowledge and are important in testing of meaningful learning of fundamental empirical facts and the terminology of a discipline.

Examples of learning outcomes using the remember process are:

"*Identify* a tropical cyclone on the presented synoptic chart"

"*Recall* the definition of potential temperature."

While not understating the importance of remembering facts to learning, we try to avoid the use of such learning outcomes in the BIP-M. Instead we have focused on higher-order cognitive processes, and leave supporting lower-order processes as implied, to clearly represent the higher-order thinking required of professional meteorologists.

2. **Understand**. "Construct meaning from instructional messages, including oral, written, and graphic communication". Understanding in this context refers to the building of connections between the concepts in the instructional messages with existing schemas in long-term memory, giving the student the ability to use the new concepts with existing knowledge and concepts in mental tasks such as: interpreting, exemplifying, classifying, summarising, inferring, comparing, and explaining.

The ability to *understand* concepts as defined here makes up the largest subset of outcomes presented in the BIP-M, particularly across the more fundamental topics such as physical and the more elementary parts of dynamic meteorology. Where a need exists for both understanding and higher-order processes, we have presented the higher one, with the supporting understanding outcome implied. Many of these outcomes require the student to *explain* a concept. The verb to explain means more than simply describing the component parts of a concept, rather they need to understand the interconnections and feedbacks between the parts of the system or concept and be able to think through problems of cause-and-effect.

A complaint heard from many educators is that learning outcomes such as "a student should understand the Coriolis force" are not helpful. As "understanding" is an internal cognitive process it is impossible to observe and test, so we do not use the word as a verb in the outcomes here.

3. **Apply**. "Carry out or use a procedure in a given situation". Often used with procedural knowledge, these outcomes are used when the ability to carry out a task is required, such as in a calculation. Outcomes at this level can be placed in one of two categories. Firstly, *executing* or carrying out a known procedure to a familiar task. This is the case of exercises in learning situations, where a 'recipe' for carrying out a task exists and worked examples will have been presented. Secondly *implementing* a procedure which is unknown, requiring the student to determine which conceptual knowledge to use in building a strategy they then

use to work out a solution. This is the case for problems in learning situations, where the student is required to work out how to solve the problem.

4. **Analyse**. “Break material into its constituent parts and determining how those parts are related to one another and to an overall structure”. Analysing can be thought of as an extension of *understanding*, in that it is the process used to determine how ideas are related to one another, support conclusions with supporting evidence, and to distinguish relevant from extraneous material. Verbs used in the BIP-M requiring learners to use the analyse process include *select*, *integrate*, and *outline*.

5. **Evaluate**. “To *evaluate* is to make judgements based on criteria and standards”. Relevant uses of evaluation in meteorological education include detecting inconsistencies within a prognosis and between it and newly available data, and to determine which approach is most likely to be best for solving a particular problem.

6. **Create**. The *create* cognitive process is often misunderstood to require the generation of novel ideas or processes. In reality it encompasses functions which are pervasive within meteorology even during education, such as generating hypotheses to account for observed phenomena, planning a small piece of research, or even generating a customer-focused weather briefing.

We also define some of the other words or phrases used within the learning outcomes in order to assist the reader understand the intention of the authors.

Word or phase	Intended meaning
And (when used to join two clauses in a sentence)	On occasion we have, for reasons of brevity, included a number of distinct outcomes in a single sentence. In this case, the student must attain the outcome in both/all of the clauses.
For example / e.g. ...	Used to precede a list of
Such as…	
Including.	

Evolution of the BIP-M learning outcomes

To demonstrate how the contents of the BIP-M (and its antecedents) have evolved over the past 50 years, an example set of outcomes from dynamical meteorology are presented in Table 2 below. The change from a list of topics to assessable learning outcomes is clearly represented, as is the change from an academic or theoretical perspective to one grounded in the application of the science. The last two rows exemplify the application of the approach described above in terms of use of higher order thinking skills.

This table shows that it is now possible to design BIP-M courses of study along the spectrum of more academic to more applied as previously discussed, all being of equal worth; all programmes should be designed with the needs of employers in mind and use a mix of evidenced-based teaching methods to maximise the transfer of learning.

Table 2 - Analysis of dynamics learning outcomes as stated four iterations of the BIP

Version	Sample outcomes / topics	Description of knowledge	Cognitive level	Character
WMO 258 1969	Equations of motion in vector form as derived from Newton's second law; discussion of pressure force and gravitation; transformation from non-rotating to rotating co-ordinate systems; discussion of centripetal acceleration and Coriolis force; the concept of gravity. Equations of motion in Cartesian co-ordinates (tangent plane approximation) and in spherical co-ordinates; orders of magnitude of various terms (based on observations) leading to the simplified equations.	- (list of topics)	-	More theoretical
WMO 258, 2001	Scalar and vector fields; Gauss and Stokes theorems; kinematics of flow fields; material derivative; Eulerian and Lagrangian rates of change; conservation of mass, momentum and energy. Navier-Stokes equations. Rotating frames of reference; equations of motion in coordinate form: spherical coordinates; preliminary approximations to the equations in spherical coordinate form; Coriolis parameter; tangent-plane geometry; f- and β-plane approximations.	- (list of topics)	-	More theoretical
WMO 1083, 2015	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;	Concepts	Understand	Theoretical

2020 revision	Outline the application of the concepts of force, acceleration, and frames of reference to a physics of atmospheric dynamics as exemplified in the equations of motion. Illustrate the concept of a balanced flow, including by demonstrating the description of idealised atmospheric flows using these balanced flows. Summarise the process of scale analysis to explain simple expressions for these flows. Use the principle of ageostrophy to explain cross-contour and vertical motion in unbalanced idealised flows. Apply the main results of quasi-geostrophic theory to diagnose vertical motion and predict changes to surface and upper-air flow, judging when the assumptions behind these results are valid.	Concepts, Procedures	Understand, Apply, Evaluate	Mix of theory and application

2.4 Design of teaching & learning, and assessment activities

Traditionally, education and training in university and professional contexts relied on lectures for imparting information, backed up with tutorials and laboratory work to deepen understanding and application of knowledge. Just as our approach to curriculum design has evolved from the syllabus describing what knowledge to 'cover' into the learner-centric outcomes-based approach, a more diverse range of learning activities which involve the student actively applying knowledge have become standard practice.

Given learning outcomes which are well defined as set out in the previous section, then it should be straightforward to design teaching & learning and assessment methods to enable students to achieve those outcomes. Unfortunately, the methods used traditionally, and which are still widespread, such as the lecture, are often not well suited to learning or assessing our outcomes.

This process is illustrated by the concept of "constructive alignment" (Biggs & Tang, 2011) as shown in Figure 2[18]. The constructive alignment approach is based in constructivism and states simply that for effective learning the following three elements need to be both appropriate and relevant to one another:

- learning outcomes
- learning and teaching activities that enable learners to meet those outcomes
- assessment methods through which learners can demonstrate that they have met the outcomes

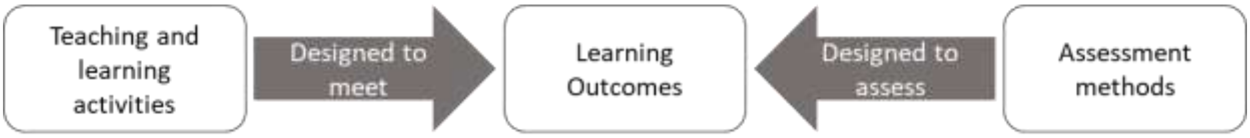


Figure 2 - Constructive alignment between outcomes and activities

2.4.1 Learning declarative knowledge

Consider as an example a lecture designed to meet one of the BIP-M learning outcomes in climatology: "Apply physical and dynamical reasoning to explain the mechanisms responsible for climate variability and climate change". The action verb in this LO is *explain* which, as described above, requires the student to tell somebody how the components of the climate system interact with one another in a complex chain of cause and effect to give the observed phenomena. Analysing the lecture to determine the activities being carried out by the instructor on one hand and the students on the other may produce a summary such as the one in Table 3[19].

Table 3 - Example lecture activity analysis

Instructor activity	Student activity
Introduce	Listen
Explain	Take notes

[18] After (Imperial College London, n.d.)
[19] After (Biggs & Tang, 2011, p. 134)

Elaborate	Understand (but correctly? Deeply enough?)
Show some slides and a video	Watch, take notes
Questions on slides	Write answers to questions
Wind up	Listen, possibly ask a question

In this example the student takes a passive role. The outcome is for the student to be able to *explain* something, but they are not given the opportunity or motivation to do any *explaining* in this setting. The lecturer may be doing some good explaining, but from the learners' perspective they are busy receiving declarative knowledge which they are working hard to *remember*. A disciplined student with good study technique and enough spare cognitive load may internally build the schema including connections between the information they are receiving and explain the whole, otherwise an entirely different outcome is realised from that intended (*remembering* versus *explaining*).

For facilitating the acquisition of the body of declarative knowledge needed in meteorology, activities in which the student is active and in control of the learning should be used in preference to passive experiences. A combination of instructor-led and self-led learning can be used, but whether listening to a lecture, active reading, or group discussions, the key is that the student is using the right metacognitive skills to actively retrieve and use the knowledge required. If the learning outcome is to recall some fact, then the student should be doing *recall*; if the outcome is to explain, the student should be doing *explaining*; in either case the teaching and learning activity needs to be aligned with the learning outcome.

2.4.2 Learning procedural knowledge

Many of the learning outcomes in the BIP-M are written in terms of higher-order cognitive processes skills; the procedural knowledge associated with the apply, analyse, evaluate, and create categories in the taxonomy really defines what it is to be a professional meteorologist.

Teaching and learning activities must activate those cognitive processes in the student for them to master both the knowledge and use of those very processes. Examples of teaching and learning activities which encourage or require the use of these processes include case-study based learning, group and individual projects, and workplace-based learning (known as a placement, internship, practicum, and other terms).

Development of the necessary metacognitive abilities such as problem solving are likely beneficial to the learning of procedural knowledge but are unfortunately often not explicitly taught.

2.4.3 Assessment

Just as the methods used in teaching and learning must be aligned to the learning outcomes, so must the means of assessing learning. Clear learning outcomes, specifying the knowledge and cognitive process needed, should be made available to learners to allow them to self-assess and gauge their progress. The aim of constructive alignment between the learning outcome and the assessment item should make devising those assessment items far easier but might require innovation in assessment methodology.

If the students are being asked to explain a piece of knowledge, then assessment items should give them the opportunity to explain it. Similarly, learning outcomes which require students to evaluate a situation must be assessed in ways which test their critical thinking and analytical ability. It is often easier to test for recall of declarative knowledge than application of procedural knowledge, but this is not appropriate when the outcome calls for procedural knowledge.

As described in the previous sub-section, activities such as development of case studies, individual research projects, etc and the presentation of the results are useful for learning but are also useful for the assessment of a range of higher-order cognitive processes.

2.5 Curriculum design

It remains the case that institutions must define their own detailed outcomes at level of the programme, modules, and learning activities. These will use the BIP-M as a basis but will necessarily be tailored to regional, national, or local needs. Instructional outcomes give the detailed guidance needed by instructors who will develop instructional materials and assessments. They are not given here due to their dependence on local needs and instructional approaches.

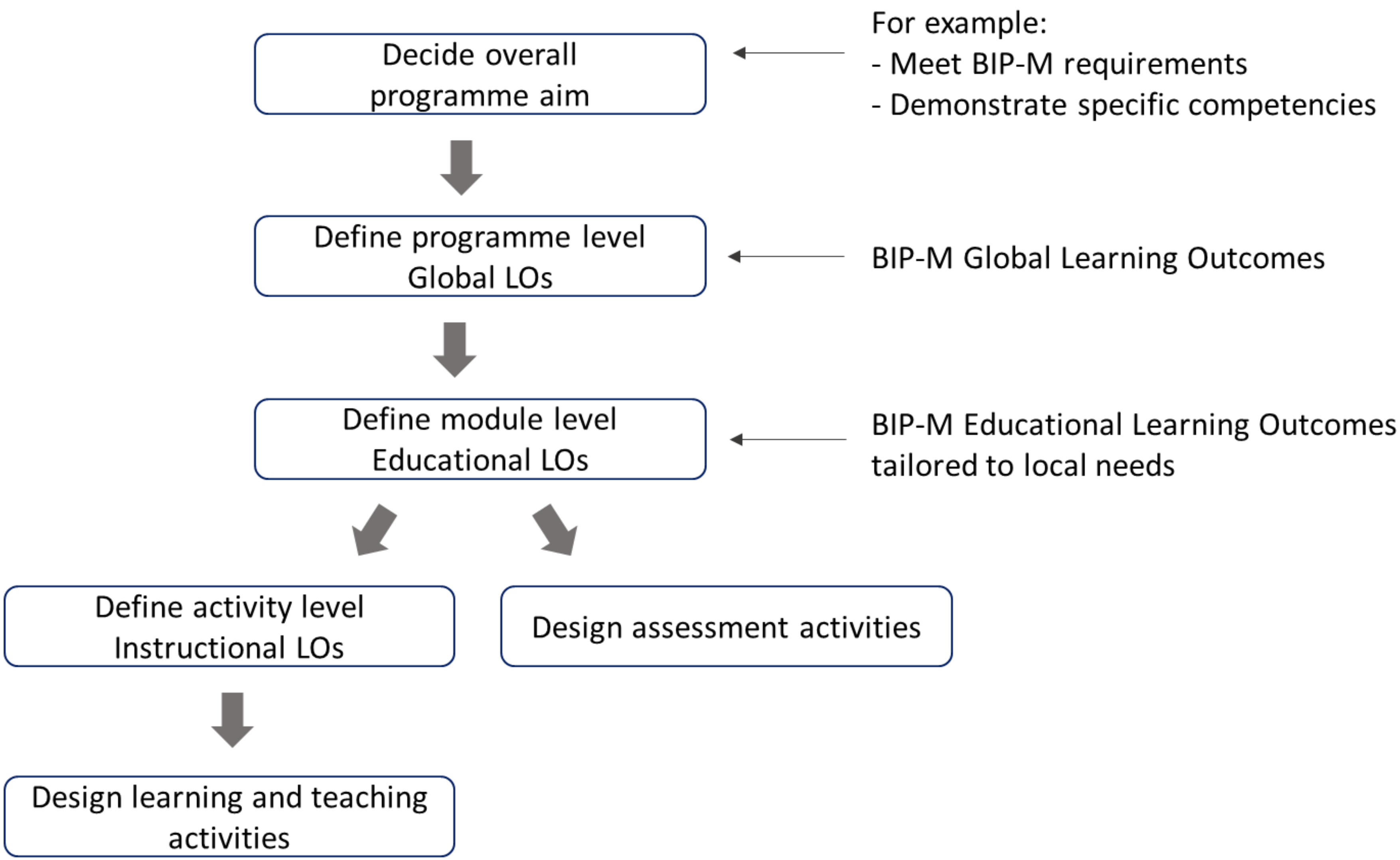


Figure 3 - Mapping BIP-M to programme outcomes

2.6 Inclusive teaching and assessment

Objective 5.3 of the WMO Strategic plan for 2020-2023[20] is to "Advance equal, effective and inclusive participation in governance, scientific cooperation and decision-making". The plan says that:

> "Organizations that respect diversity and value gender equality demonstrate better governance, improved performance and higher levels of creativity. Gender equality and the empowerment of women are further key to scientific excellence and essential to meeting the challenges of climate change, disaster risk reduction and sustainable development, particularly Sustainable Development Goal 5."

In order to contribute towards that objective and derive the benefits described it is important to have equal access to programmes of education and training, and for learning and teaching materials and assessments to be fully accessible to all and representative of the diversity of the potential student base. Programmes which are inclusive and accessible to part-time students, including for reasons of childcare, benefit gender equality especially, as has been highlighted during the COVID-19 pandemic.

As has already been discussed, having clear learning outcomes coupled with transparent and fair assessment policies is beneficial to student attainment and contributes to a more inclusive culture.

2.7 Case studies in the application of the BIP-M

The sections of the BIP-M are not intended to mandate a course structure or to rigidly define the contents of a programme of study. Each member state, NMHS, university, or other training institutions will have their own requirements, systems of regulation, and education systems, meaning that course curricula and outcomes must be developed which fit with these. Courses will also include content, such as other complementary subjects to meet the institutions research or operational interests and to provide a rounded education for their graduates.

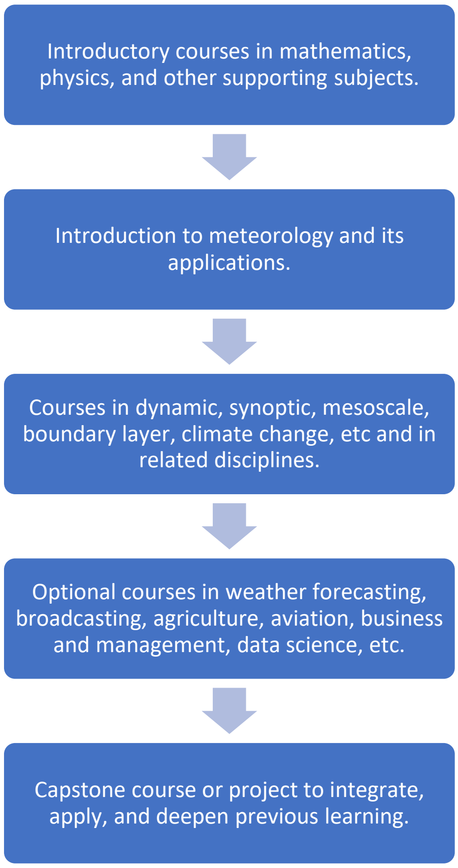
Add in a Masters example

[20] (World Meteorological Organization, 2019d)

2.7.1 Case 1 – Undergraduate course in meteorology

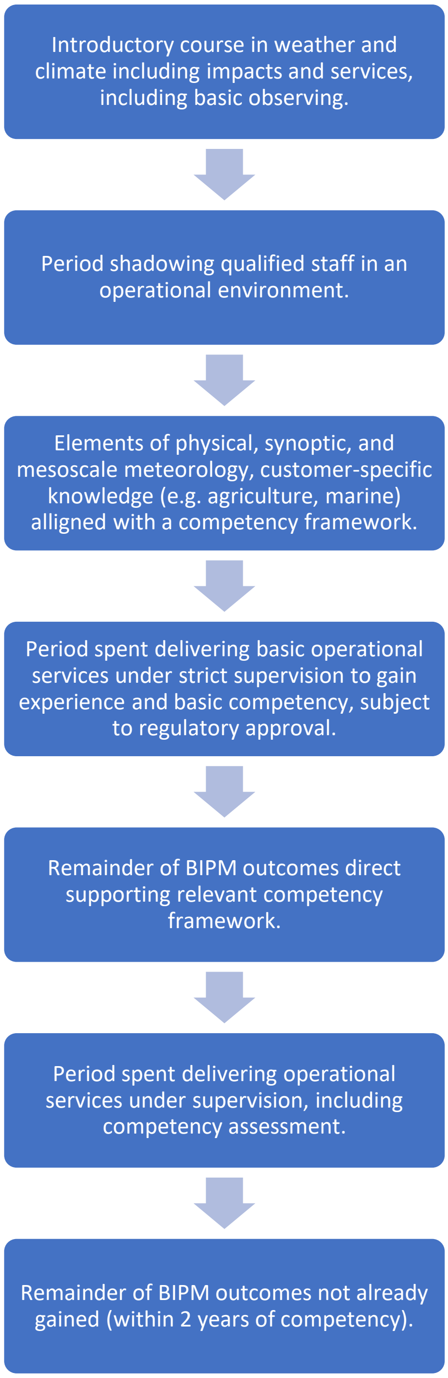
One way of implementing the BIP-M is as the core of an undergraduate course in meteorology over a 3- or 4-year period. An outline example of such a course is pictured below. In this example, it is assumed that students have pre-requisite school education in mathematics and physics to access the more advanced undergraduate courses in these topics.

Unless specific courses in weather forecasting or other specialist areas are included within the degree programme, whether delivered by academic staff or in partnership with the NMHS, such a programme would not prepare a graduate to take up a forecasting role without further training.



2.7.2 Case 2 – NMHS graduate forecasting course

In this example of a course in an NMHS training centre or an RTC. It is assumed that students are either graduates in a physical science subject, or are staff employed as meteorological technicians or in other roles who have the pre-requisite education, possibly gained in-service (for example by accredited online programmes or at local colleges). The level of the education should be at university degree level.



2.7.3 Case 3 – Blended individual qualification route

The WMO Global Campus initiative is encouraging educational institutions to offer education and training opportunities outside of traditional academic or employment settings. Technology today allows for a blend of synchronous and asynchronous, self-directed and instructor-led, learning in the time and place most suited to learners. A possible route to BIP-M qualification would be for individuals to access the necessary learning from either a single provider or from a range of different providers.

Such a route would open access to meteorological education to those traditionally excluded by reasons of location, employment status, caring responsibilities or other reasons.

As there is no international system of registration of meteorologists, responsibility for evidencing achievement of the BIP-M learning outcomes remains with the organisation that employs the meteorologist. To facilitate this, institutions are encouraged to be specific in their enrolment literature and in certification and transcripts with regard to which BIP-M outcomes any particular course meet and to what extent.

Chapter 3 Guidance on implementation of the BIP-M

This chapter contains guidance on how to implement the learning outcomes of the BIP-M which are contained in WMO-49[21]. It gives some narrative on the intention behind the outcomes as written and includes more detail on the topics which *might* be included in a programme of study in order to meet the learning outcomes. It must be remembered that the detail given in this chapter is neither exhaustive nor intended to constrain member states in the definition of programmes. Put another way, it is the learning outcomes in the bulleted lists which define the BIP-M, not the explanatory detail in the tables beneath.

As professionals, meteorologists need to be able to apply high-level creative problem solving, think critically, produce incisive analyses, and carry out routine and non-routine tasks autonomously. It is these higher-order cognitive processes, and a deep understanding of atmospheric processes, that graduates of BIP-M programmes must develop.

For this reason, we have where possible avoided the lower-order thinking skills associated with the *Remember* level of the taxonomy[22] – that is, recognising and recalling. Of course, there is a great deal of declarative knowledge, both empirical knowledge and terminology, which is important for meteorologists to know and which provides a vital foundation for the higher-order skills. In most cases this factual knowledge is implied rather than explicitly stated here.

We have also been circumspect in using verbs associated with the *Understanding* cognitive process level, such as *explain* and *describe*. These verbs are often misunderstood by students and instructors alike as requiring simple recitation of an explanation, derivation, etc, rather than the ability to construct cause-and-effect system models to demonstrate understanding which *explain* means. The definitions given in the previous chapter should be used to determine what verbs in these outcomes mean within the context of BIP-M.

3.1 Interpretation

> In this chapter, text enclosed in grey-shaded boxes, like this example, comprises extracts from WMO Technical Regulations Volume 1, Part VI and has the regulatory status of standard practices and procedures.

The remainder of this chapter comprises narrative and suggested learning outcomes, intended to guide member states on the implementation of the BIP-M, but not having regulatory status.

3.2 Overarching learning outcomes

This section describes the key attributes and skills which mark out a professional meteorologist, no matter which role they might go on to undertake. As stated above, these overarching learning outcomes are also intended to summarise the overall philosophy of the BIP-M, by describing how a professional meteorologist thinks and uses the data and tools at their disposal to carry out professional work.

[21] And included at Appendix 1 (page 55) for reference.

[22] See section 2.3.2

The outcomes described here are not intended to describe any specific role, nor do they assume the context within which an individual might eventually be employed. Nor is it intended that these outcomes necessarily map directly to modules or units of study. Rather they should permeate and be used to assess an overall programme of study, to ensure individual units of study contribute to the broader aims of the programme in embedding meteorological thinking and practice and making links between theory, the real atmosphere, and provision of scientific and professional services to the benefit of society.

Meteorologists shall be able to:

- Combine available sources of relevant observational data in a systematic way to produce coherent analyses of the state of the atmosphere at the spatial and temporal scales under consideration.
- Generate reasonable hypotheses for the evolution of the atmosphere in the region of interest in terms of relevant dynamic and physical processes, and of conceptual models.
- Predict the evolution of the state of the atmosphere and the degree of uncertainty in those predictions, combining relevant numerical model products with physical and dynamical thinking and empirical methods, to a level of precision appropriate to the spatial and temporal scales under consideration and the known sources of uncertainty.
- Compare predictions with observations using qualitative or quantitative methods to assess hypotheses and to assure the quality of services including through evidencing changes needed to hypotheses, products, and services.
- Communicate with colleagues, customers, and other stakeholders using a range of media with relevance, clarity, precision, and reflecting uncertainty and impacts.
- Determine the sensitivities of society to weather and climate phenomena, drawing on other disciplines where necessary, to ensure that the impacts of weather and climate on people and society are central to their work.
- Evaluate their work outputs against relevant standards, take corrective action if needed, and contribute to the development of work systems and processes.
- Reflect on their learning and working practices, critically evaluate their performance, and use a range of approaches to continuously develop their professional knowledge and competence.

These learning outcomes should be achieved through learning and assessment of the atmospheric science topics described in sections 3.43.3 to 3.7, supplemented where necessary by the professional learning outcomes in section 3.8 and other outcomes as required to meet national needs, and supported by the advice on basic mathematics and physics given in section 3.3.

3.3 Pre-requisite mathematics and physics

Meteorology, being a physical science, builds upon basic physics to describe mathematically the processes at work in the atmosphere. It is therefore necessary that meteorologists have a solid grounding in mathematics and physics before learning the specifics of atmospheric physics, not least because even introductory literature uses mathematical language to succinctly describe the science. At the same time, it should be borne in mind that the BIP-M is not designed to educate mathematicians or pure physicists: mathematics is a means through which people can learn meteorological concepts rather than an end in itself.

For these reasons, learning outcomes on mathematics and physics are included in the BIP-M, but only those elements of mathematics or physics which directly support other learning outcomes. None of this precludes institutions going beyond what is set out here in order to support their approach to teaching atmospheric science, or to take advantage of standard introductory mathematics courses as part of their offering, or to prepare students for more advanced study.

The outcomes in this section may be achieved in numerous ways, including by using these options or a combination thereof:

1. By setting pre-requisite learning which students must achieve before embarking on the atmospheric science study. This may be through a blend of secondary education[23] or introductory level undergraduate modules.
2. By including specific introductory mathematics and physics modules into an integrated meteorology programme.
3. By embedding study within the core meteorology programme (for example by including basic electromagnetic radiative transfer in a remote sensing module).

Meteorologists shall be able to:

- Interpret and apply the mathematical language, concepts, and techniques used in introductory meteorological literature and teaching materials.
- Use their mathematical knowledge to make logical and reasoned decisions in solving problems, and recognise incorrect reasoning, being able to communicate their reasoning clearly in mathematical language.
- Apply and interpret the basic statistical measures used to summarise meteorological data and forecast output and to analyse errors.
- Represent physical and meteorological situations mathematically, understanding the relationship between the real world and the mathematical model, and making reasonable interpretations of results.
- Use basic physical laws to solve problems related to mechanics, thermodynamics, wave motion, and electromagnetic radiation.

The guidance in Table 4 and Table 5 should aid in the definition of instructional learning outcomes within modules of study. It is intended to be indicative of the range and type of knowledge needed to meet the pre-requisites and thus access the study of meteorology, rather than being either exhaustive or limiting:

[23] Many of the mathematics and physics learning outcomes needed here are fulfilled by secondary education certificates such as the ‘A’-level, International Baccalaureate, Advanced Placement program, etc.

Table 4 - Suggested instructional outcomes to meet the pre-requisite mathematics requirements

Mathematics	
Trigonometry	Solve simple geometric problems using the definitions of sine, cosine tangent, and their inverse functions in degree and radian units.
	Describe the sine, cosine, and tangent functions, their graphs, symmetries, and periodicity.
	Explain and apply the small angle approximation.
Logarithms and exponentials	Manipulate and interpret expressions containing logarithms and exponentials
	Use logarithmic graphs to estimate the coefficients of exponential equations
Algebra and functions	Manipulate polynomial equations including expanding brackets and collecting like terms and factorisation.
	Solve simultaneous equations of two variables by elimination or substitution
	Read and interpret graphs of functions, and sketch curves defined by simple polynomials
	Measure the slope and intercept of a linear graph
Vectors and linear algebra	Represent vectors graphically and using vector notation and translate between the two.
	Calculate the magnitude and directions of a vector and convert between component form and magnitude/direction form.
	Add and subtract vectors and multiply vectors by a scalar. Do these both algebraically and graphically.
	Calculate the scalar (dot) product and vector (cross) product of two-dimensional vectors.
Complex numbers	Solve any quadratic equation with real coefficients, including those with complex roots
	Explain the terms real part and imaginary part
Differential and integral calculus	Interpret the derivative of a function as the gradient of the tangent to the graph at a point, and as the rate of change of that function.
	Explain the interpretation of the second derivative of a function as the rate of change of the gradient, and use this to identify maxima, minima, and inflection points.
	Interpret the physical meaning of ordinary and partial differential equations containing space- and time-derivatives.
	Interpret the integral of a function as the area under a graph and as the limit of a sum.
	Use Taylor series to approximate a function around a point of interest.
Vector calculus	Sketch representations of scalar fields of a given function and of vector fields showing translation, deformation, divergence or vorticity.
	Define the gradient, divergence and curl operators and interpret the results of these operators on scalar or vector fields

Statistics	Interpret basic measures of the central tendency, range and spread of data.
	Interpret data plotted as a histogram.
	Explain the concept of probability, conditional probability.
	Interpret plots of probability distribution function, probability mass function & probability density function.

Table 5 - Suggested instructional outcomes to meet the pre-requisite physics requirements

Physics	
Mechanics	Describe the concept of a force; explain and apply Newton's first law.
	Add forces graphically or algebraically to find the resultant force in a system.
	Describe and apply Newton's second law of motion to solve simple problems.
	Solve problems using the principle of conservation of (linear) momentum
	Explain the concepts of Eulerian and Lagrangian frames of reference, when to use each, and how to translate from one to the other.
	Explain the concept of centripetal acceleration and describe circular motion in a system by relating the resultant force to the centripetal acceleration.
	Apply the principle of conservation of angular momentum to rotating systems
	Explain the concepts of work, kinetic energy, potential energy and internal energy.
	Solve simple problems using the principle of conservation of energy.
	Solve simple problems using the relationship between power, work, and force.
Kinematics	Use the language of kinematics to describe physical systems: position, displacement, distance, velocity, speed, acceleration.
	Solve problems using equations describing the relationship between distance, speed, acceleration, and time for uniformly accelerated motion in a straight line.
	Use vectors and differential calculus to describe motion in one and two dimensions.
Fluid mechanics	Explain the concept of hydrostatic pressure, transmission of pressure in a fluid, and Pascals law. Explain why pressure decreases with height in the atmosphere.
	Explain the principle of buoyancy and Archimedes' principle
	Describe the concept of viscosity
	Describe a wind field or other vector field in terms of translation, deformation, divergence, and vorticity.
	Describe and apply the concepts of stream function and velocity potential.
	Explain the relationship between streamlines and trajectories.
Heat transfer	Explain the physical basis of heat transfer via conduction, convection, and radiation.

Basic thermodynamics	Describe the kinetic theory of gases and explain the physical basis of temperature.
	Apply the fundamentals of thermodynamics to gaseous systems, including the gas laws for dry and moist air, the first and second laws of thermodynamics and Dalton's law.
	Explain the physical basis of sensible heat, specific heat, latent heat, vapour pressure, and saturation.
	Explain the physical basis of reversible and irreversible processes, entropy and enthalpy.
	Describe the phase changes of water within a gaseous system and their effects on other parts of the system.
Waves	Describe the properties of oscillations and waves and explain simple harmonic motion; solve problems using the relationship between speed, frequency and wavelength for waves
	Explain the difference between longitudinal and transverse waves
	Explain the fundamentals of wave motion, including the concepts of reflection, refraction, diffraction, interference 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 the Stefan Boltzmann law, and scattering, absorption and emission of radiation

3.4 Physical meteorology

Physical meteorology deals with the scientific explanation of fundamental atmospheric phenomena. It builds upon prior learning of physics, applying basic physical laws to explain the observed nature of the atmosphere. Concepts making up this section include the thermodynamic structure of the atmosphere, solar and terrestrial radiation, boundary-layer processes, cloud physics, and the principles of instrumentation and measurements. In some ways these concepts are building blocks which help understanding of larger-scale phenomena, but they are also directly applicable to solve many problems in meteorology.

Meteorologists shall be able to:

- Use their knowledge of atmospheric composition and radiative transfer to explain the structure of the atmosphere, global energy balance and the greenhouse effect, and common optical phenomena.
- Use the laws of thermodynamics to explain the stable stratification of the atmosphere, the effects of adiabatic and non-adiabatic processes, including the effects of water. Use a thermodynamic diagram to assess the properties and stability of the atmosphere.
- Summarise the micro-physical processes involved in formation of cloud, precipitation, and electrical phenomena and use a thermodynamic diagram to diagnose and predict these.
- Use knowledge of turbulence and surface fluxes to explain the structure and characteristics of atmospheric boundary layers, and the behaviour of contaminants.
- Select instruments to observe surface and upper-air atmospheric phenomena, considering their physical principles of operation, sources and characteristics of error and uncertainty, and the quality control practices in use.
- Use relevant remote sensing, earth- and space-based, to observe atmospheric and surface phenomena qualitatively and quantitively. Explain how radiation measurements are made, how they are turned into atmospheric data, and uses and limitations of these data.

The guidance in Table 6 should aid in the definition of instructional learning outcomes within modules of study. It is intended to be indicative of the range and type of knowledge needed to achieve the learning outcomes in physical meteorology, rather than being either exhaustive or limiting:

Table 6 - Suggested instructional outcomes in physical meteorology

Atmospheric composition, radiation and optical phenomena	
Atmospheric structure and composition	Summarise the characteristics of those atmospheric regions (troposphere, tropopause, stratosphere) of most relevance to meteorologists with reference to their major constituents, temperature, and moisture content.
	Summarise the composition of the atmosphere including trace gases, aerosols, mineral dust, volcanic ash, and pollutants, including the effects of these constituents.

Radiation in the atmosphere	Explain the effects of variance in the distribution of atmospheric constituents (including aerosols, water vapour, clouds, greenhouse gases, and reactive gases) and of surface conditions (moisture, vegetation, snow cover) on incoming and outgoing radiation.
Global energy balance	Explain the latitudinal and seasonal variations in climate due to the global radiational energy balance, variation in solar flux, and the orbital characteristics of the earth.
Optical phenomena	Explain the transparency of the atmosphere, the physics of common optical phenomena (for example: rainbows, haloes, coronas, sky colour, cloud colour), and describe the meteorological conditions that favour the occurrence of these phenomena
Thermodynamics and cloud physics	
Applied thermodynamics	Apply the laws of thermodynamics to solve basic problems based on an understanding the concept of an air parcel, including describing adiabatic and diabatic processes, dry and saturated adiabatic motions, and the associated conserved quantities.
Atmospheric moisture	Explain the physical basis for and applications of the common parameters used to represent the amount of moisture in the atmosphere. Describe how these quantities are measured and the relationships between them.
	Use knowledge of thermodynamics to describe the phase change processes of water, including the effects these phase changes have on a both a hypothetical air parcel and on larger-scale processes.
Atmospheric stability	Summarise the characteristics of statically stable, neutral, and unstable regions in terms of variation in density and behaviour of a perturbed parcel.
	Use knowledge of thermodynamics to describe and apply the concepts of conditional, latent, and potential/convective instability.
	Select the most relevant thermodynamic parameters to assess measures of stability in data, using knowledge of the physical basis of those parameters.
	Predict how the measures of static stability might change as a result of diabatic and adiabatic processes (e.g. insolation, latent heat release, inclined flow, etc)
Thermodynamic diagrams	Use a thermodynamic diagram to determine or calculate common parameters used to describe the thermodynamic state of the atmosphere, including stability, from a sounding.
	Infer information about atmospheric structure (such as presence of cloud and precipitation) and synoptic scale processes from thermodynamic diagrams.
Clouds and precipitation	Describe the microphysical processes leading to the formation, growth, and dissipation of atmospheric hydrometeors including both warm and cold cloud droplets and precipitation sized particles.
	Describe the macroscopic structure and essential dynamics of the main types of cold and warm clouds.
	Given an analysis of the synoptic and mesoscale conditions, predict the likelihood of the development of the various cloud types, precipitation types, dew, icing, frost, and the various types of fog. Explain how local conditions may aid or hinder development of these phenomena.
Electrical phenomena	Describe the mechanisms causing electrical phenomena to occur in the atmosphere and assess the likelihood of these phenomena in a given synoptic and mesoscale situation.
Boundary-layer meteorology and micrometeorology	

Turbulent processes	Describe how the nature of turbulent flows differ from laminar flows, the mechanisms for generation and dissipation of turbulence, and the role of viscosity in providing a lower boundary condition constraining boundary layer flows.
	Explain why statistical measures are used to describe turbulent flows, the common averaging schemes used, and the physical basis for decomposing flow variables into mean and fluctuating parts.
	Explain qualitatively how turbulent fluxes of mass, heat, moisture, and momentum arise and how these act to redistribute these quantities
	Predict the evolution of the boundary layer in terms of mass, heat, moisture, and momentum based on fluxes of these quantities being a function of the vertical distribution of their mean values.
Boundary layer energy exchanges	Describe the energy budget near the Earth's surface and the energy (thermal and kinetic) exchange processes with the surface layer.
	Describe the energy and mass budget at the top of cloudy and cloud-free boundary layers, including the role of turbulence, entrainment, and radiative transfer.
Boundary layer structure and variation	Use knowledge of turbulence, surface- and top of boundary layer-processes to explain the structure and diurnal variation of stable, neutral, and unstable boundary layers.
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). Predict the occurrence of these effects for a location in a given synoptic and mesoscale situation.
	Explain the origin, significance, and limitations of the Ekman spiral and the mixing-length hypothesis. Use the latter to estimate the vertical structure of the wind in the surface layer given a relevant observation.
Air contaminants	Based on knowledge of common contaminants affecting air quality, their sources and sinks, behaviour, and effects, predict how contaminants may be dispersed in light of meteorological conditions including stability, and how this may affect air quality and visibility.
In-situ observations and instrumentation	
In-situ 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.
	Describe the way cloud, visibility, and weather types are classified and observed, and the uses and limitations of this data.
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).
	Assess the utility of balloon- and aircraft-borne instruments in providing information for a given location given the flight characteristics and reporting frequency of these platforms.
Characteristics of instruments	Use knowledge of the characteristics of surface and upper-air instruments to select the best source of data to observe parameters or phenomena of interest.
Instrument errors and uncertainty	Use knowledge of the common sources of error and uncertainty in standard instruments and observing techniques to estimate the

	confidence in a particular measurement, including assessment of local effects affecting representativeness of an observation.
Use and limitation of observations	Describe the uses of conventional observations in monitoring both weather and climate and in making forecasts, and their limitations.
Global standards of instrumentation and collaboration	Explain the importance of national and international standards of measurement, and compliance with best practice for the accurate calibration of instruments.
	Describe the role of international collaboration in the making and sharing of observations, with emphasis on the WMO Integrated Global Observing System (WIGOS) component systems.
Remote Sensing	
These learning outcomes are intended to give a meteorologist the essential knowledge of common remote sensing systems, and the ability to intelligently use this data in a range of situations. Further learning will be required in order to use remote sensing data in the workplace. Courses built around BIP-M, especially those attracting students entering the forecasting profession, should consult the knowledge and skills frameworks for satellite and radar meteorology contained in WMO 1209 (World Meteorological Organization, 2019b) which build upon those given here.	
Principles of remote sensing	Use remote-sensed data from radar, satellites, and other systems together with in-situ observations, NWP, and guidance to synthesise an overall picture of the state of the atmosphere, and identify errors introduced by using a single data source in isolation.
	Select relevant remote-sensed data taking into account the characteristics of the different systems, the geographical area of interest, and the meteorological problem being considered.
	Choose display formats to maximise the benefits of remote-sensed data, including suitable projections and colour schemes, and animations.
Active sensing	Explain how active sensing systems such as radar, LIDAR, and SODAR are used to provide quantitative and qualitative data about atmospheric parameters (e.g. precipitation rate and type, wind speed and direction, cloud, humidity, temperature, turbulence and aerosol loading) and phenomena (e.g. thunderstorms, microbursts, tornadoes).
Passive sensing	Explain how passive sensing systems are used to provide digital data from received radiation (e.g. in the visible, infra-red, or microwave parts of the spectrum).
	Describe how data from passive sensors are used to derive information such as temperature, humidity, atmospheric composition, lightning, wave heights, and soil moisture.
Meteorological satellites	Describe the orbital characteristics of geostationary and low-earth orbit satellites used for meteorology, including the benefits, limitations, and applications of data derived from these platforms.
	Describe the characteristics, limitations, and applications of common channels available from satellite sensors, including visible, near infra-red, water vapour and infra-red.
	Explain the reasons for combining channels, including by creating RGB images, the applications of this imagery, and the advantages over single-channel imagery.
	Select single- or multiple-channel imagery to observe common features of interest including synoptic- and mesoscale weather systems and natural hazards.

Radar	Use knowledge of the physical principles of weather radar to explain limitations due to precipitation size, phase changes, and the attenuation effects of meteorological conditions and non-meteorological targets.
	Describe how radar data may be processed to mitigate attenuation, produce composite data from a network of radars, and create quantitative estimates of precipitation rate and type, wind, etc.
	Select the most relevant radar derived imagery to give supplement other forms of data in the given synoptic and mesoscale situation and the meteorological problem under consideration.

3.5 Dynamic meteorology

If meteorologists are to have insight into the evolution of the atmosphere and the ability to infer the consequences to that evolution of errors between models and observations, then a thorough understanding of the physics of atmospheric motions, including the interactions and feedbacks between features at different levels in the atmosphere, is needed (Carroll, 1997). The development of numerical models which are now the foundation of the majority of research and operational meteorology is entirely dependent on atmospheric dynamics. Thus, a study of basic dynamics and of numerical modelling is included as an important part of these learning outcomes.

Care must be taken by institutions to match the approach to teaching dynamics and numerical modelling to the needs of students: a mathematics-led approach will be common, and is more powerful when accompanied by practical application of dynamical ideas and NWP to real-world data.

Meteorologists shall be able to:

- Outline the application of the concepts of force, acceleration, and frames of reference to a physics of atmospheric dynamics as exemplified in the equations of motion.
- Apply conceptual models derived from the dynamic meteorology to explain and predict the evolution of the atmosphere in the area of interest.
- Use numerical model outputs to represent phenomena of interest based on knowledge of the characteristics of the modelling system, the spatial and temporal scales under consideration and the need to represent uncertainty.

The guidance in Table 7 should aid in the definition of instructional learning outcomes within modules of study. It is intended to be indicative of the range and type of knowledge needed to achieve the learning outcomes in dynamic meteorology, rather than being either exhaustive or limiting.

Table 7 - Suggested instructional outcomes in dynamic meteorology

Atmospheric dynamics	
Equations of motion	Use Newton's second law of motion and a consideration of the forces acting on a fluid parcel to outline the derivation of the horizontal and vertical equations of motion (momentum equations) in an inertial frame of reference.

	Explain the physical basis for, and the effects of, the additional terms representing the apparent forces acting in a rotating frame of reference.
	Explain the concept of geopotential and the reasons why geopotential height is used rather than geometric height.
	Explain why pressure is often used as the vertical coordinate in the primitive equations when considering synoptic scale atmospheric flows.
Scales of motion	Categorise atmospheric phenomena according to their length and time scales as micro-, meso-, or synoptic-scale.
	Use the concept of scale analysis to describe simplifications to the equations of motion appropriate for each of these scales of motion.
Balanced flows	Describe the simplifications made in deriving the main classes of balanced flows (including geostrophic, gradient, cyclostrophic, and inertial flows); describe the nature of these balanced flows and recognise real-world examples of them.
	Explain the concepts of thickness and thermal wind balance.
Hydrostatic equilibrium	List the simplifications made in deriving the hydrostatic equation, identify phenomena where the atmosphere is not in hydrostatic equilibrium, and explain how vertical motion can be determined under the hydrostatic assumption.
Ageostrophic motion	Use the equations of motion to explain the causes and implications of ageostrophic motions, including the effect of friction.
Vorticity and divergence	Explain the concepts of divergence and vorticity and describe the mechanisms for generating changes in these parameters.
	Describe the relationship between divergence in the horizontal wind and vertical motion.
Potential vorticity	Explain the concept of potential vorticity, including the properties of conservation and invertibility.
Quasi-geostrophic flow[24]	Explain the approximations and assumptions in the quasi-geostrophic system of equations and identify situations where these assumptions may not hold.
	Outline the derivation of the geopotential tendency and omega equations.
	Provide a physical interpretation of the forcing and response terms in these equations.
	Use the geopotential tendency equation qualitatively to diagnose the evolution of upper air features such as troughs and ridges.
	Use the omega equation qualitatively to diagnose the distribution of vertical motion associated with idealised jet streaks, troughs and ridges.
Waves in the atmosphere	Describe the physical and dynamical basis for, and characteristics of, wave motions of different scales in the atmosphere, including sound wave, gravity waves, and Rossby waves.
Baroclinic and barotropic instability	Describe wave growth through the baroclinic instability mechanism, with an emphasis on the development of mid-latitude cyclones.
	Describe how barotropic instability leads to growth of disturbances in horizontally sheared flows.
Numerical modelling[25]	
Data assimilation	Explain how information from observing networks and systems is obtained and prepared for use in an NWP model.

[24] Note: see related outcomes in weather systems and services on the *application* of QG theory.

[25] Note: suggested outcomes in the *application* of NWP are given in section 3.6

	Explain the principles behind objective analysis, data assimilation (including 3D Var and 4D Var, and hybrid schemes including the use of ensembles) and initialization.
NWP forecast models	Describe the components of an NWP model, including dynamical core, the parameterisation of physical processes, and boundary condition issues including the interaction with ocean or land surface models.
	Explain the difference between types of model (for example, spectral versus grid point and hydrostatic versus non hydrostatic models).
Strengths and weaknesses of NWP	Describe the key sources of uncertainty or error in atmospheric numerical models, and how these contribute to a limit of predictive skill.
	Describe the typical skill of global, regional, and convective-scale models in terms of the spatial and temporal scale of features likely to be forecast more or less well at a given lead-time.
Ensembles	Explain the principles and benefits of an ensemble modelling approach.
	Explain how the probability information is derived from ensembles, the effect of ensemble size, and the difficulty in forecasting extremes.
	Describe applications of ensemble model output across the range of temporal and spatial scales.
	Interpret a range of standard ensemble-derived outputs e.g. probability of exceeding thresholds plotted on maps, probability distribution functions, statistical data plotted on a meteogram, etc.
Monthly to seasonal predication	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 Kalman filtering or machine learning).
	Describe some of the applications driven by NWP output (for example, wave, hydrological, and crop yield models).

3.6 Weather systems and services

The learning outcomes in this section are intended to give students the ability to apply their knowledge of physical and dynamical meteorology to real-world weather systems, including the ability to analyse, diagnose, and forecast these using observational data and NWP. This will allow all meteorologists to make connections between their area of specialty and the effects of weather on people and society

The first two subsections cover respectively midlatitude/polar and tropical systems. Full coverage of the outcomes in one or the other of these sections is sufficient to satisfy the requirements of BIP-M. Similarly, the sub-section on mesoscale meteorology should be applied with regard to the area of responsibility and the mesoscale phenomena likely to be encountered in those areas. This is intended to give institutions or students who will work exclusively in either the tropics or mid-latitudes the flexibility to study only those outcomes relevant to their future careers and is aligned to the requirements of the WMO competency frameworks in this regard.

It is recommended that, even for courses with an exclusive mid-latitude focus or exclusive tropical focus, students are at least exposed to an introductory study of the other so that they understand the nature and language of global meteorology and as the basis for future study.

The final two subsections cover basic knowledge of how weather is observed, analysed, and forecast. However, achievement of these learning outcomes alone is insufficient to qualify a student as a weather forecaster, and that is not the intention. The WMO competency frameworks (World Meteorological Organization, 2019b), should be referred to by institutions having a requirement to educate and train weather forecasters.

Meteorologists shall be able to:

- Apply conceptual models of synoptic, mesoscale, and convective scale phenomena to integrate observed and forecast data into coherent structures, and to explain the formation, evolution, and characteristics of these phenomena using knowledge of physical and dynamical meteorology.
- Detect situations where real-world weather systems deviate from the conceptual models using knowledge of the models' limitations and suggest reasons for these deviations.
- Predict occurrences of extreme or hazardous weather conditions associated with synoptic, mesoscale, or convective scale phenomena, and monitor observed data to verify these predictions.
- Generate analyses and basic forecasts using observed and forecast real-time or historical data, including the monitoring and observing of the weather. Summarise the role of national met services and other providers using knowledge of the needs of society, impacts of severe weather, the products and services used to meet users' needs, and the processes used to manage quality.

The guidance in Table 8 should aid in the definition of instructional learning outcomes within modules of study. It is intended to be indicative of the range and type of knowledge needed to achieve the learning outcomes in weather systems and services, rather than being either exhaustive or limiting.

Table 8 - Suggested instructional outcomes in weather systems and services

Mid-latitude and polar synoptic-scale weather systems	
Weather systems	Describe the mean state and major patterns of atmospheric variability in mid-latitude and polar regions, and explain these dynamically and physically, including the effects of topography.
	Summarise the key differences between mid-latitude and polar weather systems and those in the tropics; explain the reasons for these differences.
Air masses	Explain how air masses are characterised and formed, and how their temperature, moisture, and stability characteristics are modified through movement away from their source regions.

	Apply the concepts of air mass characteristics and modification to predict the evolution of local weather, taking into account geographic, diurnal, and seasonal factors.
Fronts	Describe the structure and characteristics of synoptic scale cold, warm, occluded, and quasi-stationary fronts.
	Generate an analysis of frontal position and motion by selecting relevant information contained in observations (in-situ and remote sensed) and model output.
	Apply physical and dynamical reasoning to explain why observed fronts differ from idealised conceptual models.
	Describe the kinematic and dynamic processes leading to frontogenesis and frontolysis, and the processes causing upper-level frontogenesis.
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.
	Identify warm and cold conveyor belts associated with a mid-latitude depression in the system-relative frame of reference.
	Describe weaknesses of the basic cyclone model and recognise situations where deviations from the model or use of other models such as Shapiro-Keyser or hybrid models may be more applicable.
	Apply knowledge of dynamical processes to explain cyclogenesis and the factors contributing to explosive cyclogenesis.
Polar weather systems	Explain the characteristics, formation, and effects of polar weather systems, including phenomena such as katabatic winds, barrier winds, cold-air damming, and polar lows
Jet stream and jet streaks	Apply physical and dynamical reasoning to explain the development, structure and impact of jet streaks using a simple four quadrant model, and so explain the relationship between the jet stream and the development or persistence of mid-latitude flow patterns.
Synoptic-scale vertical motion[26]	Explain the role of vertical motion in the nature and evolution of synoptic scale weather systems.
	Diagnose synoptic-scale vertical motion in mid-latitude weather systems using an appropriate technique (for example, by considering ageostrophic motion, using the Petterssen or Sutcliffe development theory, or applying the QG omega equation in its traditional or Q-vector form), noting strengths and weaknesses of the technique employed.
Weather impacts	Describe the weather, with emphasis on extreme or hazardous conditions (e.g. windstorms, high precipitation accumulation, outbreaks of cold or heat) that might be associated with mid-latitude and polar weather systems
	Describe the likely impacts of such conditions, including the non-meteorological factors which need to be considered when assessing those impacts, and the advantages of taking an impact-based approach to communicating hazards.
Limitation of conceptual models	Analyse current and/or historical weather events to evaluate the extent to which theories and conceptual models of mid-latitude and polar weather systems resemble reality.

[26] Note: See related outcomes in dynamic meteorology on the *theoretical* aspects of some of these topics. The intent in this section is to promote links between the two sections through outcomes here on the *application* of theory to mid-latitude weather systems.

Tropical and sub-tropical weather systems	
General circulation in the tropics	Describe the mean state and major patterns of atmospheric variability in the tropics in terms of relevant variables, and how/why these differ from higher latitudes, using physical and dynamical reasoning.
Main tropical disturbances	Describe the main tropical disturbances and their temporal variability, including the Inter-tropical Convergence Zone (ITCZ), tropical waves, trade inversions, trade winds, tropical/sub-tropical jetstreams, 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.
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	Explain the development, structure, characteristics, and impacts of tropical cyclones using physical and dynamical reasoning.
	Describe the global system in place for forecasting and warning of tropical cyclones and their impacts.
Monsoons	Describe the nature, characteristics, and impacts of the major monsoon circulations.
	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, including its theoretical basis, with emphasis on the El Niño-Southern Oscillation (ENSO).
Weather impacts	Describe the weather, with emphasis on any extreme or hazardous conditions that might be associated with tropical weather systems (including tropical cyclones and monsoons).
	Describe the likely impacts of such conditions, including the non-meteorological factors which need to be considered when assessing those impacts, and the advantages of taking an impact-based approach to communicating hazards.
Limitation of conceptual models	Analyse current, recent, or historical weather events to assess the extent to which theories and conceptual models of tropical systems resemble reality.
Mesoscale weather systems	
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	Describe the mesoscale features associated with depressions (rain-bands, drylines, gust fronts, squall lines, etc.)
Gravity waves	Apply physical and dynamical reasoning to explain the structure and formation of mesoscale gravity waves.
Convective systems	Apply physical and dynamical reasoning to explain the structure, characteristics, and formation of isolated convection, 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 cyclones, etc.)
Extreme weather	Describe the weather, with emphasis on any extreme or hazardous conditions, associated with convective and mesoscale phenomena in the region of interest, and the likely impact of such conditions.
Limitation of conceptual models	Analyse recent and/or historical weather events to assess the extent to which theories and conceptual models of convective and mesoscale phenomena resemble reality.
Weather observation, analysis and diagnosis	
Weather monitoring and observation	Monitor the weather, including by making basic surface observations using instruments and visual assessments (including identifying cloud types, cloud amount, visibility, and weather type) and explain the reasons for such assessments.
	Describe the underlying physical causes of those weather phenomena that are observable from the Earth's surface.
Processing observations	Describe how and why observations are quality controlled, coded, and distributed.
Synoptic analysis and interpretation	Analyse and interpret synoptic charts and soundings plotted on thermodynamic diagrams.
	Describe the limitations of the observations used in synoptic analyses, and of the global and regional analyses produced by operational data assimilation systems.
Interpretation of radar data	Interpret common radar displays, including use of enhancements and animated imagery, to identify features associated with convective and mesoscale processes.
Interpretation of satellite imagery	Interpret satellite images, including use of common wavelengths, enhancements, and animated imagery, to identify cloud types and patterns, synoptic and mesoscale systems and other phenomena (e.g. fog, volcanic ash, dust, fires).
Integration of conventional and remote sensing data	Integrate remote sensing data with conventional observations to identify synoptic and mesoscale systems and diagnose the weather situation through relating features found in the individual data sources.
Weather forecasting	
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, communication, and verification.
Types of forecasting method	Explain the advantages and disadvantages of preparing forecasts based on persistence, climatology, extrapolation, empirical techniques, and NWP.
	Describe the role of the forecaster and how this has evolved alongside NWP and other innovations.
Conceptual models	Apply conceptual models in making short range forecasts and interpreting longer range forecasts, noting when real-world systems do not always conform to these models.
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.
	Uncertainty and impacts
Service delivery	
Service providers	Describe the role of National Meteorological and Hydrological Services in monitoring, forecasting, and communicating the weather and its impacts.
	Describe the role of other providers including private sector and international organisations.
Service provision	Communicate weather information to meet the needs of users with different levels of meteorological knowledge.
	Decide on whether to use deterministic or probabilistic approaches based on the timescales, uncertainty of the situation, and the needs of the users.
Key products and services	Describe 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.
	Describe the range of communication channels or media used to disseminate weather information, including potential weaknesses of these methods.
	Describe how the products and services are used by the public, governments, businesses, or other end users (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 with sufficient lead-times for action to be taken.
	Explain the importance of assessing the risk of hazardous weather, including interactions between weather and other natural hazards, and of issuing prompt and accurate warnings.
	Explain the benefits of issuing warnings based on the potential impacts of hazardous weather rather than purely on the intensity of the weather phenomena.
	Describe the potential impacts of hazardous weather on society.
Quality management systems[27]	Explain the role and importance of the quality management system (QMS) in service delivery.
	Describe basic techniques used within QMSs to assess the quality of products and services and to rectify quality problems.
Benefits and costs of meteorological services	Identify the economic and social impacts of meteorological services upon a country and their key user sectors.

[27] For further information on training which might be needed to help maintain a QMS, see (World Meteorological Organization, 2017)

3.7 Climate science and services

Climate change is the defining challenge of our time and is a subject that professional meteorologists of all types will find themselves addressing to a greater or lesser extent. In addition, the role of weather forecasters continues to expand in the provision of longer-range forecasts including monthly and seasonal predictions.

The learning outcomes in this section of the BIP-M are not intended to give learners all the knowledge and skills required to be a professional climatologist or climate researcher. The separate BIP-CS under preparation should be consulted when preparing courses aimed in this area. What these outcomes are intended to do is to ensure all meteorologists have a basic grounding in the earth's climate system, its variability, and climate change so they can speak credibly about climate, can use longer-range forecast products intelligently and communicate these to customers clearly.

Meteorologists shall be able to:

- Apply conceptual models of the earths global circulation, climate system, and the interactions between land, ocean, atmosphere, and cryosphere, to explain the mean state of the climate.
- Describe products and service based on climate information and their inherent uncertainty.
- Describe the observed variability in the climate system, the causes and the impacts of that variability. Use this knowledge to interpret products such as climate predictions and monthly to seasonal forecasts.
- Communicate the results of monthly, seasonal, and climate predictions based on an understanding of probability, uncertainty, predictability at different scales, and sensitivities of the audience.
- Explain the long-term changes occurring to the climate system, using knowledge on how these changes are observed, the drivers for change including feedbacks within the system, potential impacts of climate change, and adaptation and mitigation strategies.

The guidance in Table 9 should aid in the definition of instructional learning outcomes within modules of study. It is intended to be indicative of the range and type of knowledge needed to achieve the learning outcomes in weather systems and services, rather than being either exhaustive or limiting.

Table 9 - Suggested instructional in climate science and services

The earth-atmosphere system and the general circulation	
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 estimated and the uncertainty inherent in climate data; explain how climate data is analysed using statistics and how climate can be measured using remote sensing data.
Cycling of material	Describe the main features of the energy cycle, hydrological cycle, carbon cycle and nitrogen cycle.

Features of 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.
	Describe the global energy balance and the role of the atmosphere and oceans in balancing the radiative heating differences between the equator and the poles.
Regional and local climates	Assess the factors that determine regional and local climates.
Classification and description of climates	Describe the techniques used for classifying climates, the principles behind these techniques, and the meaning and use of standard statistical variables used to describe the climate.
Local climate	Describe the climatology and seasonal changes of the region of responsibility and the way climatological information can be obtained and displayed.
	Extract information from tables, etc Interpret basic climate data to formulate a description of a local climatology.
Key products and services	Describe the key products and services based on climate information that are provided to the public and other users.
	Describe the inherent uncertainties of such products and services and how they are used (for example, for decision making and managing risk).
Climate variability and climate change	
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 interaction	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

3.8 Professional learning outcomes

This section contains suggestions for learning outcomes to support the achievement of several of the overarching learning outcomes on page 25 and thus give meteorologists the base of professional skills they will need at the outset of their careers. The outcomes given below are not an exhaustive list of these, and institutions will be guided by national and regional human resource needs. Neither are the outcomes in this section mandatory, rather they are intended to act as a guide to some of the knowledge which might be needed now or in the future.

3.8.1 Management skills

Institutions are encouraged to provide opportunities for general business and management education as part of an overall meteorology programme. Suggestions of topics which may usefully be included in such courses are to be found in ETR-24 (World Meteorological Organization, 2018), published in 2018.

3.8.2 Communication skills

The communication of forecasts, impacts, or research findings to a range of audiences is included in several learning outcomes within the weather systems and climate sections of the BIP-M. The outcomes below expand upon those outcomes and provide the basis for learning and assessment of communication skills.

An individual achieving the learning outcomes for communication skills should be able to:

- Communicate meteorological information in the form of forecast policy discussions and handover briefings that are impacts focussed and utilise the forecast funnel.
- Identify the key weather and climate sensitivities of customers, and deliver tailored briefings that focus on impacts, uncertainties, confidence, and decision-making support.
- Prepare and provide media interviews and community outreach activities using plain language, talking points, documents, that communicate key messages.[28]
- Effectively engage customers and colleagues with suitable tone, body language, and empathy.
- Produce clear and concise written documents.

Table 10 - Suggested communication learning outcomes useful for operational meteorology roles

Impacts based weather briefings	
Summarise weather observations	Summarise significant past and present weather phenomena and their impacts.
Explain the current situation	Present a coherent narrative of past and present weather conditions, utilising the forecast funnel and atmospheric conceptual models
Summarise current products	Accurately and concisely summarise the content of current forecast policy, forecast products and warnings;

[28] Competencies for broadcasters and communicators are detailed in the Compendium of WMO Competencies (World Meteorological Organization, 2019b, pp. 21-25)

Deliver a prognosis	Summarise future hazardous and high impact weather, including required warnings;
	Present a coherent weather narrative of the future evolution of the atmosphere, utilising the forecast funnel and conceptual models;
	Discuss uncertainties, confidence, and alternative scenarios.
Delivery style	Be timely and concise.
	Use variety of tone/voice to engage colleagues.
	Employ active listening to ensure information has been effectively communicated, and staff are aware of their responsibilities
Customer briefings and customer decision support	
Assess customer needs	Acquire knowledge of customer needs through interactive dialogue.
	Research customer operations, including operational standards and procedures, weather and climate sensitivities and key decision thresholds.
Deliver tailored forecast briefings	Deliver an impacts-based weather briefing that supports customer decision making by employing knowledge of customer needs.
	Use language and conceptual models of weather as suited customer meteorological knowledge and timeliness of briefing.
	Deliver briefing using voice/tone and empathy to engage customers and meet their needs.
Add value to current products	Explain current forecast policy, warnings and forecasts to customers aligned with their needs.
	Explain forecast uncertainty and alternative scenarios based on an understanding of conceptual models and customer sensitivities.
Media briefings and community outreach	
Preparation	Identify the angle of the story being sought after/purpose of the outreach activity.
	Employ the inverted pyramid to focus the media briefing on the most important information/address the key concerns or interests of the target audience.
	Identify and prepare for tough questions, avoiding controversial topics where appropriate.
	Use or develop talking points to deliver a tailored media interview.
Language skills	Express meteorological terminology in plain language.
	Use tone/voice to express empathy and engage listeners.
Body language	Use eye contact and body language to express empathy and engage listeners.
Written skills	
Forecast and warning documents	Construct written products, including forecasts, warnings, briefings, and talking points
	Use technical or plain language to suit customer and colleague needs.
	Modify graphically and automatically generated text for clarity and accuracy.
Social media	Compose short impact-based posts using clear and concise plain language, images, and links to warnings and forecasts.
	Compose responses to comments, maintaining emphasis on weather narrative and avoiding controversial topics, adhering to NHMS values and code of conduct.

3.8.3 Information technology

The ability to extract and present meaningful, valuable, information from meteorological data has always been a core competence for meteorologists. In recent years the volumes of observational and forecast data produced have increased dramatically, and this presents challenges as well as opportunities. To exploit these data, many meteorologists now need skills in computer programming, data manipulation and visualisation, and a knowledge of the application of machine learning techniques.

The aims of these outcomes are that the student should be able to:

- Access, manipulate, and visualise meteorological data held in diverse formats.
- Use statistical tools to extract useful information from data.
- Understand how machine learning techniques are used to build simple predictive models of weather, climate, and their impacts.

Basic IT skills	Write simple shell scripts to automate processes and combine the functionality of several programs to complete a task.
	Use the command line to interact with the operating system, including running programs, managing files and processes.
	Use word processing, spreadsheet, and presentation software.
Programming	Write simple programs in a high-level programming language, including the use of variables, loops, flow-control, and input/output from files and the command line.
	Use language features such as functions to structure code in an efficient way through re-use.
	Use functionality provided by standard language libraries or imported from specialised libraries.
	Utilise arrays and array operators from standard mathematical libraries and explain the benefits of using array operators versus looping over datasets.
	Check for and handle errors and exceptions using standard language features.
	Utilise the software development life cycle to ensure requirements are captured, the code is well designed and implemented, documented, peer reviewed, and tested.
	Use version control system to maintain the integrity of the code and facilitate collaborative working.
Meteorological data	Describe and compare the common file formats for storing meteorological data, including text based and binary formats.
	Explain the importance of maintaining metadata and of understanding the provenance, validity, and units of data.
	Use standard libraries for loading, navigating, and manipulating structured meteorological data.
Visualisation	Plot data using chart types which clearly and unambiguously present the information in the data, including line charts, scatter plots, and histograms.
	Include titles, axes and data labels, and other standard features to ensure comprehension of the data.

	Take into account accessibility and the needs of users, for example by choosing perceptually uniform colour scales.
	Plot geospatial data using symbols, contours, or a colour mesh, using a suitable map projection, scale, and colour scale.
Statistical computing	Use programming tools such as mathematical libraries to calculate standard statistical parameters and analyses to summarise and compare data.
	Apply techniques including Fourier transforms and empirical orthogonal functions to reduce dimensionality of datasets and discover temporal signals in timeseries data.
Machine learning	Describe the steps which may be necessary to transform raw data in order to analyse it, including cleaning, transformation of units, normalisation, categorisation.
	Divide data into training and testing sets and explain the reasons for doing this.
	Explain supervised and unsupervised machine learning algorithms and choose an appropriate scheme for a given problem.
	Explain the principles behind supervised linear regression and classification schemes and apply these to data to produce simple predictive models.
	Describe how simple unsupervised learning algorithms such as k-nearest neighbours can be used to classify data.
	Describe how algorithms such as neural networks can be used to build non-linear models.
	Explain why the problems of bias and variance arise, strategies to minimise these, and possible implications for weather and climate forecasting applications.
	Describe potential ethical or legal issues arising from using machine learning techniques, including use of personal data, and not being able to explain the decisions made by the algorithms.

3.8.4 Research skills

Many undergraduate programmes include a capstone module during which students undertake some independent research which is often presented in the form of a dissertation. This experience is clearly a useful foundation for more thorough education in research methodologies during postgraduate study. For others, having the skill to carry out basic independent research can still prove to be useful through their careers, whether to aid their continuous professional development, preparation of case studies or training material.

Note: the following section remains a work in progress and will be more fully described prior to the full BIP-M consultation process in early 2021.

Formation of hypothesis

Experimental design

Paper writing

Peer review process

Scientific presentations

3.8.5 The historical and scientific context of meteorology

To aid in continuous learning through a meteorologist's career and to enable the integration of meteorology with related sciences, it is recommended that study of the topics listed below be incorporated into a programme of study:

1. The history of advances in science, technology, and service delivery that have contributed to the development of meteorology and its application.
2. Contemporary challenges in meteorology and emerging scientific and technological innovations which might influence

Appendix 1 – Review process

It is important to keep the Basic Instruction Packages and associated guidance up to date as the science, technology, and practice of meteorology evolve. Additionally, it is recognised that, despite the meticulous care taken in the preparation of this edition, some errors or omissions might be discovered after publication.

To meet these needs, a review process is defined which will allow both for corrections or amendments to be proposed by member states and for a more proactive assurance review to be held regularly.

The General Provisions section of the WMO Technical Regulations[29] includes, *inter alia*, the process to be followed in making changes to standard practices of which the Basic Instruction Packages form part. Thus, the following process will be followed to fit with those provisions:

1. The ETR office in the secretariat will seek and collate suggestions for amendments from member states.
2. Should evidence emerge of the need or desire to amend the BIP, ETR will task an expert team to consider and report on the changes.
3. Should no proposals for amendments be received from member states, then a regular review will be undertaken by an appointed expert team at five-yearly intervals to consider the necessity to update the BIP-M.
4. If changes are recommended by the expert team, the amended BIP will be consulted on widely and if supported put forward for approval by Congress.

The guidance in this volume does not form part of Technical Regulations, but corrections or amendments do need approval of Executive Council. The following process will be followed to facilitate necessary changes to this guidance:

1. ETR will collate suggestions for corrections or amendments from member states.
2. Maintain and publish a biannual update where changes are minor and non-contentious
3. Conduct a thorough review of the guidance alongside the five-yearly review of the BIP as described above.

[29] (World Meteorological Organization, 2019c)

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