**DRAFT**

**Guidelines for Developing and Implementing a Basic Instruction Plan for Climate Services (BIP-CS)**

**Table of Contents**

**Page**

[FOREWORD 3](#_heading=h.2s8eyo1)

[ACKNOWLEDGEMENTS 4](#_heading=h.3rdcrjn)

[1. INTRODUCTION 5](#_heading=h.lnxbz9)

[1.1 CLIMATE SERVICES, CLIMATE, CLIMATE SYSTEM AND CLIMATE SERVICES 5](#_heading=h.35nkun2)

[1.2 USES OF CLIMATE INFORMATION 8](#_heading=h.1ksv4uv)

[1.3 EVOLUTION OF THE EDUCATION AND TRAINING OF CLIMATOLOGISTS 9](#_heading=h.44sinio)

[1.4 PURPOSE OF BIP-CS 9](#_heading=h.2jxsxqh)

[1.4.1 BIP-CS in context 10](#_heading=h.30j0zll)

[1.4.2 BIP-CS and national needs 11](#_heading=h.2et92p0)

[1.4.3 Structure of BIP-CS 12](#_heading=h.tyjcwt)

[1.4.4 Curriculum design 13](#_heading=h.z337ya)

[1.4.5 Inclusive teaching and assessment 14](#_heading=h.ijfqm53tssj4)

[1.4.6 BIP-CS at later stages of a career 15](#_heading=h.3j2qqm3)

[2. CLIMATOLOGIST TASKS 16](#_heading=h.3hb3mf70tsxo)

[2.1 CREATING AND MANAGING CLIMATE DATA SETS 16](#_heading=h.r6ga25jv7flp)

[2.1.1 Observations 16](#_heading=h.r8uok5z5qndf)

[2.1.2 Data processing 17](#_heading=h.7hmno911h5tu)

[2.2 DERIVING RETROSPECTIVE PRODUCTS FROM CLIMATE DATA 18](#_heading=h.r2ov7tgheehj)

[2.3 CREATING AND/OR INTERPRETING CLIMATE PREDICTIONS, PROJECTIONS, OUTLOOKS AND MODEL OUTPUT 20](#_heading=h.97wdaxesez8w)

[2.4 ENSURING THE QUALITY OF CLIMATE INFORMATION AND SERVICES 21](#_heading=h.vg063lgqupqb)

[2.5 COMMUNICATING CLIMATOLOGICAL INFORMATION TO USERS 22](#_heading=h.1y810tw)

[3. COMPETENCIES AND LEARNING OUTCOMES 24](#_heading=h.yxp5mbncor7f)

[3.1 WMO TOP-LEVEL COMPETENCIES 24](#_heading=h.4i7ojhp)

[3.2 COMPETENCIES AND LEARNING OUTCOMES DEFINED BY WMO 24](#_heading=h.1pxezwc)

[3.3 COMPETENCIES DEFINED BY OTHERS 27](#_heading=h.49x2ik5)

[3.4 ASSESSMENT 28](#_heading=h.32hioqz)

[4. EDUCATION AND TRAINING TO ACHIEVE COMPETENCIES 29](#_heading=h.1hmsyys)

[4.1 ACADEMIA 29](#_heading=h.1v1yuxt)

[4.2 TARGETED TRAINING 30](#_heading=h.3tbugp1)

[4.3 WMO TRAINING 30](#_heading=h.28h4qwu)

[5. BASIC INSTRUCTION PACKAGE FOR CLIMATE SERVICES 33](#_heading=h.nmf14n)

[5.1 PRE-REQUISITE MATHEMATICS AND PHYSICS 33](#_heading=h.37m2jsg)

[5.2 TOPICS IN ATMOSPHERIC SCIENCE 35](#_heading=h.2lwamvv)

[5.3 TOPICS IN CLIMATE SERVICES 46](#_heading=h.4k668n3)

[6. REFERENCES 51](#_heading=h.2zbgiuw)

[Annex 1. Fields of activity pertaining to the use of climate information, based on actual requests for information from a climate service centre 53](#_heading=h.1egqt2p)

# FOREWORD

The Basic Instruction Package for Climate Services (BIP-CS) establishes a common understanding of the abilities required for individuals to be recognized as climatologists. It is intended that the resulting guidance will allow NMHSs to achieve consistency in the classification of their climatologists and compliance with qualification standards as set out in the *Technical Regulations* ([WMO-No. 49](https://library.wmo.int/?lvl=notice_display&id=14073)), Volume I. On completion of the BIP-CS, a climatologist will have demonstrated the ability to apply, develop and communicate climate science professionally for the benefit of society.

Competency frameworks are established to describe the critical job skills and knowledge required of operational personnel. By doing so they provide assessment criteria regarding readiness to perform service delivery tasks and help training providers offer impactful learning opportunities. WMO has developed and implemented frameworks for many service delivery areas that are consistent with good practices in the use of competencies in other disciplines and industries and supports good quality management practices.

Following the philosophy and approach of the BIP for meteorologists and meteorological technicians (WMO-No. 1083), BIP-CS presents learning outcomes and various methods of attaining the education that underpins the competencies. It explicitly provides latitude for institutions, WMO Members and employers to tailor learning outcomes to the nature of the course of study, national or local needs.

Because climatology is based on atmospheric science, many of the mathematics and science pre-requisites, competencies and learning outcomes for climatologists are the same as those for meteorologists. Therefore, most (but not all) of the learning outcomes for meteorologists are repeated in BIP-CS. Additional outcomes are presented that are specific to climatology.

Secretary-General

Celeste Saulo

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**1. INTRODUCTION**

1.1 **CLIMATOLOGY, CLIMATE, CLIMATE SYSTEM AND CLIMATE SERVICES**

As defined in *Guide to Climatological Practices* (WMO-No. 100, 4th ed.), climatology, which is sometimes referred to as climate science, is the study of the earth’s atmosphere, weather patterns and interactions between the atmosphere and the hydrosphere, cryosphere, lithosphere and biosphere over time. Climate is the set of weather conditions observed at a particular location or region over typically decades or longer. It considers both climatic variability and change. In general climatic variability is connected with variations in the state of the atmospheric and ocean circulation and land surface properties at the intraseasonal to interdecadal timescales. Climate change, in contrast, refers to a systematic change in the statistical properties of climate, such as mean and variance, over prolonged periods like decades to centuries. Climatology also includes the influences of these descriptions on a variety of activities including, but far from limited to, water resources, human health, safety and welfare. The climate system is a complex and interactive system consisting of the atmosphere, land surface, snow and ice, oceans and other bodies of water, and living organisms described by the [Global Climate Observing System (GCOS) Essential Climate Variables (ECVs)](https://gcos.wmo.int/en/essential-climate-variables) in the *2022 GCOS Implementation Plan* ([GCOS-No. 244](https://library.wmo.int/index.php?lvl=notice_display&id=22134)) and later versions. Climate services provide climate information to help individuals and organisations make climate smart decisions ([GFCS](https://gfcs.wmo.int/what-are-climate-services)).

Climatology today encompasses the relationships between climate and most aspects of human activity It also includes the important element of climate services It concerns past, present and future environmental conditions that affect plant and animal life on a variety of space and time scales. The current state of climatology has evolved from simple climate descriptions by ancient Greeks to more detailed descriptions associated with advances in instrumentation and in the understanding of the atmosphere and oceans by the middle of the last century. By the end of the 19th century the global community recognized the importance of climate and society. A more complete history of climatology is given in WMO-No. 100 4th ed.

1.1.1 **Overview of Climate Information**

Climate information includes data, summaries, tables, graphs, maps, reports and analyses. Products are defined in the [*Implementation Plan of the Global Framework for Climate Services*](https://library.wmo.int/index.php?lvl=notice_display&id=20047) (WMO, 2014) as derived syntheses of climate data. They combine climate data with climate knowledge to add value. Spatial distributions may be illustrated on maps. More complex products, such as climate atlases or analyses, may combine several kinds of visualisation with descriptive text. There may also be databases with software tools that allow online customers to produce statistics and visualisations according to their own needs. Climate information may be retrospective, current (climate monitoring), predicted from initial conditions or projected using scenarios. Historically, products were produced in hard copy; now, many are produced electronically and could be available online.

Another class of products is climate watches. The watches are advisories that serve as a mechanism to heighten awareness in the user community that a significant climate anomaly exists or might develop and that preparedness measures should be initiated. Thus, climate watches support Early Warning Systems (EWSs).

The value of historical and statistical climatological data tables can usually be improved by the inclusion of a supporting text that helps the user to interpret the data and emphasises the more important climatological elements. All products should include sufficient information and data regarding the location and elevation of the observing stations, the homogeneity of the data from all stations, the periods of record used, the statistical or analytical procedures employed and a quality assessment. In lieu of all this information and data being specified in the products, users should be notified where or how it can be obtained.

1.1.2 **Types of Climate Products**

Climate products may be broadly categorised in several ways: periodic or occasional, standard or specialised, and public or private. A periodical climatological publication is one that is scheduled for preparation and publication on a routine basis over set time intervals. Most climatological data periodicals are issued on either a monthly or annual basis. Some services, however, also publish periodicals at different intervals such as a week or a season. Weekly or monthly publications are issued immediately after the close of the period in question and usually contain recent data that have not necessarily undergone complete quality control procedures. Quarterly or seasonal data periodicals are often issued to disseminate summarised seasonal data such as winter snowfall, growing-season precipitation, summer cooling degree-days and winter heating degree-days.

Unlike climate data periodicals, which are produced to a schedule, occasional publications are produced as the need arises. They are in a form that will satisfy many users for a considerable time, so they will not need frequent updating. They are designed to summarise or explain unusual events, such as extreme weather, and to describe or update an important predicted event such as a strong El Niño. The content and format of a specific occasional publication must reflect the interests and needs of the users for whom it is published.

Standard products can be used by a wide range of users and should be locally developed to meet the needs of groups of users. Specialised products are those that are developed specifically for an individual user or sector. The use of the product usually dictates the types of analysis and data transformation that need to be performed and the methods used to deliver the product.

Public climate products are those which are readily and freely available to anyone who wishes to obtain them, whereas private climate products are typically developed for, and purchased by, an individual user or sector. Public climate products are typically periodical and standard, while private climate products are often occasional and specialised.

Most NMHSs issue monthly bulletins containing data from a selection of stations within particular areas or the country as a whole. While most monthly bulletins contain only surface climatological data, some NMHSs include a selection of basic data from upper-air stations or issue separate monthly bulletins containing upper-air data. Some of the most useful national products are those containing simple tables of monthly and annual values of mean daily temperature and total precipitation. Such tables are prepared by NMHSs and are made available either in a manuscript or as is now common, electronically. Some NMHSs include historical climatological data series in yearbooks or other annual bulletins. These publications often provide historic context for contemporary observations by including climate rankings. Monographs on the climate of a country or area are valuable to a wide range of users and should be published and updated periodically and made available electronically for ease of access and exchange. According to [Meteorological Service for International. Air Navigation. Annex 3](https://www.icao.int/airnavigation/IMP/Documents/Annex%203%20-%2075.pdf#search=Meteorological%20Service%20for%20International%2E%20Air%20Navigation%2E%20Annex%203) (ICAO, 2010), each Member should prepare aerodrome climatological tables and summaries for each regular and alternate international aerodrome within its territory.

Long-term, continuous and homogeneous series of data are of great value for comparative climatological studies and research on climatic fluctuations, trends and changes. Several NMHSs have published such series for a selection of stations ([Centennial Stations](https://public.wmo.int/en/our-mandate/what-we-do/observations/centennial-observing-stations)) where observational practices and the environmental surroundings have remained essentially unchanged over long periods of time. The collection of maps in atlas format is another valuable national product.

National products often include climate indices. Indices are widely used to characterise features of the climate for climate monitoring and prediction and also to detect climate change. They may apply to individual climatological stations or describe some aspect of the climate of an area. Indices usually combine several elements into characteristics of, for example, droughts, continentality, heating degree-days, large-scale circulation patterns and teleconnections.

Climate outlooks are forecasts of the values of climate elements averaged or accumulated over timescales of about one month to several years. Seasonal forecasts are more commonly used and can be generally issued with monthly frequency. Alternatively, some forecasts are issued only for specific seasons or at other predefined intervals.

*Regional Climate Outlook Forums* [RCOFs ()] operatively produce consensus-based climate outlooks using input (climate predictions) from national, regional and international climate experts. By bringing together countries with similar climatological characteristics, the Forums ensure consistency in access to, and interpretation of, climate information. Additionally, through interaction with users in the key economic sectors of each region, extension agencies and policymakers, the Forums assess the likely implications of the outlooks for the most pertinent socio-economic sectors in a given region and explore the ways these outlooks could be used by them.

1.1.3 **Monitoring Products: National, Regional and Global**

Owing to the impact of varying and changing climatic conditions on society and ecosystems, countries around the world have created a variety of climate monitoring products at different spatial and temporal scales. National climate monitoring products (NCMPs) are products that specifically summarise climatic conditions at a national scale and show how current conditions compare with those in the past. Guidance on creating products is given in *WMO Guidelines on Generating a Defined Set of National Climate Monitoring Products* ([WMO-No. 1204](https://library.wmo.int/?lvl=notice_display&id=20166)).

Regional products include climate information spanning more than one country or geopolitical area. These typically require contributions from several NMHSs or individuals with expertise spanning the region. Regional products are an effective means of presenting a coherent set of information generated from adjacent but distinct NHMS and countries. WMO issues annual regional updates on the State of the Climate and on climate change indicators to political leaders and decision makers. In order to provide such regional-scale products and services WMO has established [Regional Climate Centres (RCCs)](https://public.wmo.int/en/our-mandate/climate/regional-climate-centres) in all of its regions, including cross-regional RCCs such as for the Arctic.

Global products include climate information spanning the majority of or all the globe. These typically require contributions from numerous NMHSs and many individuals with expertise spanning the national and regional boundaries. Global products are an effective means of presenting a comprehensive set of information generated from many NHMS and countries. WMO issues annual global updates on the State of the Climate and on climate change indicators to political leaders and decision makers. WMO also collaborates with its Members to produce global seasonal outlooks such as the El Niño/La Niña Update and the Global Seasonal Climate Update (GSCU). [WMO Lead Centre for Annual-to-Decadal Climate Prediction](https://hadleyserver.metoffice.gov.uk/wmolc/) collects and provides hindcasts, forecasts and verification data from a number of contributing centres worldwide. Periodicals sponsored by WMO include data from Members. Examples are *Monthly Climatic Data for the World* (data from all CLIMAT stations), *World Weather Records* (single-station, historical, monthly and annual values of station pressure, sea-level pressure, temperature and precipitation), and *Marine Climatological Summaries* (monthly, annual and decadal climatological statistics and charts for the oceans). Climate information by sectors should be included in a manual or other publication that describes details about the information and its uses so that users can simply apply the information to design and implement their projects.

In operational numerical weather analysis and prediction, “analysis” refers to the process of creating an internally consistent representation of the environment on a four-dimensional grid. The time-critical nature of weather prediction means that the initialising analysis must usually begin before all observations are available. Reanalysis uses the same process (and often the same systems), but as it is done weeks or even years later, it is able to use a more complete set of observations. The output is an integrated historical record of the state of the atmospheric environment for which all the data have been processed in the same manner. [Reanalyses.org](https://reanalyses.org/) is a collaboration of the [Atmospheric Circulation Reconstructions over the Earth initiative](http://www.met-acre.org/), the [Global Climate Observing System (GCOS) Working Group on Surface Pressure](http://www.esrl.noaa.gov/psd/gcos_wgsp/), and the [World Climate Research Programme](http://www.wcrp-climate.org/), and their partners. It provides overviews and the current status of global and regional atmospheric, oceanographic and observation reanalyses.

Gridded climate data facilitate the spatial analysis of climate variables and the static or dynamic visualisation of climate patterns and trends. The products are values of surface or upper-air climate variables or indices, arranged on a regular grid with coverage ranging from local to national to regional to global. In addition to the scale of coverage, the resolution of gridded data can vary from as little as a few square metres in the case of sub-urban data sets to 200-300 km as found in global scale data sets. Similarly, temporal resolution may vary from the sub-hourly to annual timescale. Some data sets are updated regularly or periodically, while some are static or contain a time series of climate variables.

While some of the observed gridded climate data sets are based purely on surface observations, others are constructed from reanalysis systems and blended data sets including observations from both surface and satellite-based platforms. Some observation-based gridded climate data sets use values interpolated from stations for which data has been adjusted and homogenised.

## 1.2 USES OF CLIMATE INFORMATION

Climate information is used in almost all human sectors such as construction, transportation, energy, agriculture, insurance, water supply, utility, engineering, health, legal and economic development. Appendix I lists examples of the variety of actual fields of activity for which users requested climate information from a climate service centre.

While extensive, the list is certainly not all-inclusive. Many requests for climatic information concern historical data therefore necessitating a system of data storage and extraction as well as assessing the quality of the data. Other requests involving planning for future environmental conditions necessitate climate monitoring to assess current climate variability and change as well as climate modelling to forecast weather and project future scenarios. Fulfilling requests for climate information requires expertise in not only atmospheric science, but also in data management and data analyses. Ancillary knowledge of disciplines germane to the requestor’s field of inquiry, as well as communication skills, allow climate service personnel to provide and explain climate information in a meaningful manner to a user who may not be knowledgeable about climate or climate products.

The following principles embody an effective delivery of climate-related services:

* User engagement and feedback are essential for designing and delivering effective services;
* Sharing best practices leads to effective and efficient service design and implementation;
* Partnerships with other international and regional organisations also engaged in delivering services are essential for maximising the use of weather-, climate-, water- and environment-related information in the decision-making process;
* Partnership with social sciences, communication and marketing personnel are important for tailoring the services;
* The concepts and best practices of service delivery are applied to all WMO activities and accepted by the entire WMO.

## 1.3 EVOLUTION OF THE EDUCATION AND TRAINING OF CLIMATOLOGISTS

Since the early 1900s, the training of climatologists has mirrored the development and expansion of climate science. Until the Second World War, climatologists mainly compiled statistics about weather conditions for regions of interest such as the average temperatures, extremes of rainfall, etc. Most climatologists were not concerned with the planet as a whole but only with regional problems. The people who needed climate information were farmers planning their crops and engineers designing structures. A climatologist was somebody who described climate, mainly at ground level, where the crops and structures were found. Training of climatologists was minimal. Knowledge of how to calculate basic statistics such as averages was all that was needed.

When climatologists did try to go beyond statistics to explanations, they would explain the temperature and precipitation of a region in mostly qualitative geographical terms such as the sunlight at that particular latitude, the prevailing winds as modified by mountain ranges or ocean currents. The geographical way of explaining regional climates was an essentially static exercise loosely based on elementary physics. Attempts to make physical models of the simplest regular features of the planet's atmosphere (for example, the trade winds) failed to produce any plausible explanation for how the winds circulated, let alone for variations in the circulation.

The careers of climatologists rested on the conviction that statistics of the past could reliably describe future conditions. Textbooks defined "climate" as the long-term average of weather over time, an intrinsically static concept. As stated by Lamb (1959), "Authoritative works on the climates of various regions were written without allusion to the possibility of change, sometimes without mention of the period to which the quoted observations referred."

The sciences of meteorology and geophysics rapidly expanded after the Second World War with the advent of new instrumentation, ample funding and an environment of scientific curiosity. Concurrently with the increased understanding of the atmosphere was the rapid expansion and professionalism of climatology. Since climatology was considered to be a subdiscipline of meteorology, training of climatologists was the same as for meteorologists. Any additional training that was needed was usually through in-house or short-term specialised courses or through in-house mentoring.

By the early 1990s questions regarding climate change rose to the forefront of scientific inquiry. It was recognized that climate was not a stationary process and also that the impact of climate, climate variability and climate change was consequential to most human activity. Climatology expanded to the study of the interdisciplinary climate system. Climatologists therefore needed to be educated and trained not only in atmospheric science, but also in other disciplines such as biological, marine, chemical, computer and other environmental sciences. The interdisciplinary and expanded nature of climatology and climate services also required training to facilitate communication among the disciplines and users of climate information. As climate science grows and becomes more sophisticated, the education and training needed by climatologists also grows and becomes more sophisticated.

1.4 **PURPOSE OF BIP-CS**

The Basic Instruction Package for Climate Services (hereafter referred to as BIP-CS) defines the essential knowledge that all professional climatologists must acquire and how they need to be able to think and act using that knowledge. As such it must reflect the role of climatologists of all types, whether they are developing the science or practice of Climate Services or applying that science or practice to the benefit of society.

Professionals in any field are identified not necessarily by what they do, but by *why* they do it. They take certain actions by having deliberated on the matter and having made an informed decision based on their knowledge of the domain and the critical-thinking skills they have developed.[[1]](#footnote-1) For this reason, BIP-CS mandates that, in addition to climate science, students learn an array of applied professional knowledge focusing on higher-order cognitive skills rather than on specifying declarative knowledge to be covered in a syllabus.

BIP-CS defines the educational requirements of those studying to become a climatologist. On completion of the Basic Instruction Package (BIP), a climatologist will have demonstrated – through the study and application of the atmospheric and environmental sciences – the ability to apply, develop and communicate professionally for the benefit of society.

The competencies and skills required of climatologists working in diverse fields, including research, consultancy and data management, will often be highly localised to a certain region, country, service, etc. These competencies and skills will evolve quickly as science, technology and service provision change. The role of BIP-CS is to provide the underlying knowledge and skills common to all climatologists. BIP-CS should be used as a platform for developing the necessary skills and competencies for specific roles and for continued learning throughout a climatologist’s career.

BIP-CS follows the rationale and approach of *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No, 1083, part 1) and is focused on specifying the learning outcomes required by climatologists of all types, including underlying knowledge and skills common to the WMO competency frameworks. At the same time, it explicitly provides latitude for institutions, WMO Members and employers to tailor learning outcomes to the nature of the course of study or national needs. The core of the BIP is a system based on learning outcomes – in other words, a system in which the learner’s attainment is central. It provides the essence of what all climatologists must be able to do in a set of overarching learning outcomes while making it explicit that the role of the more detailed outcomes is to guide rather than to restrict institutions. WMO-No. 1083, part I, gives an extensive and detailed discussion of the learning outcome approach.

### 1.4.1 BIP-CS in context

Much work has been done to define the role of job competencies and competency frameworks, notably in aviation forecasting and observing, other forecasting, climate services, instrumentation and observing. The community has also started to develop skills frameworks such as in satellite and radar meteorology. WMO has published these in a *Compendium of WMO Competency Frameworks* ([WMO-No. 1209](https://library.wmo.int/index.php?lvl=notice_display&id=21607)).

It is the acquisition of skills and competencies, either as described in the competency frameworks or as defined by employers or training institutions that mark somebody as being a competent professional. Achieving the learning outcomes as specified in BIP-CS is a prerequisite to gaining workplace competence. These outcomes do not, however, define job competencies and are thus insufficient by themselves to prepare someone to do a particular job.

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

Institutions and employers must define an overall set of learning outcomes that meet national needs, using the BIP-CS as the foundation. WMO Members are encouraged to work with educational institutions to ensure education programmes are designed with the future employability of students and the human resources needs of NMHSs in mind by considering the need to include the application of the science as described in the competency frameworks.

The key aims of this BIP-CS are:

* To place the BIP in the context of an overall framework for education and training, encompassing educational foundations, skills and competency frameworks;
* To ensure the BIP meets the needs of diverse and evolving job roles and provides clarity and guidance on how to apply BIP to these roles, with standard skill and competency frameworks being central for many of them;
* To meet the needs of the entire global climatological community, regardless of size or level of development. In particular to remove barriers to the education and training of climatologists, who are vital to the delivery of services to key sectors of the economy and government;
* To be flexible enough to meet future needs in a rapidly evolving world;
* To maintain the intellectual rigour of the BIP so that it will continue to offer an attractive option for those wanting a grounding in a numerate, physically based, Earth-science subject;
* To minimise the work needed to validate or change existing programmes while clearly highlighting the necessary changes.

To ensure that BIP-CS is not misinterpreted as being made up of a series of related but disconnected topics, a set of overarching learning outcomes has been developed that summarise the demonstrable abilities of climatologists. Overarching outcomes are the desired end; the means to achieve them should be the study and assessment of the educational outcomes for climatology and Climate Services . They are intended to provide the “glue” that connects the educational learning outcomes and to encourage holistic education and training programmes in which interconnections between the various components are made explicit and the application of our science to solving real-world problems is central. The approach is to:

* Provide specific information on the knowledge and thinking skills required of climatologists;
* Give a range of methods for teaching and assessing the learning outcomes so that the document is not inadvertently prescriptive;
* Describe alternative approaches to meeting the learning, such as through the WMO Global Campus, which provides a platform and reference material.

This publication cannot, and does not attempt to, define the detailed skills and competencies needed in particular branches of professional practice, such as data management, consulting and research. It is expected that additional and more specific education and training is needed beyond or alongside BIPs for somebody to be able to take up a particular professional role.

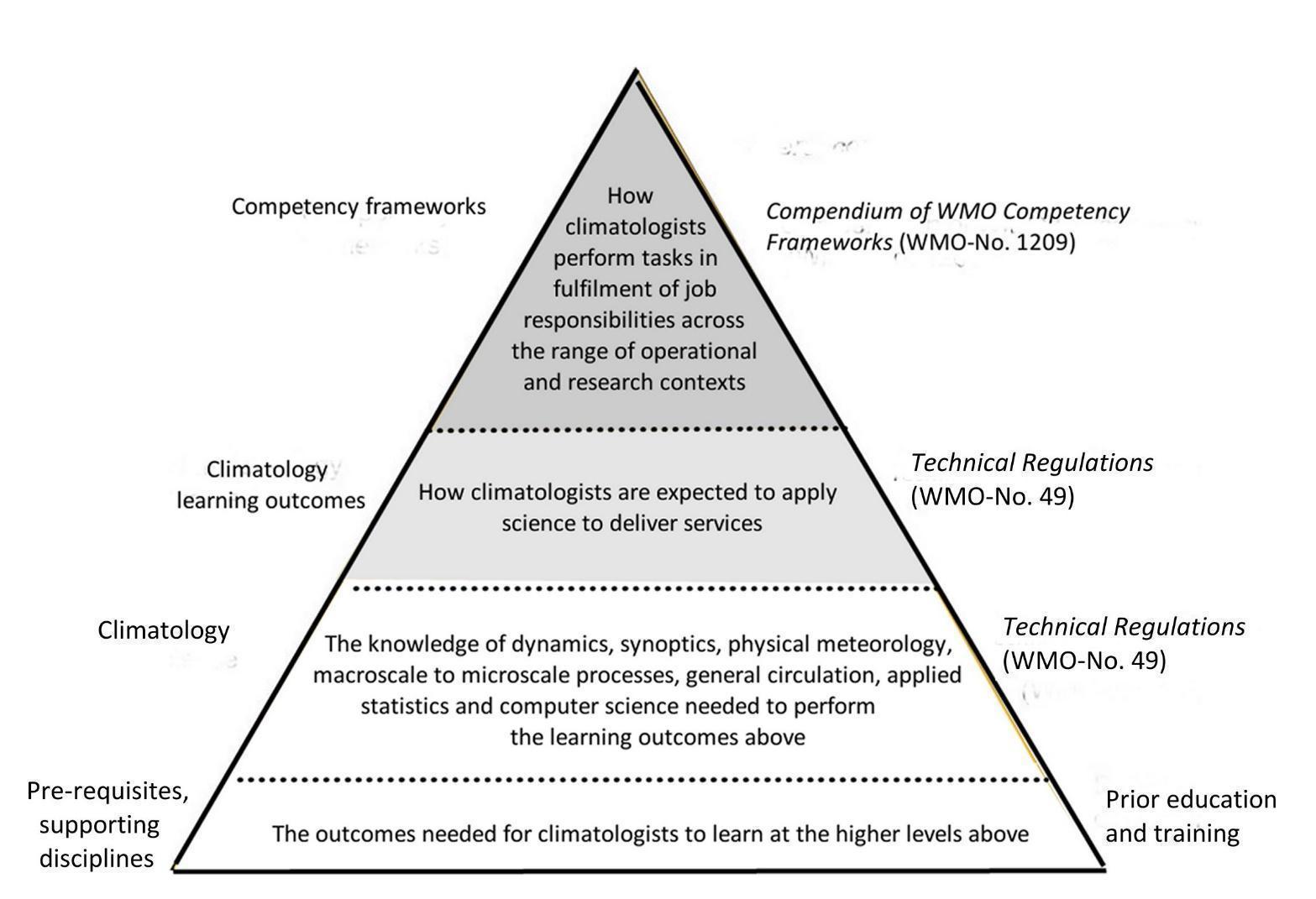
### 1.4.2 BIP-CS and national needs

The application of the learning outcomes to building a programme of study, including restating the fact that how outcomes are achieved, is a decision that should be made by institutions and individual instructors based on their specific national or regional needs. The BIP provides guidance to the NMHSs in establishing their personnel classifications and educational programmes to bring them in line with international standards. This structure allows for a spectrum of implementations of BIPs. For example, BIP-CS may take highly mathematical or theoretical approaches geared towards research careers, or it may take more qualitative but still rigorous approaches that meet the needs of NMHSs to have people who can apply Climate Services to support customers in a consultation setting. Section 1.4.4 briefly explains a process that can be used to map BIPs into a curriculum suited to national needs.

### 1.4.3 Structure of BIP-CS

The hierarchy of outcomes is presented in Figure 1. At the top of the hierarchy sit the competency frameworks as defined in [WMO-No. 1209](https://library.wmo.int/index.php?lvl=notice_display&id=21607). The *Guide to Competency* ([WMO-No. 1205](https://library.wmo.int/?lvl=notice_display&id=20181)) describes more fully the relationships between the competencies required for a given job role and qualifications required to enter a profession. The competency frameworks should be the primary guide to assess whether an individual is competent for any given role. *Guidelines for the Assessment of Competencies for Provision of Climate Services* ([WMO-No. 1285](https://library.wmo.int/index.php?lvl=more_results&autolevel1=1)) aids in the implementation of the WMO competency frameworks for climate services.

Although the learning outcomes are presented in several distinct sections, there are connections within and among the sections. It is therefore important to bear in mind that the division of learning outcomes into distinct sections does not imply that the outcomes should be taught in isolation. Cross-disciplinary thinking should be encouraged and may be explicitly included in curricula.



**Figure 1. A hierarchy of education and training for climatologists**

### 1.4.4 Curriculum design

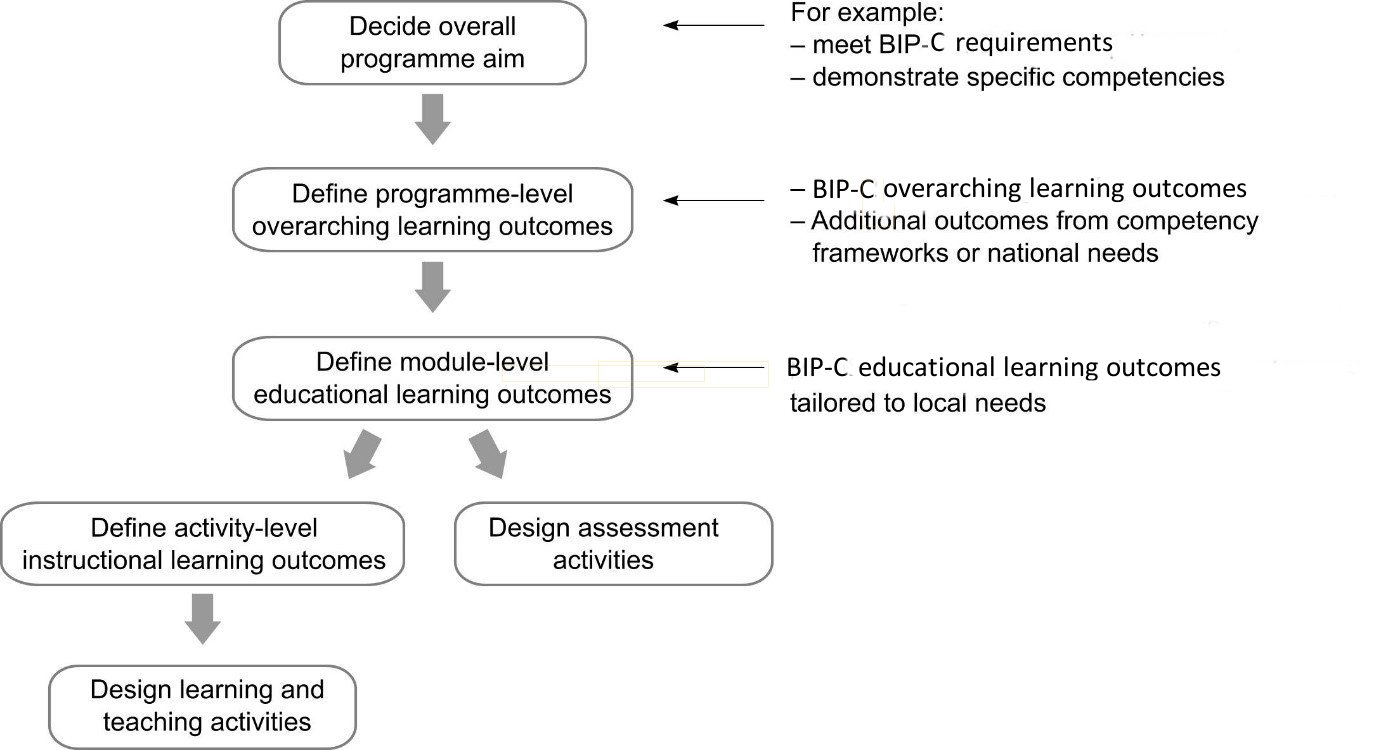
Institutions must define their own detailed outcomes at the level of the programme, modules and learning/assessment activities. They should use BIP-CS as one of the bases for doing so, but outcomes should be tailored to regional, national, and local needs.

Whether developing new programmes or reviewing existing ones, institutions should adopt a systematic approach to designing their curricula, such as the approach set out in Figure 2. This is to ensure that each programme meets the requirements of BIP-CS and enables prospective students and their future employers to understand clearly how the programme will benefit them. A holistic, systematic approach to curriculum design should also ensure that the connections and interdependencies between the components are made explicit and that activities are designed that utilise those connections. This will give students an overall picture of how the weather and climate system works and how NMHSs and other providers of weather and climate services contribute to society.

Note that a feedback loop is included in Figure 2 so that the programme can be monitored and possibly improved. The loop also should be used to modify the learning objectives when, for example, agency priorities change, advances in science and technology render some of the education and training obsolete, duties and responsibilities of the climatologist change, or the needs and expectations of the user community change.

The present guide does not provide the detailed module-level instructional outcomes that include the detailed guidance needed by instructors to develop instructional materials and assessments. That is because such outcomes are dependent on local needs, national educational practices and instructional approaches. This detailed design of learning and assessment activities is vitally important and must be a deliberate act of design taking advantage of evidence-based teaching and assessment practice, educational technologies, etc.

Given the wide range of programme modalities and aims, as well as the wide range of prior education of students, BIP-CS does not define a recommended programme duration. As has been stated already, it is the achievement of the outcomes that mark a person as a climatologist, not the fact the person has spent a certain amount of time carrying out the learning and assessment activities.



**Figure 2. Mapping BIP-CS to programme**

### 1.4.5 Inclusive teaching and assessment

Objective 5.3 of the *WMO Strategic Plan 2024–2027* ([WMO-No. 1336](https://library.wmo.int/viewer/68578/download?file=1336_WMO-Strategic-Plan-2024-2027_en.pdf&type=pdf&navigator=1)) is, “Advance equal, effective and inclusive participation in governance, scientific co-operation and decision-making”. The Plan states:

Organisations 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.

To contribute towards that objective and obtain the benefits described, it is important to have equal access to education and training programmes 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 that are inclusive and accessible to part-time students, including for those who need childcare, particularly benefit gender equality. This also applies equally to education and training staff.

As has already been discussed, having clear learning outcomes coupled with transparent and fair assessment policies benefits student attainment and contributes to a more inclusive culture. Programmes should be established that encourage inclusion. Examples of programmes that could foster inclusion are multi-year undergraduate programmes, postgraduate programmes of advanced study, NMHS in-service training, professional society workshops, Regional Training Centre programmes and virtual (on-line) courses.

The WMO Global Campus initiative is encouraging educational institutions to offer education and training opportunities outside of traditional academic and workplace settings. Today’s technology allows a combination of learning methods –synchronous and asynchronous, self-directed and instructor-led– at a time and place that is most suited to the learners. A possible route to BIP-CS qualification would be for individuals to access the necessary learning either from a single provider or from a range of different providers. Such a route would open access to those traditionally excluded because of their location, employment status, care-giving duties or other reasons.

As there is no international registration system for climatologists, providing evidence that the climatologist has achieved the BIP-CS learning outcomes remains the responsibility of the organisation that educates or employs the climatologist. To facilitate providing evidence, institutions are encouraged to ensure that their enrolment literature and their certificates and transcripts clearly specify which BIP-CS outcomes their courses achieve and to what extent.

### 1.4.6 BIP-CS at later stages of a career

The requirements specified by BIP-CS have been presented as if they are normally met by an individual taking an initial programme of study at a university or training institution. This would usually happen before or shortly after the person takes up employment at an NMHS. In practice, however, satisfying the requirements to be a climatologist might be achieved mid-career. Many of the learning outcomes specified by BIP-CS may have already been achieved. Provided that recognition of prior learning can be formally established and recorded, the programme of study need only cover those learning outcomes that have not already been achieved. Establishing and recording of prior learning may be undertaken by those responsible for training within an NMHS, when the NMHS is designated (if so required by the national educational regulator or department) as a “recognition-of-prior-learning” centre.

The specific national or institutional regulations and requirements of a particular country will determine whether reclassification that takes recognition of prior learning into account is accepted in that country.

# 2. CLIMATOLOGIST TASKS

Fully qualified climatologists usually perform some, but not all, of the tasks that comprise climate services. These tasks are described for the primary climate service activities in the sections below. Guidance for performing the tasks can be found in WMO-No. 100, 4th edition, [WMO-No. 1285](https://library.wmo.int/index.php?lvl=more_results&autolevel1=1), [WMO-No. 1205](https://library.wmo.int/?lvl=notice_display&id=20181) and [WMO-No. 1209](https://library.wmo.int/index.php?lvl=notice_display&id=21607).

## 2.1 CREATING AND MANAGING CLIMATE DATA SETS

The collection of observations of the environment provides the empirical evidence needed to understand and predict the evolution of climate, guide mitigation and adaptation measures, assess risks and enable attribution of climate events to underlying causes, and underpin climate services. The management of the vast variety of geophysical data requires a systematic approach that encompasses paper records, microform records (where relevant) and digital records. *The High-quality Global Data Management Framework for Climate* [(HQ-GDMFC), [WMO-No. 1238](https://library.wmo.int/index.php?lvl=notice_display&id=21686)] provides definitions, standards and recommended practices for managing data for climate purposes. The framework and specifications for a systematic approach are given in the *Manual on the WMO Information System* ([WMO-No. 1060](https://library.wmo.int/index.php?lvl=notice_display&id=9254)). This publication and the manuals and guides it references are designed to ensure adequate uniformity and standardisation of data, information and communications practices, procedures and specifications employed among WMO Members.

### 2.1.1 Observations

Most observations of the environment have been made for purposes other than for providing climate services, such as for weather forecasting. Using these data for climate purposes necessitates the climatologist to have an understanding of how the data were observed. Knowledge of instrumentation includes:

* Reliability (how well an instrument functions within its design specifications at all times);
* Suitability (for the operational environment at the station and to other equipment with which the instruments must operate);
* Accuracy and precision;
* Reasons for taking observations.

The homogeneity of climatological records and how well the records represent true conditions are closely related to the location of the observing site. A station sited on or near a steep slope, ridge, cliff, hollow, building, wall or other obstruction is likely to provide data that are more representative of the site alone and not of a wider area. These stations, such as lighthouses, may be of value if they have been in a stable environment for a long period of time. A station that is or will be affected by the growth of vegetation, including even limited tree growth near the sensor, growth of tall crops or woodland nearby, erection of buildings on adjacent land, or increases (or decreases) in road or air traffic (including those due to changes in the use of runways or taxiways) will provide neither broadly representative nor homogeneous data.

The competency of the observers should be considered when using data for climate purposes. NMHS observers are usually highly trained and competent. Often, however, observers are either volunteers, part-time employees or take observations as part of their other duties. They may have little or no training in climatology or in taking scientific observations.

Data are usually collected as part of a network (a group of multiple stations of the same type, such as precipitation stations or climatological stations). The climatologist should understand the purpose for establishing the network as well as how the networks are managed. When the data are used to describe climate, it is essential to consider the impacts of the density and distribution of stations and of the geography of the area for which the station is representative. Networks are not restricted to ground-based observations. Upper-air, satellite and other remote-sensing systems such as weather radar observations support climate activities that include monitoring and detecting climate variability and change, climate prediction on all timescales, climate modelling, studies of climate processes, data reanalysis activities, and satellite studies concerning calibration of satellite retrievals and radiative transfer.

Management of a network operated by a climate service includes:

* Selection of observing platforms;
* Selection of instrumentation;
* Station or platform inspection;
* Instrument calibration;
* Facility maintenance;
* Personnel requirements;
* Assessing observer competency;
* Training;
* Data transmission;
* Quality management of network operations.

### 2.1.2 Data processing

The basic goal of climate data processing is to capture, preserve and provide access to climate data and products for use by planners, decision-makers and researchers. Permanent archiving is an important objective. The data management system of a climate archive must provide the information to describe the climate of the domain of interest for which the archive has been established, be it national, regional or global. It is critically important that climate information, both current and historical, be managed in a systematic and comprehensive manner. An effective and comprehensive Climate Data Management System (CDMS) is essential for modern climate centres. [WMO-No. 1131](https://library.wmo.int/index.php?lvl=notice_display&id=16300) provides comprehensive guidance on CDMS specifications.

[WMO-No. 1238](https://library.wmo.int/index.php?lvl=notice_display&id=21686) provides guidance and requirements on the development, provision, exchange and maintenance of high-quality climate data sets. The standards and recommended practices it describes are intended to ensure that the data made available for climate assessment, monitoring, applications and related services meet sustainably a minimum set of requirements with regard to quality, governance, accessibility and usability. It enables the effective development and exchange of high-quality climate data, based on a reliable, integrated, underpinning data infrastructure at the global, regional and national levels. HQ-GDMFC provides a robust data foundation for the generation of climate products and the delivery of climate services through the Climate Services Information System (CSIS) of the Global Framework for Climate Services (GFCS).

Data rescue involves organising and preserving climate data at risk of being lost due to deterioration, destruction, neglect, technical obsolescence or simple dispersion of climate data assets over time. Non-digitized data are at risk, owing to the vulnerability of the original paper record. Data rescue includes:

* Organising and imaging paper, microfilm and microfiche records;
* Keying numerical and textual data and digitising strip-chart data into a usable format;
* Archiving data, metadata and quality-control outcomes and procedures.

The tasks of a data manager include, but are not limited to:

* Designing a CDMS;
* Documenting the overall design and underlying data model of the CDMS to facilitate subsequent extension or modification as needs or technologies change;
* Monitoring how well the processes that use and support the database (such as metadata maintenance, database ingestion, quality control actions that modify the database, and information retrieval) are performing;
* Estimating storage requirements including the estimation of future growth;
* Considering the frequency and methods of acquiring data from the observing sites;
* Constructing an adequate set of metadata to inform future users about the nature of the data in the system, how the various data sets were collected, and any inherent problems;
* Maintaining the CDMS;
* Controlling the quality of the data to verify whether a reported data value is representative of what was intended to be measured and has not been contaminated by unrelated factors;
* Data stewardship, including business and operations continuity plans.

## 2.2 DERIVING RETROSPECTIVE PRODUCTS FROM CLIMATE DATA

A role of the climatologist is to identify users and understand their needs for climate and environment-related information in their decision-making practices and then to provide the users with the information in a manner that is understandable to the user. The information is usually presented in products derived from the observed data. Ideally, the products should be designed jointly with the user community. Examples of products include tabular summaries, summaries of collections of data, maps and atlases, indices and reports. This role requires the analyst to understand and infer what physical processes the data represent and to describe uncertainties in the inferences. Inferences are often based directly on probability theory, and the use of statistical methods to make inferences is therefore based on formal mathematical reasoning.

Prior to using a data set for developing products, the data should be checked for accuracy and validity. Accuracy refers to the correctness of the data, while validity refers to the applicability of the data to the purpose for which the values will be used. The initial step in using a data set is usually to look for some basic features and patterns. Some that are often sought are the middle or typical value, the spread or range of the observations, the existence of unexpected observations, sudden shifts of patterns, how the observations trail off from either side of the middle value, and the clustering of observations and extremes. Without systematic organisation, large quantities of data cannot be easily interpreted to find basic features and patterns. The first step is to gain a general qualitative understanding of the data through visual displays of the distribution of the observed values. These displays often suggest data irregularities, inhomogeneities and suspect values that need to be addressed before any further analysis. The purpose of a product usually dictates the level of data errors or inhomogeneities that can be tolerated without degrading the utility of the product.

It is often useful to extract several quantitative summary measures. The summary measures help describe patterns of variation in observations. Understanding these patterns furthers the knowledge of the physical processes that underlie the observations, and improves inferences that can be made about past and current climate conditions. Care must be taken to ensure that the contents of a data set that are summarised are really comparable. For example, a series of temperature observations may be comparable if they are all taken with the same instrumentation, at the same time each day, at the same location, and with the same procedures. Sometimes the summary descriptors of a data set identify unexpected variations; any unexpected patterns should be examined to determine whether they are artificially induced or real effects of the climate system. Climatologists usually calculate measures of central tendency, variation, correlation and sometimes probability density functions.

Any series of observations can be modelled by purely mathematical functions that reproduce the observations. The main intent of fitting a function is to approximate the distribution of the observations. If the fit is acceptable, then with just a few parameters, the summary function of the observations should provide a realistic description of the data that is compatible with the underlying physics in a smoothed form that ignores data errors. A secondary intent is to describe the data within a theoretical framework that is sufficiently simple so that an unrealistic description of the data with too much weight placed on data errors or random factors that are extraneous to the processes being studied. The degree of smoothing is usually determined by how the data are to be used and by what questions the climatologist is trying to answer. How well a summary function describes the observations is determined by examining the differences between the observations and the values produced by the function.

Although it is possible to calculate numerous summary measures, it may not be appropriate to use them to describe the data set. Even though a calculation *can* be made does not mean it *should* be made. All measures that reduce observations with the purpose of detecting and describing a climate signal or relationship are based on assumptions, and if these assumptions are not valid the summary measures may be misleading. There are four issues that the climatologist must consider in detail before using summary measures:

* Data set errors – instrumental, observational, processing;
* Inhomogeneity – location, instrument, observation protocol, processing;
* Independence of observations – correlation;
* Neglect of important factors – anything that violates assumptions.

Technological advances in hardware and software have made it easier and quicker to process a large volume of data and output a variety of statistics, graphics and conclusions. The analyst should consider and be aware of some of the more prevalent problems with and characteristics of geophysical data that could impact the results and conclusions of not only statistical packages but of any data analysis. Some of the considerations are:

* Data uncertainty – climate data are usually more complex because of, for example, nonnormality and dependence, than standard statistical packages allow for;
* Data errors – errors in climatological data are often correlated in time, such as homogenization errors, and/or in space, such as interpolation errors;
* Model fitting – residuals from models should be assessed for patterns and outliers;
* Data transformation – compensate for non-normality;
* Time series analysis – assess stationarity;
* Multivariate analysis – assess the validity of model assumptions;
* Smoothing – assess the impact of smoothing techniques on decisions and conclusions;
* Data estimation – ensure that estimated values are realistic and consistent with physical considerations;
* Indices – assess how well an index represents the physical processes that are being summarised by the index;
* Extreme value analysis – assess the impact of limitations and assumptions of the techniques and models;
* Robustness – assess the effect of assumptions on the results of analyses.

## 2.3 CREATING AND/OR INTERPRETING CLIMATE PREDICTIONS, PROJECTIONS, OUTLOOKS AND MODEL OUTPUT

The climate system, its behaviour, its components and their interactions, and its future possible evolution and changes can be simulated on computers. Models are used for a range of applications including climate predictions and climate projections. Climate outlooks providing the expected average or accumulated value of a climate element, typically over a period of months and several years, are derived from the analysis and interpretation of observations and climate model outputs.

A climate prediction is an output of a model that computes the evolution of targeted parameters from initial conditions up to the final state at seasonal, annual or decadal timescales. A prediction assumes that factors beyond those explicitly or implicitly included in the prediction model will not have a significant influence on what is to happen. In this sense, a prediction is most influenced by the current conditions that are known through observations (initial conditions) and assumptions about the physical processes that will determine future evolutions.

A climate projection is usually a statement about the likelihood that something will happen several decades to centuries in the future, if certain influential conditions develop. In contrast to a prediction, a projection specifically allows for significant changes in the set of boundary conditions, such as an increase in greenhouse gases, which might influence the future climate.

Climate outlooks are forecasts of the values of climate elements averaged or accumulated over timescales of about one month to several years. Seasonal forecasts are more commonly used and can be generally issued with monthly frequency.

Global Climate Models (GCMs) are designed mainly for representing climate processes on the entire Earth. They provide the essential means to study climate variability and climate change for the past, present and future. They are based upon the physical laws governing the processes and interactions of all of the components of the climate system, expressed in the form of mathematical equations in three dimensions. The highly nonlinear governing equations are solved numerically on a four-dimensional grid of the atmosphere (three space dimensions plus time). Many physical processes such as individual clouds, convection and turbulence take place on much smaller spatial and temporal scales than can be properly resolved by the grid. These processes have to be included through a simplified representation called parameterization: this is a method used to replace small-scale, complex processes that are in the model with a simplified process.

Over many parts of the world, GCMs provide credible climate simulations at subcontinental scales and for seasonal to decadal timescales, and are therefore considered as suitable tools to provide useful climate predictions and projections. GCMs cannot provide direct information for scales smaller than their own resolution, but downscaling relates the properties of a large-scale model to smaller-scale regional and local climates. However, prior to downscaling, it is important to assess the influence of the large-scale features on the climate of the region or location of interest.

Modelling is prone to uncertainties caused by lack of knowledge of the Earth system, model parameter and structure approximations, randomness and human actions. The additional uncertainty introduced by a downscaling process must be assessed even if validation and verification of the results of a downscaled model are quite difficult, especially if there is an inadequate observational base. In this respect, the use of spatialisation techniques can help to interpolate the ground observations at the relevant spatial resolution and to provide a relevant reference dataset for validation and verification purposes.

Models and model outputs are complex. Climate models are based not only on atmospheric processes, but also on other environmental disciplines. Developers of models usually work in a collaborative setting with experts in several disciplines. Climatologists who develop models must have a thorough understanding not only of atmospheric processes but also have knowledge of other collateral fields such as marine science, biology and ecology. Climatologists who use or need to explain model outputs should know what a given model is intended to represent, what the model assumes and if the assumptions are met, what the strengths and weaknesses of the model are and what the intended use of the model is.

## 2.4 ENSURING THE QUALITY OF CLIMATE INFORMATION AND SERVICES

WMO is dedicated to ensuring the highest possible quality of all meteorological, climatological, hydrological, marine and related environmental data, products and services. To achieve this goal WMO is committed to the adoption and implementation of an organisation-wide quality management approach, associated with meeting WMO's main objectives and strategic priorities.

WMO has provided a comprehensive set of WMO Technical Regulations and guidance documents that includes [WMO-No. 49](https://library.wmo.int/?lvl=notice_display&id=14073), *Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers* ([WMO-No. 1100](https://library.wmo.int/index.php?lvl=notice_display&id=15574)), [WMO-No. 1205](https://library.wmo.int/?lvl=notice_display&id=20181), [WMO-No. 1209](https://library.wmo.int/index.php?lvl=notice_display&id=21607) and *Guidelines on Quality Management in Climate Services* ([WMO-No. 1221](https://library.wmo.int/index.php?lvl=notice_display&id=20652)), all of which provide a sound foundation for the operation of NMHSs and compliance with national and international regulatory requirements.

Senior management climatologists should adopt a quality management approach and develop and implement a Quality Management System (QMS) by:

* Developing the operational unit’s quality management program;
* Overseeing the quality of the output of all personnel;
* Introducing all personnel to the principles of quality management;;
* Modifying operational processes to reduce errors;
* Motivating all personnel to adhere to quality principles.

All climatologists should:

* Be able to describe the agency’s QMS principles;
* Adopt the agency’s quality management approach;
* Minimise errors in climate data and analyses;
* Seek training to improve efficiency;
* Seek training to improve performance.

## 2.5 COMMUNICATING CLIMATOLOGICAL INFORMATION TO USERS

Climate science and data play an important role to produce climate information which is invaluable in the decision-making processes of individuals, organisations and institutions. *Guidelines for Communicating Climate Science and Services* ([WMO-No. 1288](https://library.wmo.int/index.php?lvl=notice_display&id=22137)) is a convenient reference for success in communicating climate services. It details:

* Purpose (why communicate);
* Content (what to communicate);
* Medium (where to communicate);
* Timing (when to communicate);
* Composition (how to communicate).

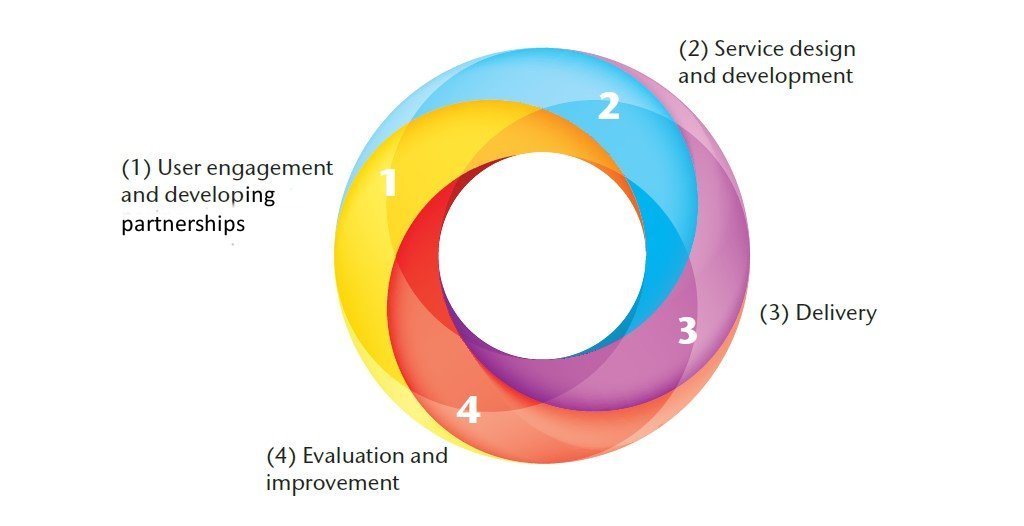
Many people with a need for climate information have a limited understanding of meteorological science and related concepts. Thus, they may not know what information is available (including the limitations and applicability of the information), what information they might benefit from having or how best to use it. Many users may not know how best to incorporate climate information into their decision-making processes.

Climatologists, in conjunction with or in the absence of social scientists and communication specialists, are a link between the technical aspects of the data, analyses, projections and scenarios, and users of the information who may not be technically proficient. Depending on the nature of the information, climatologists should be prepared to respond to requests for data with additional information about sites, elements and instrumentation, mathematical definitions of various parameters, the ways in which observations are performed, and the science of meteorology and climatology in particular. Mechanisms to support users should be formalised and well known to users. Personnel should cultivate a broad range of skills and expertise or have access to people with the necessary expertise.

Customer service personnel need to be courteous and tactful and recognize the importance of professional services. Ideally, the climate service should have good basic communications with technological and training facilities supporting the customer service personnel. Personnel providing customer services are the people with whom the public directly interacts, the people on whom the service provider’s reputation depends.

Communicating information to users is a continuous, cyclic process for delivering user-focused services (Figure 3). It comprises four stages:

* Stage 1: Identifying and engaging with users and understanding their needs, through understanding the role of climate information in their decision-making;
* Stage 2: Involving users, providers, suppliers and partners in developing services and striving to ensure that user needs are met;
* Stage 3: Producing and disseminating data, products and information (i.e., services) that are fit for purpose and relevant to user needs;
* Stage 4: Collecting and acting on user feedback and performance metrics to continuously evaluate and improve products and services.



**Figure 3.** **Four stages of a continuous, cyclic process for developing and delivering services**

*Source*: [WMO-No. 100](https://library.wmo.int/index.php?lvl=notice_display&id=5668), 3rd edition, figure 7.1

# 3. COMPETENCIES AND LEARNING OUTCOMES

BIP-CSS is a pre-requisite to gaining workplace competence. However, BIP-CSS does not define job competencies and is thus insufficient by themselves to prepare someone to do a particular job. In view of the complementarity between BIP and competencies, the top level competencies in climate services is provided in Annex to this publication. The concept of competencies and learning outcomes is described by Krathwohl and Payne (1971) and Anderson et al. (2001) and summarised in WMO-No. 1083. A competency framework is defined by [WMO-No. 1285](https://library.wmo.int/index.php?lvl=more_results&autolevel1=1) as a generic term to describe all the details associated with a competency requirement or competency standard, including the top-level competency statement, competency description, performance criteria or components, and background skills and knowledge or learning outcomes. It describes job responsibilities and the skills and knowledge required to perform specific job functions.

## 3.1 WMO TOP-LEVEL COMPETENCIES

A top-level competency is a statement that represents the overarching competency to be demonstrated by an individual or group. The overarching competencies for personnel providing climate services are:

* Apply conceptual models of the Earth’s global circulation, climate system and the interactions between the land, ocean, atmosphere and cryosphere to explain the mean state of the climate;
* Interpret products and services based on climate information, taking into account their inherent uncertainty;
* Describe the observed variability in the climate system and the causes and impacts of that variability; to 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 and predictability at different scales and the sensitivities of the audience;
* Explain the long-term changes occurring in the climate system using knowledge on how these changes are observed, what the drivers for change are, including feedback within the system, what the potential impacts of climate change are, and what adaptation and mitigation strategies are possible.

In a given institution, the competencies to be met and the associated performance criteria should be determined by its infrastructural capacity. Similarly, learning outcomes must be determined by an institution’s needs and capacity as well as by those services it offers. Competencies falling in the areas of quality of climate information and services, as well as communication of climatological information to users are considered cross-cutting and should be met, at least at basic levels, by all institutions providing climate services.

## 3.2 COMPETENCIES AND LEARNING OUTCOMES DEFINED BY WMO

[WMO-No. 1209](https://library.wmo.int/index.php?lvl=notice_display&id=21607) and [WMO-No. 1285](https://library.wmo.int/index.php?lvl=more_results&autolevel1=1) give detailed descriptions of the five top-level competencies, performance criteria and learning outcomes. They are intended to show the range of competencies required of climatologists and should be tailored to an institution:

* Organisational mandate, mission and priorities, and stakeholder requirements;
* Way in which internal and external personnel are engaged in the provision of climate services;
* Available resources and capabilities (financial, human, infrastructural and technical);
* National and institutional legislation and rules, organisational structures, policies and procedures;
* Adherence to WMO guidelines, policies and procedures for climate data and products;
* Experience with dominant weather influences and extremes within the institution’s purview;
* Basic knowledge of user needs and requirements.

WMO-No. 100, 4th ed. and [3rd ed.](https://library.wmo.int/index.php?lvl=notice_display&id=5668) provide additional guidance. The references (chapter 5) should be consulted for guidance about specific topics.

Implicit in the WMO competencies is an understanding of the concepts and principles of atmospheric science and depending on the type of climate service, statistics, data management and other environmental sciences. All professional climatologists should have:

* An understanding of the Earth’s general circulation and climate system in terms of the physical and dynamical processes that are involved;
* An understanding of the products and services based on climate information, including the assumptions upon which they are based, their inherent uncertainty and use;
* A physical and dynamical background that enables the climatologist to explain the mechanisms responsible for climate variability and climate change (including the influence of human activity) to describe the impacts of possible changes to the global circulation, primary weather elements and effects on society, to outline the adaptation and mitigation strategies that might be applied, and to describe the application of climate models;
* An awareness of quality assurance principles and methods.

Climatologists who create and manage data sets should also have the knowledge to be able to:

* Select and implement data input, storage, backup and retrieval structures;
* Compile, store and retrieve metadata necessary for activities such as understanding what data values represent, assessing data validity, homogenisation, instrument calibration, and network operations;
* Use computer hardware and software to create a functioning database that serves the purposes for creating the database;
* Apply database management techniques to keep a database functional;
* Develop and apply quality control and homogenisation requirements for maximising the accuracy of the information stored.

Climatologists who derive products from climate data should also be able to:

* Assess the need for and purpose of creating a product;
* Assess the quality of the information used in the product;
* Determine how data are to be manipulated, corrected, processed, summarised or changed for use in the product;
* Perform data manipulations, corrections, summaries and changes;
* Describe the methodology, assumptions and limitations of statistical techniques and software packages;
* Select and use appropriate methodologies;
* Analyse the advantages and disadvantages of different ways of presenting information in a product;
* Select and create appropriate displays;
* Document the processes used to create the product.

Creating and interpreting climate forecasts, climate projections and model output also requires knowledge of the:

* Mathematics, physics and dynamics to be able to create scientifically reasonable models for the spatial and temporal scales of interest;
* Software and computer systems to be able to produce the desired outputs;
* Strengths and weaknesses of a climate forecast, projection or model output to be able to interpret, explain, modify or refine modelled products;
* Intended use of a modelled product to be able to assure that the product is being properly used.

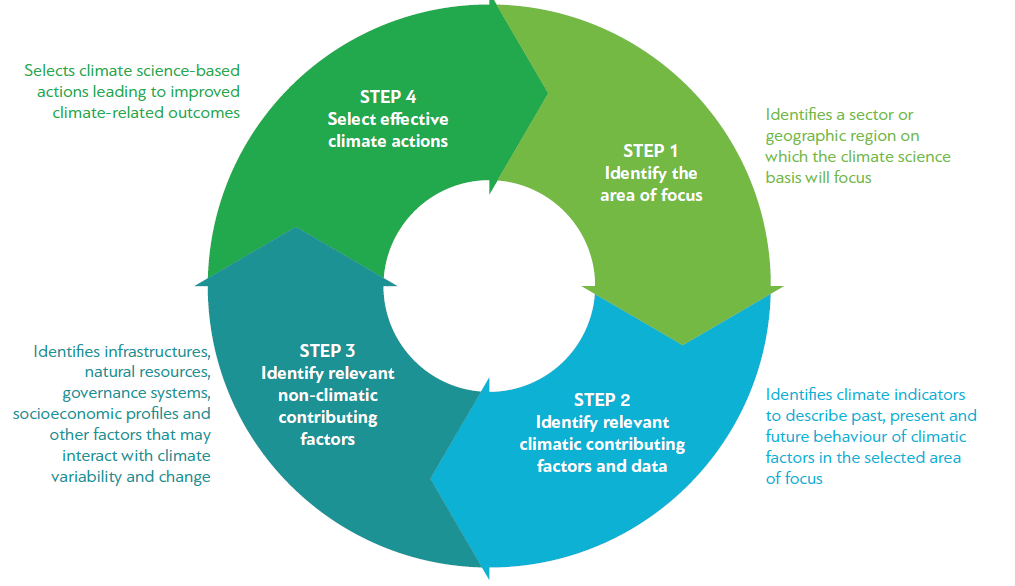
Ensuring the quality of climate information and services also requires:

* An understanding of the principles of quality management;
* An understanding of the principles and practices of quality control;
* Knowledge of all facets of data flow from observation to processing to storage to product development to product dissemination to be able to design and use a quality management system.

Communicating climatological information to users also requires:

* Skill to assess the information that users desire. Questions to consider are:
* What specific questions are users asking?
* Are users focused on local, national or global issues?
* Are users looking far into the future, or just into the next few years?
* What skills, capabilities and resources do users have at their disposal?
* What is the sphere of influence or the users?
* Using shared terminology so that the meaning of words is the same to the communicator and to the audience;
* Translating the language of science into the language of lay people;
* Putting facts into context that is relevant to the audience;
* Applying different methods of displaying and presenting information:
* Visualisation;
* Animations;
* Interactive tools;
* Scenarios.
* The ability to explain the process by which conclusions are made and the strengths, weaknesses, advantages and disadvantages of products.

*Developing the Climate Science Information for Climate Action* ([WMO-No. 1287](https://library.wmo.int/index.php?lvl=notice_display&id=21974)) shows how these competencies are used to bridge the gap between climate information and the use of climate information. Figure 4 shows the integration of competencies into a methodology that uses past, present and projected future climate information to understand how climate affects a region or sector. The conclusions drawn from implementing the methodology support the identification of science-based climate actions and the design of climate services that respond to the local context, address potential vulnerabilities and promote resilience to future climatic conditions. [WMO-No. 1287](https://library.wmo.int/index.php?lvl=notice_display&id=21974) provides several examples of the application of the methodology.



**Figure 4. Four-step methodology integrating competencies into the development of climate science information for climate action**

*Source:* [WMO-No. 1287](https://library.wmo.int/index.php?lvl=notice_display&id=21974) figure 1

## 3.3 COMPETENCIES DEFINED BY OTHERS

Governmental and public national and regional meteorological or climatological services are encouraged to subscribe to the WMO competencies so that the exchange of products and services across geopolitical boundaries and among institutions is standardised. Based on an individual institution’s capacity development and requirements, modifications are often needed, but the principles and goals of WMO should be followed.

Private sector climatologists are employed by, for example:

* Colleges and universities;
* Engineering consulting firms;
* Environmental consulting firms;
* Non-governmental organisations;
* Research institutions.

Their tasks are similar to those described in chapter 2, and their competencies and learning outcomes are similar to those described above in this chapter. A sampling of career guidance websites defines additional skills that are important to employees in both public and private organisations:

* Critical thinking and reading comprehension in order to interpret data and reports;
* Using deductive and inductive reasoning to reach conclusions;
* Being able to easily read charts and graphs to assimilate information;
* Computer programming for developing software applications;
* Knowing how to use software such as Geographical Information Systems for displaying information;
* Problem solving to bridge the gap between climatic information and user needs;
* Scientific research methodology;
* Designing graphics for displaying information**.**

These additional skills are complementary to the skills defined by WMO.

## 3.4 ASSESSMENT

As described in [WMO-No. 1285](https://library.wmo.int/index.php?lvl=more_results&autolevel1=1), competency-based assessment is defined as a process with the following characteristics:

* It is based on standards that describe the competency levels;
* Standards include competence criteria that provide details regarding the operational work and have to be correlated to the job position;
* The assessment is individual; there is no comparison among workers;
* It provides a measure for the assessed workers: competent or not yet competent;
* It is done, preferably, in real working situations based on direct observation or simulations;
* It is an ongoing process rather than a snapshot;
* It is not directly related to the completion of specific training;
* It includes the recognition of competencies acquired as a result of work experience;
* It plays an important role in the development of skills and abilities for the person being assessed;
* It is repeatable and fair.

The competency assessment should bridge the gap between “knowing” and “doing”. Instead of a test that asks someone to “tell me what you know”, competency assessment takes the approach of “show me what you can do”. Competency assessment tools can take a variety of forms:

* Direct observation of job responsibilities;
* Traditional written examinations, such as multiple-choice tests;
* Experiential questions;
* Simulations;
* Portfolio evidence;
* Checklists and matrices.

Each tool chosen should specifically assess a set of performance criteria. It is possible, and even desirable, for a tool to assess several competencies at the same time.

Assessments should identify gaps in competencies, and the reasons for the gaps should be determined. If the gaps are attributed to a lack of training instead of other causes such as a lack of awareness of tasks, lack of motivation or lack of resources, then competency oriented training should be prioritised.

# 4. EDUCATION AND TRAINING TO ACHIEVE COMPETENCIES

Education and professional development training are critical to building the workforce capable of meeting the challenges of climate services. Both academic and professional development training are essential. Traditionally, education and training in university and professional contexts relied on lectures for imparting information. These lectures were supported by tutorials and laboratory work to deepen students’ understanding and application of knowledge. Traditional methods such as the lecture, which remain widespread, are often not well suited to learning or assessing outcomes. It is becoming standard practice to have a more diverse range of learning activities in which the student actively applies knowledge.

To facilitate the acquisition of the body of knowledge needed in providing climate services, activities in which the student is active and in control of the learning should be preferred over passive experiences. A combination of instructor-led and self-led learning can be used. The key is that, whether the student is listening to a lecture, actively reading, or participating in group discussions, the student is using skills to actively retrieve and use the knowledge required. If the learning outcome is to recall a certain 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.

Many learning outcomes are associated with the words “apply”, “analyse”, “evaluate” and “create”. These words really define what it is to be a professional climatologist. Teaching and learning activities must activate those cognitive processes in the student for the student to master both the knowledge and the use of those very processes. Examples of teaching and learning activities that encourage or require the use of the processes include case study-based learning, group and individual projects, and workplace-based learning (known as placements, internships and practicums, among other terms). Development of abilities such as problem-solving are likely beneficial to the learning of procedural knowledge but are unfortunately often not taught explicitly.

The requirements of the Basic Instruction Package for Climate Services may be satisfied in a number of ways, such as: completion of a university degree in meteorology; completion of postgraduate study or a programme at [WMO Regional Training Centres](https://public.wmo.int/en/our-mandate/climate/regional-climate-centres) or NMHS training centres, having already completed studies in the pre-requisite mathematics and physics; accessing education and training from institutions as part of [WMO Global Campus](https://public.wmo.int/en/resources/meteoworld/wmo-global-campus). What matters is that providers of education and training can evidence how their programmes of study aid students in achieving the learning outcomes defined above. Some of these training resources are described in the following sections. They illustrate a range of options for providing training and are intended as examples of programs that could be developed by institutions providing climate services.

## 4.1 ACADEMIA

Institutions of higher education are the usual places where climatologists are taught dynamics, synoptics, physical meteorology, microscale and macroscale processes, general circulation, applied statistics and computer science. These subjects and their prerequisites constitute the basic knowledge of atmospheric sciences and usually suffice for entry level climatology and climate services positions. Additional courses in other sciences such as chemistry, marine sciences and ecology may be required for some climatology and climate services positions. For research and academic positions, a postgraduate degree is usually required.

Most higher education programs feature lectures, labs, and hands-on experience. At the undergraduate or certificate level, students participate in lectures, as well as work collaboratively with peers and faculty to make weather predictions based on data analysis, field work, and weather models. Many degree programs require the completion of a research project based on a specific area of interest. At the graduate degree level, students pursue a refined course of study, again, participating in labs, research, and field work. A thesis or dissertation is often required in order to graduate.

Some institutions of higher education offer online degree programs in climatology that are designed for those who work full-time and for those who do not have easy access to a physical academic location. Courses taught in the online format function similarly to those taught in the traditional classroom. Lectures, labs, research and field work are still a requirement. Labs are either conducted virtually or via a lab kit mailed to students. Once complete, students either return the kit to the teacher for a grade or simply write a report based on their findings. Many online degree and certificate programs do not operate on a set classroom schedule; it is up to the individual to conduct research, and complete course, lab, and field work. Therefore, obtaining an online degree requires a high level of time management and self-discipline. Students must be dedicated, organised, and structured in order to be successful.

## 4.2 TARGETED TRAINING

Training is often required to become knowledgeable about a specific subject or competent in a specific skill. The necessity for the training arises from many reasons, including but not limited to:

* Scientific advances in climatology;
* New technologies;
* Career progression;
* Professional development;
* Institutional program changes;
* Institutional operation changes;
* New competencies required for tasks;
* Remedial competency training;
* Individual desire.

There are several mechanisms for targeted training, including:

* In-house courses;
* In-house mentoring;
* Institution sponsored courses taught by contractors to the institution;
* Courses offered by institutions of higher education;
* Courses offered by professional scientific societies and organisations;
* Courses offered by private learning centres.

## 4.3 WMO TRAINING

The [WMO Global Campus](https://public.wmo.int/en/resources/meteoworld/wmo-global-campus) is the collaborative network of WMO Member institutions and National Meteorological Hydrological Services involved in the development and delivery of education and training. Its goal is to address the evolving global priorities for learning. It is based on the [WMO Regional Training Centres](https://public.wmo.int/en/our-mandate/climate/regional-climate-centres) and other WMO-designated centres engaged in learning activities, but embraces all institutions contributing to the learning needs of WMO Members.

[WMOLearn](https://public.wmo.int/en/resources/training/wmolearn) is a communication mechanism for the [WMO Global Campus](https://public.wmo.int/en/resources/meteoworld/wmo-global-campus). It provides portals for sharing and discovering learning events and resources, information about collaborative projects, and forums for stimulating collaborative efforts[. WMOLearn](https://public.wmo.int/en/resources/training/wmolearn) facilitates collaboration, raises awareness of successful Global Campus efforts and fosters innovations for learning by WMO Members.

There are 28 [WMO Regional Training Centres](https://public.wmo.int/en/our-mandate/climate/regional-climate-centres), composed of 43 components, providing a diverse portfolio of education and training opportunities through residence classes, distance-learning and blended learning. They are located throughout the world as shown in Figure 4.



**Figure 5. Map of WMO Regional Training Centres**

*Source:* <https://community.wmo.int/wmo-regional-training-centres>

There has been progress in many parts of the world through the WMO Voluntary Cooperation Programme ([VCP](https://public.wmo.int/en/programmes/voluntary-cooperation-programme)) and training workshops which have helped to create some national capacity to develop and deliver climate information. Furthermore, considerable effort has been made in conducting training in climate activities for Data Rescue ([DARE](https://www.idare-portal.org/)), data management and use of CDMS, as well as in development of climate indices for climate change detection. WMO hosts other climate-relevant training activities, including the Global Atmospheric Watch Training and Educational Centre ([GAWTEC](https://www.gawtec.de/)) which develops capacity in the specialised field of atmospheric composition monitoring, calibration standards and data quality control. WMO Members such as the United States ([COMET](https://www.comet.ucar.edu/) Program) and the United Kingdom provide comprehensive training in basic climatology and in climate statistics through online activities and workshops. The United States also, through [NOAA International Training Desks](https://www.wpc.ncep.noaa.gov/international/intl2.shtml), supports professional development training in operational climate monitoring and forecasting for NMHSs around the world.

## 4.4 [UN CC:Learn](https://www.uncclearn.org/about/who-we-are/)

The One UN Climate Change Learning Partnership*,* or [UN CC:Learn](https://www.uncclearn.org/about/who-we-are/), is a collaborative initiative of 36 multilateral organisations supporting countries to design and implement continued, results-oriented climate change learning programmes. Currently, [UN CC:Learn](https://www.uncclearn.org/about/who-we-are/) engages with 30 countries, either bilaterally or through regional programmes. In close collaboration with partners across the UN system and partner countries, [UN CC:Learn](https://www.uncclearn.org/about/who-we-are/) aims to build human capacity to plan and implement effective climate change actions.

At the global level [UN CC:Learn](https://www.uncclearn.org/about/who-we-are/):

* Supports knowledge-sharing on climate change;
* Promotes the creation of common climate change learning materials;
* Raises the visibility of climate change education and training.

At the national and regional levels [UN CC:Learn](https://www.uncclearn.org/about/who-we-are/):

* Supports countries to develop and implement climate change learning strategies aligned with their National Determined Contributions (NDCs) and National Adaptation Plans (NAPs);
* Supports countries to share experiences and promote joint climate change learning activities.

The key areas of knowledge needed to empower individuals in organisations to tackle climate change include:

* Climate change science;
* Climate finance;
* International climate negotiations;
* Adaptation planning;
* Climate change and its impacts;
* Climate change education for children and youth;
* Gender and climate change.

# 5. BASIC INSTRUCTION PACKAGE FOR CLIMATE SERVICES

This chapter provides more detail on the topics that might be included in a programme of study to meet the learning outcomes. It must be remembered that the detail given in this chapter is neither exhaustive nor intended to constrain WMO Members in the definition of programmes.

## 5.1 PRE-REQUISITE MATHEMATICS AND PHYSICS

Climatology, being a physical science, builds upon basic physics to describe mathematically the processes and interactions at work in the atmosphere and provides the core scientific information required for climate services. It is therefore necessary for climatologists to have a solid grounding in mathematics and physics. It should be borne in mind that BIP-CS is not designed to educate mathematicians or pure physicists; mathematics is a means through which people can learn climatological concepts. BIP-CS includes mathematics and physics learning outcomes, but only for those areas that directly support other learning outcomes. None of this precludes institutions from going beyond what is set out here in order to support their approach to teaching climate science, from taking advantage of standard introductory mathematics courses as part of their offering, or from preparing students for more advanced study.

Climatology and Climate Services often concerns topics in biology, chemistry, ecology, geography, economics and other disciplines that affect plant, animal and human life. Instructional outcomes for these disciplines are not included in this BIP, but it should be recognized that a general knowledge of these subjects is very beneficial for providing climate services.

Suggested instructional outcomes to meet the pre-requisite mathematics and physics requirements are given in tables 5.1 and 5.2.

**Table 5.1 Mathematics pre-requisites**

|  |  |
| --- | --- |
| Trigonometry | Solve simple geometric problems using the definitions of sine, cosine and tangent and their inverse functions, both in degrees and in radian units. |
| Describe the sine, cosine and tangent functions and 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 by expanding brackets, by collecting like terms and by applying factorization. |
| 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 use vector notation and translate between the two. |
| Calculate the magnitude and direction 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 concepts of probability and conditional probability. |
| Interpret plots of probability distribution function, probability mass function and probability density function. |
| Apply regression with one or multiple variables and assess the fit of the resulting model to prediction problems. |

**Table 5.2 Physics pre-requisites**

|  |  |
| --- | --- |
| 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 and 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 Pascal’s 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, as well as scattering, absorption and emission of radiation. |

## 5.2 TOPICS IN ATMOSPHERIC SCIENCE

This section contains learning outcomes of the core topics that are necessary for a climatologist to understand atmospheric science. Tables 5.3, 5.4 and 5.5 give outcomes in physical meteorology, dynamic meteorology and weather systems.

**Table 5.3. Suggested learning 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 climatologists 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 and 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 of 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 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 measures of static stability might change as a result of diabatic and adiabatic processes (for example, insolation, latent heat release and inclined flow). |
| 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 the 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 that cause electrical phenomena 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 differs from that of laminar flows; describe the mechanisms for the generation and dissipation of turbulence; describe 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 they 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 processes 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 of the terrain, coastline and urban areas on boundary-layer flows, 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 and use the latter to estimate the vertical structure of the wind in the surface layer, given a relevant observation. |
| Air contaminants | Use knowledge of common contaminants and their sources, sinks, behaviour and effects to predict how contaminants may be dispersed according to the 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, as well as the limitations and sensitivities of those instruments. |
| Describe the way clouds, visibility and weather types are classified and observed and the uses and limitations of the data. |
| Upper-air measurements | Explain the physical principles used in instruments to record upper-air measurements of geographical position, pressure, temperature, moisture and wind, ozone, and other atmospheric constituents (such as 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 that influence the representativeness of an observation. |
| Use and limitation of observations | Describe the uses and limitations of conventional observations in monitoring weather and climate and in making forecasts. |
| Global standards for 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 making and sharing observations, with emphasis on the component systems of the WMO Integrated Global Observing System. |
| **Remote sensing** | |
| These learning outcomes are intended to give a climatologist essential knowledge of common remote-sensing systems and the ability to intelligently use these data in a range of situations. | |
| Principles of remote sensing | Use remote-sensed data from radar, satellites and other systems together with in situ observations, numerical weather prediction (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, colour schemes and animations. |
| Active sensing | Explain how active sensing systems such as radar, lidar and sound detecting and ranging (SODAR) are used to provide quantitative and qualitative data about atmospheric parameters (for example, precipitation rate and type, wind speed and direction, cloud, humidity, temperature, turbulence and aerosol loading) and phenomena (such as thunderstorms, microbursts and tornadoes). |
| Passive sensing | Explain how passive sensing systems are used to provide digital data from received radiation (for example, in the visible, infrared 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-infrared, water vapour and infrared. |
| Explain the reasons for combining channels, including by creating RGB images, the applications of this imagery, and the advantages over single-channel imagery. |
| 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. |

**Table 5.4. Suggested learning outcomes in dynamics**

|  |  |
| --- | --- |
| **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 timescales as micro-, meso-, synoptic- or planetary-scale phenomena. |
| 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 recognize 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 | 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 wave motions of different scales in the atmosphere and the characteristics thereof, including sound waves, gravity waves and Rossby waves. |
| Baroclinic and barotropic instability | Describe wave growth through the baroclinic instability mechanism, with emphasis on the development of mid-latitude cyclones. |
| Describe how barotropic instability leads to the growth of disturbances in horizontally sheared flows. |
| **Numerical modelling** | |
| Data assimilation | Explain how information from observing networks and systems is obtained and prepared for use in an NWP model. |
| Explain the principles behind objective analysis, data assimilation (including three-dimensional and four-dimensional variational data assimilation and hybrid schemes including the use of ensembles) and initialization. |
| 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 usefulness and limitation of ensembles in the forecasting of extremes. |
| Interpret a range of standard ensemble-derived outputs, for example, the probability of exceeding thresholds plotted on maps, probability distribution functions and statistical data plotted on a meteogram. |
| Subseasonal to seasonal (S2S) predictions | Explain the scientific basis of monthly/subseasonal, seasonal and intra-annual forecasting. |
| Downscaling | Describe the techniques used to provide detailed regional atmospheric information based on the output from global models. |

**Table 5.5. Suggested learning outcomes in weather systems**

|  |  |
| --- | --- |
| **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 tropical weather systems on the one hand and mid-latitude and polar weather systems on the other; explain the reasons for those differences. |
| Air masses | Explain how air masses are characterised and formed and how their temperature, moisture and stability are modified as the air masses move away from their source regions. |
| Fronts | Describe the structure and characteristics of synoptic-scale cold, warm, occluded and quasi-stationary fronts. |
| 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. |
| Describe weaknesses of the basic cyclone model and recognize 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 to explain the relationship between the jet stream and the development or persistence of mid-latitude flow patterns. |
| Synoptic-scale vertical motion | 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, applying the quasi-geostrophic omega equation in its traditional or Q-vector form or using “PV-thinking”), noting the strengths and weaknesses of the technique employed. |
| Weather impacts | Describe the weather, with emphasis on extreme or hazardous conditions (such as windstorms, high precipitation accumulation and 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 that 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. |
| **Tropical and subtropical meteorology** | |
| General circulation in the tropics | Describe, using physical and dynamical reasoning, the mean state and major patterns of atmospheric variability in the tropics in terms of relevant variables and how and why these differ from those in higher latitudes. |
| Main tropical disturbances | Describe the main tropical disturbances and their temporal variability, including the Inter-Tropical Convergence Zone, tropical waves, trade inversions, trade winds, tropical/subtropical jetstreams, cloud clusters, squall lines, tropical depressions, subtropical 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 organised 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. |
| 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 that 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 timescales 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 (rainbands, drylines, gust fronts, squall lines, etc.). |
| Gravity waves | Apply physical and dynamical reasoning to explain the structure and formation of mesoscale gravity waves. |
| Convective systems | Apply physical and dynamical reasoning to explain the structure, characteristics and formation of isolated convection, including single-cell, multicell and supercell storms and meso-cyclones. |
| 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, upslope and downslope winds, valley winds, gap flows, lee cyclones, etc.). |
| 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 conducting such assessments. |
| Describe the underlying physical causes of 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 satellite imagery | Interpret satellite images, including the use of common wavelengths, enhancements and animated imagery, to identify cloud types and patterns, synoptic and mesoscale systems and other phenomena (such as fog, volcanic ash, dust and 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 by relating features found in the individual data sources. |

## 5.3 TOPICS IN CLIMATOLOGY

Table 5.6 contains learning outcomes of the core topics that are specific to climatology and Climate Services. These suggested outcomes, coupled with the learning outcomes above in atmospheric science, underpin the competencies required for climatologists. Consideration should also be given to the climatology and climate service learning outcomes for meteorologists and meteorological technicians described in WMO-No. 1083. Implicit in these outcomes is a knowledge and understanding of the advanced statistical theory and application that is necessary to perform specific climatological tasks such as:

* Analysis of correlated, dependent, nonnormal data;
* Time series analysis of correlated data;
* Extreme value analysis;
* Spatial analysis;
* Index creation;
* Ensemble analysis;
* Modelling;
* Climate projection;
* Detection of errors and biases;
* Data and process quality control and assurance.

**Table 5.6. Suggested learning outcomes in climatology and cimate services**

|  |  |
| --- | --- |
| Creating and managing climate data sets | Explain the workflow of climate dataset creation and management, including the successive application of data rescue, quality control, homogenization and integration into a climate database management system. |
| Describe the geographical characteristics of the area of study and the historical events that might affect the climate observing network, including political events, evolution of observing policies and instrumentation changes. |
| Discuss the strengths and weaknesses of the observational network and data availability for climate studies. |
| Characterise the climate of the area of study and describe its variability and recent changes. |
| Identify climatological similarities and differences across the area of study, relate them to climate controlling factors and explain them using a climate classification. |
| Use and adapt commercial and specifically designed software (including office suites, image treatment software, statistical packages, climate database management systems, graphical and geographic information system packages, and specific quality control and homogenization packages) to analyse climate data. |
| Use digitising devices such as scanners and digital cameras to produce soft copies of climate records. |
| Key climate data into a computer from images or paper copies and use real-time quality control techniques to avoid errors. |
| Use librarian and archival techniques to organise and preserve hard and soft copies of climate data and metadata. |
| Explain the use of various units of measurement and convert these to ensure that parameters within one time series are in the same unit for that parameter. |
| Collect information on additional sources of climate data and metadata and use it to prepare and run data-rescue campaigns. |
| Explain the concepts of climate time series quality and homogeneity and the causes of quality problems and inhomogeneities. |
| Apply statistical concepts associated with quality control, interpolation and homogeneity, namely descriptive statistics, hypothesis testing, probability distributions, correlation, regression models and multivariate statistics. |
| Apply quality control and homogenization techniques and evaluate the quality and homogeneity of a climate data network after gathering documentary, statistical and graphical pieces of evidence. |
| Design a database of climate data and metadata using a climate data management system, including raw, quality controlled and homogenised records. |
| Construct tables and queries to serve specific purposes for climate data analysis. |
| Create and document climate datasets for specific purposes including metadata and an explanation of their possible uses and associated uncertainties. |
| Convert data into different formats and temporal resolutions. |
| Characterise the climate of the area of study and describe its variability and recent changes. |
| Product derivation | Identify the climatological similarities and differences across the area of study, relate them to climate controlling factors and explain them using a climate classification. |
| Define the impact of climate on strategic sectors, especially GFCS key sectors: agriculture and food security, disaster risk reduction, energy, health and water. |
| List different sources of climate data inside and outside the organisation, including local, regional and global networks. |
| Retrieve climate data from original sources inside and outside the organisation, and organise, store and document them. |
| Create climate and sectorial datasets for organisational usage, considering the necessary spatial and temporal coverage. |
| Describe descriptive statistics and their adaptation to climate analysis, including measures of centrality and dispersion, data centring and standardisation. |
| Produce numeric and graphic summaries, such as scatterplots and box plots. |
| Represent climate data and climate indices time series and test them for temporal changes, including significance analysis. |
| Describe inferential and multivariate statistics, including hypothesis testing, fitting and exploiting probability distributions, correlation and regression models, principal components analysis and clustering methods. |
| State the uses of geostatistics, especially the techniques involved in data interpolation (for example, Kriging). |
| Use and adapt commercial and specifically designed software (including image treatment software, statistical packages, climate data management systems, geographic information system and graphical packages, and specific packages for the generation of climate indices such as RClimdex and Climpact) to produce climate products. |
| Explain the meaning and applications of widely used climate indices, such as those included in the RClimdex and Climpact packages |
| Use climate data, climate indices, other climate-related information and sectoral data to derive climate products. |
| Create synthesis reports, including textual, graphical and cartographic information to convert climate products into climate services and communicate them to users. |
| Climate forecasts, projections and model output | Describe the fundamental concepts of atmospheric processes, weather systems and climate, including the nature and causes of climate variability and climate change. |
| Describe the teleconnection between sea-surface temperature patterns and seasonal variation in rainfall and other hydro-climatic variables for the region of interest. |
| Evaluate important contributors to climate variability in the domain of interest and identify appropriate indices for creating climate forecasts. |
| Explain the utility and limitation of models produced by RCC’s and GPC’s and identify the most appropriate model for the region of interest. |
| Assemble calibrated model outputs for distribution at national level. |
| Explain the principles of statistical and dynamical models and run these models to create climate forecasts for different user applications. |
| Create sub-seasonal, seasonal and longer-scale forecasts including measures of uncertainty tailored to specific user needs. |
| Perform forecast verification on model outputs using WMO standard verification techniques. |
| Evaluate and quantify model uncertainties for different scenarios using techniques such as single and multi-model ensembles and communicate the results to end users. |
| Perform model evaluation and validation using observation (reanalysis) data. |
| Formulate different climate scenarios using appropriate boundary and radiative forcing and model parameterization. |
| Use different types of climate scenarios such as incremental, analogue and global climate models, and explain their appropriateness in adaptation and risk management decisions. |
| Identify the effect of domain size on spatial and temporal variability and accuracy of model results. |
| Choose appropriate climate software and downscaling techniques, and use spatio-temporal statistical tools, to manipulate climate data. |
| Explain the evolution and performance of global climate models for simulating climate scenarios. |
| Create products from models relevant to end user needs such as climate means, indices specific to each sector, box plots, drought analysis, climate trends and climate extremes. |
| Quality of climate information and services | Describe WMO, national and other standard and recommended practices for climate services, including competency frameworks. |
| List quality management principles, practices and procedures. |
| Apply quality management procedures. |
| Produce and deliver climate services in a multidisciplinary team whose members have varied technical knowledge and methodologies. |
| Identify education and training systems for developing knowledge and skills for climate services. |
| Identify and describe stakeholder needs and expectations, including:   * Stakeholder operations, including procedures, tactics, communications, planning processes and cycles; * Stakeholder limitations, including operating limits, legal constraints (statutory and regulatory), geopolitical limits and level of climate knowledge; * Stakeholder time frames and frequency of engagement; * Stakeholder’s terminology; * Stakeholder climate impact. |
| Identify changing user requirements, service delivery techniques and technologies. |
| Apply programme evaluation techniques. |
| Evaluate results to define improvements and contingency plans. |
| Communication | Identify climatological similarities and differences across the area of study, relate them to climate controlling factors and explain them using a climate classification. |
| Characterise the climate of the area of study and describe its variability and recent changes. |
| List the main sectors of economic activity, and social and geopolitical key issues of the area of study. |
| Express the impact of climate on the different sectors of economic activity, and on social and geopolitical key issues in the area of study and give examples. |
| Explain the concepts of impact, risk, vulnerability, adaptation capacity and uncertainty associated with climate, climate variability and climate change. |
| Select among the available climate products those suitable to explain the impact of climate on the sectors of economic activity, and on social and geopolitical key issues. |  |
| Develop a communication plan with climate information users, adapting it to the cultural environment and educational characteristics of each user. |
| Use appropriate channels of communication, including management of social media and liaison with media agents. |
| Survey users’ needs in terms of climatological information and revise the survey on the basis of users’ input. |
| Determine how climate information is used in order to ascertain whether it has to be revised or whether users need assistance in handling it. |
| Formulate climatological information in a language that is both scientifically sound and adapted to the expected users. |
| Integrate the communication of uncertainty and risk in the delivery of climate information. |
| Develop a system to evaluate the effectiveness of climate information |
| Assess the effectiveness of climate information exchange with users in accordance with established evaluation plans. |
| Recommend improvements for the climate information process. |

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**Annex 1. Fields of activity pertaining to the use of climate information, based on actual requests for information from a climate service centre** ([National Research Council](https://nap.nationalacademies.org/catalog/6197/future-of-the-national-weather-service-cooperative-observer-network), 1998)

Agriculture/Life Sciences:

* Plant diseases (cereals, corn, berries, grasses, ornamentals, nuts, mints, melons, fruits, vegetables, hay, alfalfa, tubers, mushrooms, spices)
* Plant growth (planting times, germination, dormancy requirements, frost probabilities, lodging, harvest conditions)
* Product quality (seed spoilage, transport conditions, storage conditions)
* Product marketing
* Chemical tests (pesticides, growth retardants and enhancers)
* Seed certification
* Relocations (introducing new crops, climate changes/fluctuations)
* Erosion (water, wind)
* Viticulture
* Degree-days (growing, chilling)
* Water issues (consumption, stress, drought)
* Groundwater (use, recharge rate, contamination)
* Irrigation needs
* Soil-water balance
* Evapotranspiration
* Runoff and nonpoint pollution
* Insects (moths, worms, beetles, flies, ants, mites, maggots, grasshoppers, crickets, caterpillars, host plant environment, chilling hours, dormancy egg laying)
* Pollination conditions, wildlife (severe winters/ summers, habitat conditions, breeding success, endangered species conditions, refuge management
* Introduction of new pests
* Wildlife (severe winters/summers, habitat conditions, migration, transplantation, breeding success, birthing/calving success, endangered species conditions, refuge management)
* Fish (lethal/injurious water temperatures, in streams and rivers, behind impoundments, ice effects, weather-induced sediment loading, passage time - anadromous species, flow volume and timing, ocean conditions, hatchery conditions, disease outbreaks, condition of redds/eggs)
* Grazing and forage conditions
* Caged and penned animals (permanent and temporary)
* Bird counts (growth/hatch timing dispersion)
* Fungus distributions
* Landscaping
* Christmas trees
* Riparian (stream) conditions
* Experiment stations (research, general databases, conditions during experiments)
* Forestry (reforestation, viability of nursery stock, clear-cut/canopied microclimates)
* Ecosystem management
* Parkland grazing conditions
* Regeneration rates
* Tree-ring growth and density
* Fire (ignition and growth potential, triggering events, firefighting conditions, labour force, equipment deployment, mop-up, restoration, reseeding, erosion susceptibility, frequency assessment insect kills, descriptive indices, lightning, slash fire planning)
* Timber sale requirements
* Blowdowns
* Long-term climate variability

Engineering:

* Energy (audits, heat loss calculations, utility costs, users, cities/counties/companies, private citizens, providers, utilities, hydropower supply, rate setting, energy demand, fuel planning, strategic planning
* Alternative energy - climate-sensitive sources (wind means and extremes, passive solar, small head hydro, heat pumps, passive cooling, relative humidity)
* Construction (scheduling, equipment inventories, personnel hiring, outdoor painting, environmental conditions,
* Product testing (specific conditions needed and not needed, fog instruments, corrosion tests)
* Uniform Building Codes
* Hazardous phenomena (tornadoes, lightning, hail, ice storms, tropical storms)
* Depth of frozen soil
* Balloon and helicopter logging (likelihood, performance standards)
* Power line routing
* Stress on long atmospheric tethers
* Airports (runway orientation, runway length, number of runways needed))
* Instrumentation
* Diesel low-temperature additives
* Chip manufacturers
* Vinyl glue separation
* Electric field studies
* Design criteria (roofs, culverts, bridges, storm sewers, sanitary sewers, aquatic centre pools, city and industrial ponds, cooling ponds, settling ponds, sewage treatment, hazardous waste containment, mine tailings, evaporation calculations)
* Lighting
* Freeze/thaw cycle climatologies
* Frost effects
* Drifting snow (depth/orientation)
* Dam design
* Boiler capacity
* Refrigeration needs
* Generators
* Greenhouse heating/cooling
* Structure orientation
* Structure strength
* Pollution dispersion
* Freeze probabilities
* Excessive values (heat, cold, wind, rain, snowfall, snow depth, humidity)
* Wave Erosion (causeways)

Legal:

* Accidents (cars, motorcycles, bicycles, airplanes, railroads, hang gliders, falls on ice)
* Storm damage (claims adjusters, real cause of damage, ''act of God'' or expected, crop damage, wind, hail, heavy rain, ocean waves, open seas/beaches, event insurance claims, outdoor gatherings/events,
* Environmental Impact Statements
* Endangered Species Act needs
* Biological Opinion
* Grazing allotment decisions
* Ecosystem Management background
* Hazard Rankings
* Environmental Assessments
* Wetlands determination
* Construction overruns
* Landslides
* Shipment delays/difficulties
* Pesticide drift
* Crime conditions (murder/assault/violent crimes, decomposition rates, , burglaries, traffic tickets, evidence reconstruction)
* Water (landfill runoff, frozen/broken pipes, subdivision runoff, landlord-tenant disputes, leaky roofs, storage of household goods, industrial painting disruptions, dike/containment breaches, seed spoilage)
* Highway sanding/ploughing conditions
* Pollutant transport
* Firefighting/rescue conditions
* Cement hardening conditions
* Health/workman's compensation claims

Economic Development and Other

* Manufacturing/business development (design criteria, construction conditions, marketing and sales impacts, inventory deployment, siting of shipping facilities)
* Relocations (businesses, manufacturing plants
* Retirement decisions
* Weather - sensitive products (marketing decisions)
* Agribusiness - development of (new crops, new products, new markets)
* Outdoor gatherings (festivals, concerts, air shows, auto/air/water/foot races)
* Motion picture filming conditions
* Hiring of labour (seasonal industries, construction, agriculture/migrant labourers, forestry, recreation
* News media (magazines, newspapers , radio, television, trade publications)
* Historical event conditions
* Tourism (vacation planning, recreation climatology and climate services, hiking/camping/backpacking, rafting, bicycling, skiing/windsurfing/fishing/hunting/mountain climbing/boating
* Health (relocation influences, skin problems, asthma/respiratory allergies, trace chemical sensitivity, solar exposure, melanomas, ultraviolet effects on vision, cloudiness climatologies, altitudinal variation of radiation
* NMHS (local forecasting studies/tools)
* Classroom/Educational
* Local climatologies
* Climate trends (yearly/decadal fluctuations, regional climates, El Niño/Southern Oscillation, global climate change)
* Home energy and gardening needs
* General advice and interpretation

1. See, for example, Biggs & Tang, 2011, p. 160–161. [↑](#footnote-ref-1)