Compendium of WMO Competency Frameworks

2019 edition

Updated in 2025

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

WMO-No. 1209

Compendium of WMO Competency Frameworks

2019 edition

Updated in 2025

WORLD
METEOROLOGICAL
ORGANIZATION

WMO-No. 1209

EDITORIAL NOTE

METEOTERM, the WMO terminology database, may be consulted at https://wmo.int/wmo-community/meteoterm.

Readers who copy hyperlinks by selecting them in the text should be aware that additional spaces may appear immediately following http://, https://, ftp://, mailto:, and after slashes (/), dashes (-), periods (.) and unbroken sequences of characters (letters and numbers). These spaces should be removed from the pasted URL. The correct URL is displayed when hovering over the link or when clicking on the link and then copying it from the browser.

WMO-No. 1209

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

Tel.: +41 (0) 22 730 84 03
Email: publications@wmo.int

ISBN 978-92-63-11209-5

NOTE

The designations employed and the presentation of material herein do not imply the expression of any opinion whatsoever on the part of the Secretariats of WMO or the United Nations concerning the legal status of any country, area or territory, or of its authorities, or concerning the delimitation of its borders. The depiction and use of boundaries, geographic names and related data on maps and in lists, tables, documents and databases herein are not warranted to be error-free and do not imply official endorsement or acceptance by WMO or the United Nations.

The mention of specific companies or products does not imply that they are endorsed or recommended by WMO in preference to others of a similar nature which are not mentioned or advertised.

PUBLICATION REVISION TRACK RECORD

Date	*Part/chapter/ section*	*Purpose of amendment*	*Proposed by*	*Approved by*
November 2025	Foreword	Update of the foreword to reflect current context	ETR	SG
November 2025	2.2	Addition of new text	SERCOM-2	Cg-19
November 2025	2.5	Addition of new text	SERCOM-2	EC-76
November 2025	2.8	Addition of new text	SERCOM-2	EC-76

CONTENTS

FOREWORD

The mission of WMO is to foster international cooperation in the development and delivery of meteorological services, facilitate the rapid exchange and standardization of meteorological information, strengthen collaboration between meteorological and hydrological services, advance research and training and expand the application of meteorology for everyone's benefit. Success in this mission relies on highly qualified and competent professionals who possess education and training reflecting the latest scientific, technological and operational advancements.

Recognizing the challenges in building and maintaining such capacities, the Nineteenth World Meteorological Congress endorsed the WMO Capacity Development Framework (WCDF), with a strong focus on Strategic Goal 4: "Close the capacity gap on weather, climate, hydrological and related environmental services." A key element of this goal is human resources development, which urges Members to sustain the competencies and expertise needed for effective service delivery through structured education and training programmes.

The pace of scientific and technological innovation, combined with new approaches to communication and service delivery, necessitates ongoing updates to competencies through lifelong learning. Since 2013, when the first competency requirements for aeronautical meteorological forecasters were published, WMO has expanded and revised competency frameworks across many service areas. These frameworks play a critical role in setting standards that support Members in bridging capacity gaps and ensuring consistent, high-quality services.

This Compendium consolidates frameworks across meteorological, climatological and hydrological activities. It outlines the top-level competencies required for specific roles, the associated knowledge and skills, and the performance standards expected of operational personnel. Closely connected with the Basic Instruction Package for Meteorologists and Meteorological Technicians included in the *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I, the frameworks facilitate targeted training and implementation, helping Members uphold professional standards while adapting to their unique organizational requirements.

Although not all listed competencies are mandatory, they provide National Meteorological and Hydrological Services with valuable tools for capacity-building, strategic planning and the integration of scientific and technological progress. The enabling skills within this Compendium establish the foundation for most operational activities, initially focusing on satellite and radar operations. Future editions will expand and improve this framework by including enabling skills in numerical weather prediction.

We extend our sincere appreciation to the many experts from the technical commissions for their expertise, dedication and collaboration, which made this work possible.

WMO trusts that this Compendium will serve as a practical resource for Members and the Secretariat, supporting continuous improvements in service delivery and adapting to the evolving demands of science, technology and society.

Prof. Celeste Saulo
Secretary-General

INTRODUCTION

Purpose of the Compendium

The purpose of this Compendium is to provide Members with easy access to all the WMO competency frameworks that have been implemented since the first frameworks for aeronautical meteorological personnel were put in place in 2013.

This publication accompanies the *Guide to Competency* (WMO-No. 1205), which provides competency implementation advice to Members.

Structure of the Compendium

For ease of reference, the Compendium is divided into two parts. The first part describes some of the fundamental knowledge and skills related to specific technologies and tools required of weather forecasters and other operational staff. The second part contains competency frameworks for specific service areas and lists the job responsibilities of people working in those areas.

How to use this publication

This publication defines competencies, performance criteria, knowledge and skills required of those working in a variety of service areas of WMO Members. It does not specify how or in which order they should be taught, or how they should be assessed. For such guidance, see the *Guide to Competency* (WMO-No. 1205).

Trainers and training managers who want to align their courses to competencies should use them to develop appropriate learning objectives. The competencies should be used in conjunction with the qualifications found in the *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I.

The Compendium covers a wide range of possible competencies, skills and knowledge requirements. Individuals may need only a subset of these, depending on their job. The frameworks should be examined thoroughly and may need customization for each organization and its service requirements.

Training resources to support development of these competencies can be found in the WMO E-Library. To facilitate access, resources are organized by competency framework under the Global Campus tab, but they can also be browsed by WMO topic from the primary Library tab.

Maintenance of the Compendium

The Compendium will undergo regular reviews and updates. The content is maintained by the WMO Education and Training Office (ETR).

WMO publications

The information contained in this Compendium is designed to cover numerous service areas. Some WMO technical commissions have developed specific material to complement their competency frameworks. These and other publications are available through the WMO E-Library and individual technical commission websites.

1. KNOWLEDGE AND SKILL FRAMEWORKS

This section describes the knowledge and skills that underpin the meteorological forecasting competencies. The list is not exhaustive: other frameworks are in development or might be identified over time, and will be included as they are approved by the appropriate WMO Commission.

1.1 SATELLITE SKILLS AND KNOWLEDGE FOR OPERATIONAL METEOROLOGISTS

This framework was last updated by the WMO Space Programme in July 2018.

Summary

This section describes the enabling skills that support the WMO competency frameworks related to the use of satellite data by operational meteorologists.[1] They must be able to:

1. Identify surface features;
2. Identify cloud types and their characteristics;
3. Identify and interpret broadscale, synoptic and mesoscale systems;
4. Identify and interpret atmospheric phenomena;
5. Interpret derived fields and derived products;
6. Identify and interpret oceanic and water features and systems;
7. Compare satellite data with numerical weather prediction (NWP) outputs.

The primary focus of this section is on meteorological forecasting. More specific in-depth usage of satellite data in specialized areas, such as oceanography, hydrology, climatology and agrometeorology, is not currently considered.

The satellite skills were developed by the WMO–Coordination Group for Meteorological Satellites (CGMS) Virtual Laboratory for Education and Training in Satellite Meteorology (VLab), to help training centres to develop appropriate learning objectives for the satellite-related elements of their courses. The WMO–CGMS VLab is a global network of specialized training centres and meteorological satellite operators working together to improve the utilization of data and products from meteorological and environmental satellites.

This section provides guidance on the skills and knowledge necessary to effectively utilize the imagery and products produced by many environmental satellites used by the operational meteorologist in the forecasting process.

Background

The application of satellite data and these enabling skills supports the various existing WMO Competency Frameworks and those under development. These require the operational meteorologists to:

(a) Analyse and monitor continually the evolving meteorological and/or hydrological situation;
(b) Forecast meteorological and hydrological phenomena and parameters;

[1] Although no reference is made to "operational meteorologist" in the Convention of the World Meteorological Organization, for the purpose of this document "operational meteorologist" means someone who performs the duties of analysis, diagnosis, prognosis, forecasting and communication of the weather.

(c) Effectively communicate the information to the users.

As these skills support the competencies, they have been designated as enabling skills rather than as competencies.

How to use this section

This section defines the enabling skills required of an operational meteorologist as the interpretation, identification and application of satellite data. It does not specify how or the order in which satellite meteorology should be taught.

Trainers and training managers who want to align their courses to the competencies may use this section to develop appropriate learning objectives for the satellite-related elements of their courses. This section should be used in conjunction with the qualifications found in the *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I and the WMO competencies.

Operational meteorologists can use this section to assess their own level of skill, for example, novice, advanced or expert, with respect to the application of satellite data.

This section covers a wide range of possible skills and knowledge requirements. An individual may need only a subset of these, depending on the job requirements. The performance and knowledge requirements that support these skills should be customized for each organization, its service requirements and available satellite data.

Basic knowledge

It is assumed that the user of this section has basic knowledge in satellite remote-sensing and understands the following:

(a) Satellites include geosynchronous (GEO) and low-Earth orbit (LEO) satellites with passive and active sensing;
(b) Imagery includes single and multiple channels and combinations of channels, including RGB (red/green/blue) displays and derived products;
(c) Satellite interpretation is not undertaken in isolation but occurs within the context of all other observations, guidance and situational awareness;
(d) Systems, features and phenomena of interest will be dependent on the required forecasting tasks and location;
(e) Access, selection, display and manipulation of satellite data;
(f) Characteristics, limitations and possible errors in the satellite data.

SKILL 1: IDENTIFY SURFACE FEATURES

Description

Identify geographical features, surface characteristics and conditions.

Performance components

1.1 Identify terrain and geographical features:
  1.1.1 Discriminate between land and water (oceans, seas, lakes, rivers, inlets);
  1.1.2 Distinguish mountainous from low-lying regions;
  1.1.3 Differentiate natural versus human-modified areas;

1.2 Identify surface characteristics and conditions, including dry/wet, different vegetation types and clear areas, sand and desert:
  1.2.1 Identify vegetation-free areas and vegetation types. Identify different types of desert surface, for example, sand and desert pavement;
  1.2.2 Identify areas of recent burning;
  1.2.3 Identify hotspots (fires, volcanic activity, etc.);
  1.2.4 Identify areas of recent volcanic ash cover;
  1.2.5 Identify areas of flooding;
  1.2.6 Identify areas of drought;

1.3 Identify snow/ice cover and analyse its extent:
  1.3.1 Discriminate between cloud and snow;
  1.3.2 Identify frozen rivers and lakes;
  1.3.3 Identify sea ice.

Skills, techniques and knowledge requirements

To be contextualized depending on the local circumstances:

1.a Application of Infrared (including water vapour (WV)), visible and microwave channels;
1.b Application of multi-channel RGB imagery and products;
1.c Application of products and derived products (lighting, LEO flood and moisture products, land, etc.), particularly for longer-term monitoring such as drought;
1.d Background interpretation of satellite images (scale, texture, colour, shadow, etc.).

SKILL 2: IDENTIFY CLOUD TYPES AND THEIR CHARACTERISTICS

Description

Identify cloud types and features including height and temperature of tops, thickness and microphysics.

Performance components

2.1 Identify stratiform, cumuliform and cirriform cloud regions and individual cloud types and their characteristics;
2.2 Identify cumulonimbus clouds, their intensity, organization and stage of development;
2.3 Identify fog and discriminate between fog and low cloud;
2.4 Identify contrails and ship trails;
2.5 Deduce cloud top heights on the basis of brightness temperatures, surface observations and sounding data (observed, satellite-derived and from numerical models);
2.6 Identify clouds made of water droplets, ice particles or a mixture;
2.7 Discriminate between clouds with small and large cloud particles.

Skills, techniques and knowledge requirements

2.a Distinguish cloud types and characteristics (thick, thin, multi-layered, top height, developing, decaying) based on texture, albedo, brightness temperature, and synoptic and mesoscale context;
2.b Interpret brightness temperatures and deduce cloud thickness;
2.c Use RGB products to identify fog and night microphysics, shadows on visible imagery and animation to identify valley fogs as well as meteorological situational awareness and surface and aircraft observations;
2.d Use RGB products and/or microphysical parameters to identify clouds in different phases and clouds with small or large cloud particles;
2.e Utilize derived products;

2.f Interpret the background of satellite image properties (scale, texture, colour, shadow, etc.).

SKILL 3: IDENTIFY AND INTERPRET BROADSCALE, SYNOPTIC AND MESOSCALE SYSTEMS

Description

Identify, locate and interpret broadscale, synoptic and mesoscale atmospheric systems, their characteristics, strength and stage of evolution, and deduce atmospheric dynamical and thermodynamical properties.

Performance components

Select and apply conceptual models to locate and identify each system, its orientation, strength and stage of evolution, including precursor signatures, taking into account departures from climatological or idealized models. (Categories are not exclusive and some features relate to more than one category.)

Note that a full analysis or prediction is a higher-order competency involving all available data and guidance. Thus, the satellite interpretation task is not an end in itself but, in conjunction with other data, contributes to the higher-level task.

3.1 Identify and locate the following broadscale systems and features:
- 3.1.1 Intertropical convergence zones, monsoon and trade wind regimes;
- 3.1.2 Westerly regimes with embedded cyclones and anticyclones;
- 3.1.3 Polar and tropical easterlies and systems;
- 3.1.4 Broadscale waves;
- 3.1.5 Zonal, meridional flows, mobile and blocking systems;
- 3.1.6 Upper- and low-level circulations;
- 3.1.7 Low-level moisture boundaries;

3.2 Identify and locate the following synoptic-scale systems and features:
- 3.2.1 Anticyclones;
- 3.2.2 Cyclones, tropical cyclones and lows, extratropical and polar lows, at upper and lower levels;
- 3.2.3 Jet streams, convergence and frontal zones, conveyor belts, dry slots;
- 3.2.4 Troughs, ridges and cols, deformation axes, waves;
- 3.2.5 Cloud regions – stratiform, stratocumulus, cumulus (cold outbreaks, trade cumulus), cloud bands, cloud streets, and cloud shields;
- 3.2.6 Cold pools and thermal shear;

3.3 Identify and locate the following mesoscale systems and features:
- 3.3.1 Local thermal and topographic circulations including land and sea breezes, katabatic and anabatic winds, foehn winds, mountain waves, banner clouds, island and peninsula effects (including Kármán vortices and v-shaped wave clouds), heat lows and troughs, and lake effect snow;
- 3.3.2 Convective environments and areas of instability, convective initiation, inhibition and the breakdown of inhibition;
- 3.3.3 Convective cells and cloud systems (including pulse convection, multicells, supercells, squall lines, mesoscale convective complexes and systems) and associated mesoscale features including outflow boundaries and storm-top features;
- 3.3.4 Convergence lines (mesoscale boundaries and interactions, dry lines, cloud streets);
- 3.3.5 Low-level jets;
- 3.3.6 Gravity waves and bores.

Skills, techniques and knowledge requirements

3.a Use Infrared, water vapour and visible (including high-resolution visible channel) and detailed conceptual models to identify atmospheric systems;
3.b Utilize the Dvorak tropical cyclone enhancement and techniques to deduce tropical cyclone intensity;
3.c Use RGB products (airmass RGB, microphysics RGB, etc.) to identify atmospheric systems and use for operational forecasting.

SKILL 4: IDENTIFY AND INTERPRET ATMOSPHERIC PHENOMENA

Description

Identify and interpret atmospheric phenomena, their characteristics, strength and stage of evolution.

Performance components

Locate and identify each phenomenon and determine its strength, characteristics and, when appropriate, stage of evolution.

Note that a full analysis or prediction is a high-level competency involving all available data and guidance. Thus, the satellite interpretation task is not an end in itself but, in conjunction with other data, contributes to the higher-level task.

4.1 Identify and locate the following:
- 4.1.1 Dust and sandstorms, and plumes and areas of raised dust;
- 4.1.2 Fires and smoke;
- 4.1.3 Moisture features, precipitation types and amounts;
- 4.1.4 Volcanic ash particulates, sulphur dioxide (SO2) and other chemical emissions;
- 4.1.5 Aerosol and particulate pollution;
- 4.1.6 Features indicating regions of clear air turbulence.

Skills, techniques and knowledge requirements

4.a Discriminate between dust/sand, cloud and smoke; day and night, over land (particularly desert surfaces) and water, using single, multi-channel and RGB imagery;
4.b Locate fires, their intensity and probable movement;
4.c Distinguish precipitation type and amount (convective, stratiform and deep versus shallow precipitation) using satellite channels including microwave channel data;
4.d Identify and analyse volcanic emissions to determine the areal extent, height, thickness and temporal evolution of the ash cloud, sulphur dioxide (SO_2) and other constituents using single, multi-channel and RGB imagery;
4.e Correctly identify pollutants and atmospheric constituents (SO_2, nitrogen dioxide (NO_2), etc.) in RGB composites or products;
4.f Use the appropriate RGB to identify ozone-rich regions in the middle and upper atmosphere;
4.g Identify clear air turbulence (CAT) signatures using single channel (including water vapour channels), multi-channel, RGB composites and synthetic satellite imagery.

SKILL 5: INTERPRET DERIVED FIELDS AND DERIVED PRODUCTS

Description

Advanced interpretation of fields and parameters from product analysis across all the other skills.

Performance components

Interpret fields and parameters in order to integrate them with other data, observations and guidance (including NWP outputs) as input to analysis and diagnosis.

5.1 Correctly interpret and appropriately integrate:
- 5.1.1 Surface temperatures;
- 5.1.2 Vertical temperature and moisture profiles;
- 5.1.3 Atmospheric winds;
- 5.1.4 Cloud type, cloud top temperature;
- 5.1.5 Total and liquid precipitable water;
- 5.1.6 Vegetation and fire danger indices, soil moisture.

Skills, techniques and knowledge requirements

5.a Recognize the strengths and weaknesses of single channel, multi-channel, RGB products and satellite-derived products/fields and how they complement other meteorological information;

5.b Describe the impacts of satellite observations on Numerical Weather Prediction (NWP) outputs. This will include the use of water vapour (WV) synthetic imagery mapped against potential vorticity (PV) fields from the NWP products.

SKILL 6: IDENTIFY AND INTERPRET OCEANIC AND WATER FEATURES AND SYSTEMS

Description

Identify and interpret oceanic features and systems relevant to meteorological forecasting. Note that oceanographers would require more extensive skills that are not included in this framework.

Performance components

6.1 Interpret sea-surface temperature fields and their characteristic broadscale, synoptic and mesoscale patterns;
6.2 Interpret sea-surface wind data;
6.3 Identify and interpret sea-state data and relate these to wave height and swell;
6.4 Identify and interpret oil slicks and their evolution;
6.5 Identify and interpret pollution (including runoff and algal blooms);
6.6 Identify and interpret areas of sun glint and dark zones;
6.7 Identify and interpret sea ice, its extent, movement and characteristics (young and old sea ice, sea ice undergoing ablation and containing melt ponds);
6.8 Identify and interpret ocean currents and eddies and regions of ocean upwelling.

Skills, techniques and knowledge requirements

Recognize and/or utilize the following:

6.a Sea-surface temperature limitations, including cloud cover, skin temperature and deeper temperatures;

6.b Sea-surface wind limitations, including wind direction ambiguities, wind speed inaccuracies and rain effects;
6.c Sea-state measurement limitations and errors based on active microwave sensors and aperture radar;
6.d Sea-ice detection methods using microwave sensors, synthetic aperture radar and multispectral infrared imagery, RGBs and derived products;
6.e Relationship between sun glint, dark zones and ocean surface (windy or calm) conditions;
6.f Multispectral infrared imagery and products to distinguish between sun glint and cloud characteristics.

SKILL 7: COMPARE SATELLITE DATA WITH NUMERICAL WEATHER PREDICTION (NWP) OUTPUTS

Description

Identify variations (or differences) between meteorological phenomena as they appear in satellite imagery (for example, WV imagery) and NWP model outputs (for example, PV, synthetic WV imagery) to assess and validate NWP outputs for the improvement of operational weather forecasting.

Performance components

For the assessment of NWP model outputs, apply meteorological concepts to the interpretation of satellite imagery, for example, compare the WV imagery with NWP outputs (for example, PV fields and synthetic WV imagery) and identify the differences in location and magnitude of NWP from the satellite imagery. Finally, validate and adjust NWP outputs for the improvement of operational forecasts.

Note that new multi-channel satellites with high temporal and spatial resolution can be used as ground truth because it represents real-time atmospheric flows. Thus the contribution of satellite data to the adjustment of NWP outputs will be the highest level task based on all the dynamical concepts and observation data.

7.1 Evaluate basic NWP output fields using satellite data and model output;
7.2 Identify and assess various weather features by integrating satellite and NWP products;
7.3 Deduce when and how to use satellite imagery to address NWP limitations;
7.4 Use NWP information to enhance the understanding of the features shown in the satellite images;
7.5 Use satellite data in conjunction with NWP at different stages of the analysis and forecast process.

Skills, techniques and knowledge requirements

7.a Have a basic understanding of the atmospheric dynamics;
7.b Have a basic understanding of NWP outputs and their limitations;
7.c Understand the dynamical relationship between satellite imagery and NWP outputs for diagnosing synoptic-scale atmospheric circulation systems;
7.d Utilize the high-resolution satellite imagery in conjunction with NWP model output to better diagnose meteorological phenomena and improve operational forecasts.

ACKNOWLEDGEMENTS

These enabling skills were initially formulated by the WMO–CGMS VLab Management Group (VLMG) and were subsequently developed by Ian Bell, Roger Deslandes and Bodo Zeschke

from the Australian Bureau of Meteorology, Ian Mills and Mark Higgins from the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), and Luciane Veeck from The Open University and WMO–CGMS VLab. This document was written in consultation with the WMO–CGMS VLab Centres of Excellence and members of the CALMet community. The authors warmly thank everyone who took the time to provide feedback on the drafts.

1.2 RADAR SKILLS AND KNOWLEDGE FOR OPERATIONAL METEOROLOGISTS

Interpretation of radar products contributes to higher-order forecaster competencies. In particular, it forms part of competencies related to the analysis and continuous monitoring of the weather situation and to the forecast of phenomena and parameters, as included in several competency frameworks. The radar interpretation requirements are called contributing skills rather than competencies in their own right.

Radar interpretation skills

Meteorologists who perform nowcasting should develop skills to interpret radar products (reflectivity, Doppler, polarimetric data and estimated precipitation forms and amount) and apply them in conjunction with other data sources (satellite, numerical weather prediction (NWP), measurements/observations). Accurate interpretation also requires understanding basic radar measurement principles and associated uncertainties and limitations.

Skills

1. Analyse reflectivity products of radar;
2. Analyse velocity products of Doppler radar;
3. Analyse polarimetric radar products;
4. Identify conceptual models and deduce the related weather phenomena;
5. Identify non-meteorological targets;
6. Perform nowcasting.

Conditions of application

The forecaster should be able to select and interpret radar products in conjunction with other observation products and numerical guidance. He/she should be able to analyse the meteorological context for the interpretation of radar products, enabling the issuing of appropriate nowcasting products.

This section covers a wide range of possible skills and knowledge. Any individual will require only a subset of these, according to local needs and available products. Forecasters in different locations or performing different job tasks will have access to different radar data with their unique characteristics and to various display and manipulation systems and tools. They will also be dealing with differing local meteorological systems and phenomena.

The focus of this section is on meteorological nowcasting and use of radar data in early warning systems. Other uses of radar data, in meteorological research, oceanography, hydrology, climatology and other specialist areas, are not considered.

SKILL 1: ANALYSE REFLECTIVITY PRODUCTS OF RADAR

Performance components

1.1 Consider the technical and physical background of radar measurements:

- Select radar bands (C, S, X) according to requirements and availability;
- Consider the consequences of the radar equation during interpretation;
- Consider the constraints of volume scanning (concepts of azimuth, elevation, range, beam spread and vertical resolution);
- Take into account the maximum range depending on radar site, blockage and horizontal resolution during interpretation;
- Consider the radar waves' propagation in the atmosphere and deduce possible impacts on the analytic process;

1.2 Consider the measuring procedure and different radar products, and select the most appropriate for a particular weather situation:
- Use the Plan Position Indicator (PPI), Constant Altitude Plan Position Indicator (CAPPI), Maximum Display (Max), PseudoCAPPI, Range-Height Indicator (RHI), cross section (X-sect), echo top, and the like, and select products according to requirements;
- Apply national and international composites when radar products from one location produce limited results;

1.3 Derive precipitation amount and type from radar products, considering possible risks of misinterpretation:
- Determine precipitation amounts and estimate precipitation forms from reflectivity measurements;
- Consider the impact of different Z/R relations;
- Consider the limitations of precipitation products due, for example, to limited horizontal resolution;
- Detect evaporation, overhanging precipitation and virga;
- Detect attenuation;
- Identify bright bands and interpret vertical profiles of reflectivity accordingly;
- Consider the sensitivity of radar, i.e. minimum detectable signal;
- Apply data thresholds (depending on application, season and location) for interpreting;

1.4 Consider impacts on derived precipitation, analyse precipitation products in the light of different correction methods:
- Estimate precipitation amounts at surface;
- Select the most appropriate precipitation product according to the weather conditions, including precipitation products adjusted to precipitation gauges.

Prerequisite knowledge

Basic knowledge of physical meteorology and synoptic meteorology, as well as properties of radars and radar networks.

SKILL 2: ANALYSE VELOCITY PRODUCTS OF DOPPLER RADAR

Performance components

2.1 Take into account the technical limitations and corresponding risks of misinterpretation (limitations of the dual pulse repetition frequency (dual PRF) technique, Doppler dilemma, folding);
2.2 Interpret Doppler wind fields (speed and direction);
2.3 Estimate horizontal wind fields from single and multiple radar locations;
2.4 Recognize mesoscale structures (rotation, convergence, divergence, shear) and estimate their intensity;
2.5 Deduce 3-D-structure of wind fields, and deduce vertical wind shear and low-level jet.

Prerequisite knowledge

Basic knowledge of physical meteorology and synoptic meteorology.

SKILL 3: ANALYSE POLARIMETRIC RADAR PRODUCTS

Performance components

3.1 Deduce the relevant information from different measurement parameters: zdr, ldr, rhoHV, phiDP, KDP;
3.2 Deduce the hydrometers' properties and estimate precipitation amount and type:
- Classify the hydrometeor (fluid, solid, mixed phase);
- Estimate rain rates using dual polarization parameters;
- Analyse precipitation products in the light of possible uncertainties, for example, distinguishing between hail and sleet, drizzle and light rain.

Prerequisite knowledge

Basics of precipitation formation and precipitation type.

SKILL 4: ANALYSE RADAR PRODUCTS TO IDENTIFY WEATHER SYSTEMS AND DEDUCE THE RELATED WEATHER PHENOMENA

Performance components

4.1 Apply conceptual models in relation to frontal structures and deduce relevant weather phenomena from radar data products:
- Identify mesoscale structures and their intensity (illustrated with cross sections);
- Diagnose precipitation type changes, icing conditions, melting layer and embedded convection;
- Deduce vertical and horizontal wind shear;
- Take into account the effects of the underlying surface (sea/land, orography);
- Derive significant weather phenomena by evaluating and combining all radar information;

4.2 Apply conceptual models of convection when using radar products:
- Detect and monitor typical patterns and signatures of single-, multi- and supercells, squall lines, outflow boundary and flanking line;
- Track and forecast thunderstorm intensity and motion;
- Identify divergences, convergences, downbursts, rotations, inflow and outflow, and estimate their intensity and motion;
- Detect weak-echo regions (WER)/bounded weak-echo regions (BWER) (organized convection/supercell) by applying 3-D-products;
- Make rainfall estimates considering convective cell and system motion and storm lifecycle;
- Derive significant weather impacts of summer and winter convection by combining suitable radar products.

Prerequisite knowledge

- Basic knowledge of conceptual models of convection;
- Basic knowledge of different types of fronts and related dynamical;
- Basics of the preconditions of convection (air mass (KO and convective available potential energy (CAPE) indexes, etc.), forcing (dynamic, radiation, topography, etc.).

SKILL 5: IDENTIFY NON-METEOROLOGICAL TARGETS

Performance components

5.1 Identify echoes associated with non-meteorological targets: birds, insects, dust, sand, clutter, wind farms, ships, planes, chaff;
5.2 Identify the effects of unusual weather conditions:
- Check the probability of anomalous propagation;
- Detect second trip echo;
- Detect flare echoes (three-body scattering);
- Identify interference, for example, from to the sun.

Prerequisite knowledge

- Knowledge of meteorological conditions with a high probability of non-meteorological targets;
- Knowledge of radar signatures of meteorological phenomena.

SKILL 6: PERFORM NOWCASTING

Performance components

6.1 Apply different nowcasting techniques, including observation-based, automated, and blending;
6.2 Perform nowcasting using radar products in combination with other data, including conventional data, satellite, lightning detection, NWP, EPS and model output statistics (MOS), to issue watches and warnings;
6.3 Use radar products to identify:
- Conceptual models of convection and convective systems;
- Thunderstorm location;
- Hail size;
- Tornados;
- Microbursts;
- Strong surface winds;
- Heavy precipitation;
- Mesoscale vortices;
- Precipitation type;
- Visibility;
- Surface icing by freezing precipitation;
- In-flight icing conditions.

Prerequisite knowledge

- Basic knowledge of the interpretation of satellite data, including RGBs;
- Basic knowledge of utilisation of NWP;
- Basic knowledge of the different nowcasting techniques and their practical applications;
- Knowledge of the relevant dynamical forcing (3-D-view);
- Knowledge of air mass transformations;
- Knowledge of influence of topography;
- Knowledge of precipitation types.

2. COMPETENCY REQUIREMENTS

2.1 PUBLIC WEATHER SERVICE FORECASTERS AND ADVISERS

The following competency frameworks were revised and approved by the Executive Council at its seventieth session in June 2018.

2.1.1 Fundamental WMO competency requirements for public weather forecasters

Public weather service (PWS) forecasters should have successfully completed the Basic Instruction Package for Meteorologists (BIP-M), as defined in the *Technical Regulations* (WMO-No. 49), Volume I, Part V.

The competency requirements for personnel working in operational forecasting[1] can be divided into five top-level competencies (listed below), taking into consideration the following conditions:

(a) The nationally defined PWS[2] areas of responsibility;
(b) Meteorological and hydrological impact on society;
(c) Meteorological and hydrological user requirements, local procedures and priorities.

Competency requirements

Public weather service forecasters should be able to perform the tasks specified under the following top-level competencies:

1. Analyse and continually monitor the evolving meteorological and hydrological situation;
2. Forecast meteorological and hydrological phenomena and parameters;
3. Warn of hazardous meteorological and hydrological phenomena;
4. Communicate meteorological and hydrological information and potential impacts to internal and external users;
5. Ensure the quality of meteorological and hydrological information and services.

Each of these top-level competencies is expanded into performance criteria, which are expressed and structured in such a manner as to facilitate the clear application of an assessment procedure. The competencies are built upon a range of enabling skills, such as skills and knowledge in numerical weather prediction (NWP), and transferable skills, for example workplace skills that are not exclusive to meteorology, such as problem solving and people management. Each top-level competency is also associated with a range of background knowledge and skills that are essential to the discharge of the defined duties.

---

[1] Personnel engaged in operational forecasting may work across a variety of specializations including aviation, marine and public weather services.

[2] For the purpose of forecaster competencies, the term PWS forecaster is used to describe a person responsible for the preparation and delivery of public weather forecasts and warnings.

COMPETENCY 1: ANALYSE AND CONTINUALLY MONITOR THE EVOLVING METEOROLOGICAL AND HYDROLOGICAL SITUATION

Competency description

Observations and forecasts of meteorological/hydrological parameters and significant meteorological/hydrological phenomena are continuously analysed and monitored to determine the need for issuance, cancellation or amendment/update of forecasts and warnings according to documented thresholds, protocols and regulations.

Performance criteria

1. Analyse, interpret and diagnose data and information to identify meteorological/hydrological features pertinent to the area of forecast responsibility;
2. Monitor meteorological/hydrological parameters and evolving significant meteorological/hydrological phenomena, and validate current forecasts and warnings on the basis of these parameters;
3. Evaluate the need for amendments to forecasts and for updates of warnings against documented criteria and thresholds;
4. Monitor information related to impacts of recent meteorological and hydrological events.

Background knowledge and skills

- Awareness of the importance of meteorological and hydrological services, and an understanding of the effects of forecasts and warnings on users and decision-makers, in particular for public safety;
- Understanding of the key elements of synoptic, dynamical and physical meteorology, and core analytical and diagnostic skills at least to the level of the BIP-M;
- Application of the theory, methods and practices of meteorological and hydrological analysis and diagnosis;
- Ability to visualize and conceptualize meteorological and hydrological information in multiple dimensions (spatial, temporal);
- Appreciation of the influence of topography, land cover, and, if relevant, bodies of water and snow fields on local meteorology;
- Interpretation of in-situ and remote-sensed observations and data;
- Understanding of the characteristics of meteorological and hydrological sensors and instruments;
- Familiarity with the acquisition, processing and assimilation of meteorological and hydrological data, including quality control;
- Understanding of procedures, standards and technical regulations relating to observations, forecast and warning products.

COMPETENCY 2: FORECAST METEOROLOGICAL AND HYDROLOGICAL PHENOMENA AND PARAMETERS

Competency description

Forecasts of meteorological and hydrological phenomena and parameters are prepared and issued in accordance with documented requirements, priorities and deadlines.

Performance criteria

1. Forecast meteorological and hydrological phenomena and parameters as required, using appropriate tools and including forecast uncertainties;

2. Ensure that forecasts are prepared and issued in accordance with national or regional practices, relevant codes and technical regulations on content, accuracy and timeliness;
3. Ensure, insofar as practicable, that forecasts of meteorological and hydrological phenomena and parameters are consistent (spatially and temporally) across boundaries of the area of responsibility;
4. Monitor forecasts issued for other regions, and liaise with adjacent regions as required.

Background knowledge and skills

- Core diagnostic and prognostic skills to BIP-M level;
- Knowledge of methods used in NWP and other forecast applications;
- Knowledge of the strengths, limitations and verification outputs of the NWP models used in the forecast office, and of forecast adjustments required to accommodate them;
- Knowledge of statistical approaches applicable to meteorological and hydrological information;
- Knowledge of probabilistic approaches to forecasting, such as those available through ensemble prediction systems;
- Critical comparison of a variety of forecast models, interpretation of observational and climatological data, and synthesis of this information to make a reasoned estimate of the most likely evolution of the weather, of alternative evolutions, and of the uncertainties associated with each part of this process;
- Interpretation of model outputs at different time ranges;
- Judgement in determining which observational, model, contextual and impact information is most relevant, especially in very short-range forecasting;
- Knowledge of the potential impact of meteorological and hydrological events on users and their decision-making processes.

COMPETENCY 3: WARN OF HAZARDOUS METEOROLOGICAL AND HYDROLOGICAL PHENOMENA

Competency description

Warnings are issued in a timely manner when hazardous meteorological or hydrological conditions are expected to occur, or when parameters are expected to reach documented threshold values or generate significant impacts. Warnings are updated or cancelled according to documented criteria.

Performance criteria

1. Forecast hazardous meteorological and hydrological phenomena, including spatial extent, onset and cessation, duration, intensity and temporal variations;
2. Ensure that warnings are prepared and issued in accordance with national protocols for hazardous phenomena and their impacts;
3. Ensure, insofar as practicable, that warnings of hazardous meteorological and hydrological phenomena are consistent (spatially and temporally) across boundaries of the area of responsibility;
4. Monitor warnings issued for other regions, and liaise with adjacent regions as required;
5. Maintain awareness of the impacts of hazardous meteorological and hydrological phenomena that are the subject of warnings and notifications.

Background knowledge and skills

- Knowledge of the specific product preparation and dissemination systems used in the forecast office;
- Knowledge of and skill in using warning production tools;

- Knowledge of the policies, procedures and criteria for issuing warnings;
- Knowledge of the potential impact of meteorological and hydrological events on users and their decision-making processes.

COMPETENCY 4: COMMUNICATE METEOROLOGICAL AND HYDROLOGICAL INFORMATION AND POTENTIAL IMPACTS TO INTERNAL AND EXTERNAL USERS

Competency description

User requirements are fully understood and are addressed by communicating concise and complete forecasts and warnings in a manner that can be clearly understood by users.

Performance criteria

1. Ensure that all forecasts and warnings are disseminated through the authorised communication means and channels to designated user groups, as specified in relevant standard operating procedures;
2. Explain meteorological and hydrological data and information, including uncertainties, where required;
3. Deliver briefings and provide consultation to meet specific user needs as required.

Background knowledge and skills

- Standards, procedures and dissemination methods for the presentation of forecast and warning information to the public across all relevant media, including impact information as required;
- Knowledge of protocols for presenting warning information to emergency management partners, including information on likely impacts and mitigation activities, if relevant;
- Awareness of user needs for, and use of, meteorological and hydrological information;
- Awareness of the application of meteorology and hydrology to human activities and specific users.

COMPETENCY 5: ENSURE THE QUALITY OF METEOROLOGICAL AND HYDROLOGICAL INFORMATION AND SERVICES

Competency description

The quality of meteorological and hydrological forecasts, warnings and related products is maintained through the application of quality management system processes, where appropriate.

Performance criteria

1. Apply the organization's quality management system and procedures;
2. Validate meteorological and hydrological data, products, forecasts and warnings (timeliness, completeness, accuracy);
3. Assess the impact of known error characteristics (bias, achievable accuracy of observations and sensing methods);
4. Monitor operational systems and take contingency actions where appropriate;
5. Contribute to case studies and post-reviews as required, including assimilation of user feedback and impact information;
6. Mentor junior colleagues and provide support and advice as required.

Background knowledge and skills

- Knowledge of standard operating procedures and also contingency procedures;
- Knowledge of techniques and technology commonly used in forecast offices;
- Knowledge of validation and verification procedures relevant to meteorological and hydrological forecasts and warnings;
- Understanding methods used in developing case studies and feedback to improve the quality of forecasts and warnings.

2.1.2 Weather broadcasters and communicators

The following competency requirements are for personnel who specialize in media work and routinely present weather information on radio or television, prepare material for weather websites and social media, liaise with the media and are active in education and outreach. They build upon, and should be read in conjunction with, the fundamental WMO competency requirements for personnel working in operational forecasting, although it is recognized that some people working as broadcasters and communicators may not come from a forecasting background.

The competency requirements for personnel working in weather broadcasting and communication can be divided into four top-level competencies (listed below), taking into consideration the following conditions:

(a) The geographical areas of responsibility;
(b) Meteorological and hydrological impacts on society;
(c) Meteorological and hydrological user requirements, local procedures and priorities.

Competency requirements

Weather broadcasters and communicators should be able to perform the work indicated under the following top-level competencies:

1. Monitor the evolving meteorological and hydrological situation, updated forecasts and warnings, and the impacts of anticipated conditions;
2. Assemble meteorological and hydrological information that meet user needs for communication and delivery;
3. Communicate meteorological and hydrological information and potential impacts via broadcasts and other media;
4. Ensure the quality of meteorological and hydrological information and services.

Each of these top-level competencies is expanded into performance criteria, which are expressed and structured in such a manner as to facilitate the clear application of assessment procedures. The competencies are built upon a range of enabling skills (such as skills and knowledge in numerical weather prediction) and transferable skills (workplace skills that are not exclusive to meteorology, such as problem solving and people management). Each top-level competency is also associated with a range of background knowledge and skills that are essential to the discharge of the defined duties.

COMPETENCY 1: MONITOR THE EVOLVING METEOROLOGICAL AND HYDROLOGICAL SITUATION, UPDATED FORECASTS AND WARNINGS, AND THE IMPACTS OF ANTICIPATED CONDITIONS

Competency description

Observations, forecasts, warnings and impacts of meteorological and hydrological parameters and significant meteorological and hydrological phenomena are continuously monitored to inform the content of weather broadcasts, disseminated products, briefings and other communications.

Performance criteria

1. Monitor meteorological and hydrological parameters and evolving significant meteorological and hydrological phenomena;
2. Monitor amendments to forecasts and updates of warnings;
3. Monitor information related to the impact of recent meteorological and hydrological events.

Background knowledge and skills

- Understanding of the key elements of synoptic, dynamical and physical meteorology;
- Appreciation of the influence of topography, land cover and, if relevant, bodies of water and snow fields on local meteorology;
- Interpretation of in-situ and remote-sensed observations and data;
- Knowledge of the routine dissemination schedule of forecasts and warnings from the meteorological service provider;
- Knowledge of the thresholds and protocols associated with the issue of weather warnings by the relevant National Meteorological and Hydrological Services (NMHSs);
- Knowledge and understanding of the likely impact on society of hazardous meteorological and hydrological phenomena.

COMPETENCY 2: ASSEMBLE METEOROLOGICAL AND HYDROLOGICAL INFORMATION THAT MEET USER NEEDS FOR COMMUNICATION AND DELIVERY

Competency description

Observations, forecasts, warnings and impact of meteorological and hydrological parameters and significant meteorological and hydrological phenomena are assembled and synthesized into coherent narratives and products for dissemination to users.

Performance criteria

1. Articulate the weather story in a manner appropriate to the meteorological and hydrological situation, and to user expectations and needs;
2. Articulate the weather story in a manner appropriate to the communications medium employed;
3. Prepare graphics that visually support communication of the meteorological/hydrological story and situation;
4. Apply routine production protocols appropriate to the service provision environment.

Background knowledge and skills

- Knowledge of the range of users or audience who will access the weather information;
- Appreciation of the strengths and weaknesses of the communication medium employed;
- Skills in oral and written language appropriate to the communication medium employed;
- Knowledge and skills of relevance to operation of the weather graphics software or other information technology (IT) facilities used to prepare graphical images, and in IT-related media for the communication of meteorological and hydrological information;
- Knowledge of the function and operation of the different technological resources (personal computers (PCs), servers, mixers, amplifiers, cameras, etc.) commonly employed in weather broadcasting, where relevant.

COMPETENCY 3: COMMUNICATE METEOROLOGICAL AND HYDROLOGICAL INFORMATION AND POTENTIAL IMPACTS VIA BROADCASTS AND OTHER MEDIA.

Competency description

Observations, forecasts, warnings and impacts of meteorological and hydrological parameters and significant meteorological and hydrological phenomena are disseminated to users in a manner appropriate to the communications medium and to the needs of users.

Performance criteria

1. Identify the key points in a weather story or in high-impact meteorological and hydrological hazards, and develop them into a coherent narrative or presentation;
2. Explain and communicate to users the scope and limitations of forecasts and warnings, including the concept of forecast uncertainty;
3. Present warnings of meteorological and hydrological hazards, including information on possible mitigating actions, where appropriate;
4. Implement the "single authoritative voice" concept with respect to warnings of severe weather and other public safety messages;
5. Prepare presentations on meteorological and hydrological topics and deliver them to external agencies and to the public;
6. Deliver meteorological and hydrological information in accordance with broadcast schedules or other appropriate media protocols;
7. Develop and present new graphical representations of meteorological and hydrological information in accordance with editorial policy.

Background knowledge and skills

- Knowledge of the likely impact of upcoming meteorological and hydrological events at different timescales, and skill in judging the relative importance of these;
- Knowledge of the likely uncertainty attached to forecasts at different timescales;
- Knowledge and understanding of the likely impact on society of hazardous meteorological and hydrological phenomena;
- Knowledge of the policies, procedures and criteria for issuing warnings;
- Knowledge of the mitigating actions associated with the likely impact of hazardous meteorological and hydrological phenomena;
- Knowledge of the authoritative sources of meteorological, hydrological, impact and mitigating information relevant to hazardous phenomena;
- Skill in the use of presentation and visualisation software to support lectures, seminars and other public engagements;
- Knowledge of broadcast schedules, deadlines and other appropriate media protocols.

COMPETENCY 4: ENSURE THE QUALITY OF METEOROLOGICAL AND HYDROLOGICAL INFORMATION AND SERVICES

Competency description

The quality of meteorological and hydrological broadcasts and other communication products is maintained through the application of approved quality management processes, where appropriate.

Performance criteria

1. Apply the organization's quality management system and procedures;
2. Apply the agreed editorial policy to weather broadcasting and other meteorological and hydrological communications;
3. Ensure, insofar as possible, that all meteorological and hydrological information available to users is consistent, current and up to date;
4. Monitor and assess the effectiveness of communication of meteorological and hydrological information through user-based metrics;
5. Improve the communication of meteorological and hydrological information based on user feedback;
6. Mentor junior colleagues and provide support and advice as required.

Background knowledge and skills

- Knowledge of standard operating procedures;
- Knowledge of contingency procedures appropriate to system failure;
- Knowledge of the editorial policy relevant to weather broadcasting and other meteorological and hydrological communications;
- Knowledge of techniques and technology commonly used in the dissemination of meteorological and hydrological information;
- Knowledge of the various user-based metrics relevant to the assessment of the effectiveness of communication of meteorological and hydrological information.

2.1.3 Personnel working in the development and delivery of meteorological and hydrological products and services

The following competency requirements are primarily aimed at personnel working in the area of innovation, improvement and delivery of meteorological and hydrological services and products. They should be read in conjunction with the competency requirements for personnel in operational forecasting, although it is understood that many people working in these areas may not come from a forecasting background.

These competency requirements are divided into four top-level competencies (listed below), taking into consideration the following conditions:

(a) The nationally defined PWS areas of responsibility;
(b) Meteorological and hydrological impacts on society;
(c) Meteorological and hydrological user requirements, and local procedures and priorities.

Competency requirements

People working in development and delivery of meteorological and hydrological products and service should be able to perform the tasks defined under the four top-level competencies, as follows:

1. Keep abreast of advances in technology and science that facilitate the development and improvement of products and services to meet user requirements;
2. Develop applications, products and services that meet user requirements;
3. Develop and manage relationships with users and other stakeholders, in particular by providing documentation and delivering training on new products and services;
4. Ensure the quality of meteorological and hydrological information and services.

Each of these top-level competencies is expanded into performance criteria, which are expressed and structured in such a manner as to facilitate the clear application of an assessment procedure. The competencies are built upon a range of enabling skills, such as skills and knowledge in numerical weather prediction (NWP), and transferable skills, for example workplace skills that are not exclusive to meteorology, such as problem solving and people management. Each top-level competency is also associated with a range of background knowledge and skills that are essential to the discharge of the defined duties.

COMPETENCY 1: KEEP ABREAST OF ADVANCES IN TECHNOLOGY AND SCIENCE THAT FACILITATE THE DEVELOPMENT AND IMPROVEMENT OF PRODUCTS AND SERVICES TO MEET USER REQUIREMENTS

Competency description

The needs of users for products based on meteorological and hydrological information are monitored, as are the available technologies and techniques relevant to the development of products and services and their dissemination.

Performance criteria

1. Monitor users' current and future requirements for meteorological and hydrological products and services;
2. Keep abreast of scientific advances supporting the development and improvement of meteorological and hydrological products and services;
3. Monitor developments in communication and information technologies, standards and protocols relevant to the creation and dissemination of meteorological and hydrological products and services.

Background knowledge and skills

- An understanding of the key elements of synoptic, dynamical and physical meteorology;
- Knowledge of the range of available in-situ and remote-sensed observations and data;
- Knowledge of meteorological and hydrological information available through NWP, statistical outputs and other appropriate sources, and of their potential value for users;
- Knowledge of relevant technologies for the development of products based on meteorological and hydrological information, and for their dissemination.

COMPETENCY 2: DEVELOP APPLICATIONS, PRODUCTS AND SERVICES THAT MEET USER REQUIREMENTS

Competency description

Products and services based on meteorological and hydrological information are developed and improved in line with the needs of users and the capabilities of the available technologies and techniques.

Performance criteria

1. Develop, test and implement applications and products, including relevant uncertainties, in support of user-focused services;
2. Develop applications for the visualization and display of meteorological and hydrological information, including forecast uncertainty;
3. Optimize systems used to produce and disseminate meteorological and hydrological products and services;
4. Implement changes to applications, products and services in line with evolving user needs or changing technologies;
5. Document applications and products and their implementation processes to aid users and support maintenance and continuity of service.

Background knowledge and skills

- Knowledge of the range of users and audience who will have access to the meteorological and hydrological products, and of their requirements;
- Knowledge of statistical methods and techniques commonly used in the processing and visualization of meteorological and hydrological information;
- Knowledge of the characteristics and capabilities of the visualization and display systems used for meteorological and hydrological information;
- Knowledge of probabilistic approaches to forecasting and representation (especially graphical representation) of uncertainty in forecast products, such as those based on ensemble systems;
- Knowledge of the characteristics and capabilities of the dissemination media used;
- Knowledge of and skill in the operation of the IT facilities used to prepare graphical images for the communication of meteorological and hydrological information;
- Knowledge of procedures for documenting and keeping record of developments in software applications.

COMPETENCY 3: DEVELOP AND MANAGE RELATIONSHIPS WITH USERS AND OTHER STAKEHOLDERS, IN PARTICULAR BY PROVIDING DOCUMENTATION AND DELIVERING TRAINING ON NEW PRODUCTS AND SERVICES

Competency description

Relationships with users are developed and maintained to support the ready identification of user needs and requirements, and changes to these over time. Relationships with users are formalized through appropriate agreements where necessary.

Performance criteria

1. Participate in the assessment of users' needs, in collaboration with relevant experts;
2. Establish and maintain working relationships at operational and technical levels with users and other stakeholders;
3. Develop partnership agreements at operational and technical levels with users and other stakeholders;
4. Develop and make available adequate background documentation on new products and services;
5. Develop and deliver training to users and stakeholders on products and services as required.

Background knowledge and skills

- Knowledge of the methodologies for understanding and development of user requirements;
- Knowledge of the methodologies for development of partnerships, memorandums of understanding, service-level agreements, and the like, with users of meteorological and hydrological information and products;
- Understanding of the operational systems and working priorities of relevant users;
- Knowledge of the training methods and techniques appropriate to users and other stakeholders;
- Understanding of the vulnerabilities of various users and how they may be affected by meteorological and hydrological events.

COMPETENCY 4: ENSURE THE QUALITY OF METEOROLOGICAL AND HYDROLOGICAL INFORMATION AND SERVICES

Competency description

The quality of products and services based on meteorological and hydrological information is maintained through the application of quality management systems where appropriate.

Performance criteria

1. Apply the organization's quality management system and procedures;
2. Support the implementation and ongoing validation of automated meteorological and hydrological products and services;
3. Support training in access, use and interpretation of products and applications related to meteorological and hydrological services.

Background knowledge and skills

- Knowledge of standard operating procedures;
- Knowledge of contingency procedures in case of system failure;
- Knowledge of techniques and technology commonly used in the dissemination of meteorological and hydrological information;
- Knowledge of the various user-based metrics on the accessibility and understanding of meteorological and hydrological information through products and applications;
- Knowledge of procedures for documenting and keeping record of developments in software applications;
- Knowledge of appropriate methods and techniques for user training.

2.1.4 Public weather service advisers supporting disaster prevention and mitigation and other user activities[3]

The following competency requirements are for public weather service (PWS) advisers who work in the area of disaster prevention and mitigation (DPM) and engage with the emergency management community and other relevant users (such as those involved in health, transport, energy and food safety). They build upon, and should be read in conjunction with, the fundamental WMO competency requirements for personnel in operational forecasting, although

[3] This framework is based on Resolution 13 (EC-69) – Amendment to the *Technical Regulations* (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices, public weather services provisions, and on the outcomes of the Joint Meeting of the Expert Team on Impact of Multi-hazard Prediction and Communication (ET/IMPACT) and the Expert Team on Services and Product Innovation and Improvement (ET/SPII) of the Commission for Basic Systems Open Programme Area Group on Public Weather Service Delivery (CBS/OPAG-PWSD), Beijing, China, November 2017.

it is recognized that some people working in liaison and outreach in emergency management may not come from a forecasting background. In such cases, the PWS adviser needs to work closely with operational forecasters to develop the products and services indicated in the following sections, taking into consideration the following conditions:

(a) The nationally defined PWS areas of responsibility;
(b) Meteorological and hydrological impacts on society;
(c) Meteorological and hydrological societal requirements, local procedures and priorities.

Competency requirements

A PWS adviser should be able to perform the work (in close association with the PWS forecaster, if need be) indicated under the following five top-level competencies:

1. Monitor continually the evolving meteorological and hydrological situation, updated forecasts and warnings and the impact of anticipated conditions;
2. Develop and adopt procedures and services to meet user needs and facilitate impact assessments;
3. Develop and manage relationships with users involved in DPM, and other stakeholders;
4. Communicate meteorological and hydrological information and impact assessments to internal and external users, and engage in outreach activities;
5. Ensure the quality of meteorological and hydrological information and services.

Each of these top-level competencies is expanded into performance criteria that are expressed and structured in such a manner as to facilitate the clear application of an assessment procedure. The competencies are built upon a range of enabling skills, such as skills and knowledge in numerical weather prediction (NWP), and transferable skills, for example, workplace skills that are not exclusive to meteorology, such as problem solving and people management. Each top-level competency is also associated with a range of background knowledge and skills that are essential to the discharge of the defined duties.

COMPETENCY 1: MONITOR CONTINUALLY THE EVOLVING METEOROLOGICAL AND HYDROLOGICAL SITUATION, UPDATED FORECASTS AND WARNINGS AND THE IMPACT OF ANTICIPATED CONDITIONS

Competency description

Observations and forecasts of meteorological/hydrological parameters and significant meteorological/hydrological phenomena are continuously analysed and monitored, together with amendments and updates of forecasts and warnings. Assessments of the likely impact of anticipated conditions are developed and updated as required.

Performance criteria

1. Monitor meteorological/hydrological parameters and evolving significant meteorological/hydrological phenomena, and validate current forecast and warnings on the basis of these parameters;
2. Monitor information relating to the impact of meteorological and hydrological events.

Background knowledge and skills

- Understanding of the key elements of synoptic, dynamical and physical meteorology, and core analytical and diagnostic skills;
- Application of the theory, methods and practices of meteorological and hydrological analysis and diagnosis;

- Ability to visualize and conceptualize meteorological and hydrological information in multiple dimensions (spatial, temporal);
- Appreciation of the influence of topography, land cover and, if relevant, bodies of water and snow fields on local meteorology;
- Interpretation of in-situ and remote-sensed observations and data;
- Understanding of the characteristics of meteorological and hydrological sensors and instruments;
- Familiarity with the acquisition, processing and assimilation of meteorological and hydrological data, including quality control;
- Understanding of procedures, standards and technical regulations regarding observations and forecast products;
- Understanding of sector-specific activities and vulnerabilities affected by meteorological and hydrological events.

COMPETENCY 2: DEVELOP AND ADOPT PROCEDURES AND SERVICES TO MEET USER NEEDS AND FACILITATE IMPACT ASSESSMENTS

Competency description

Procedures and services that facilitate impact assessment based on meteorological and hydrological information are developed and improved in line with the needs of users, making full use of impact modelling and other techniques where these are available.

Performance criteria

1. Identify the meteorological and hydrological information requirements of the disaster management and civil protection community, and other users as required;
2. Tailor weather warning services for emergency management decision-makers and other users;
3. Ensure that warning dissemination schedules and related services meet the decision-making needs of emergency managers and other users;
4. Contribute to the development of very short-range forecasting and nowcasting services tailored to the emergency management community;
5. Contribute to the development of probabilistic forecast products tailored to the needs of disaster managers and other users;
6. Contribute to the development of impact-based forecast and warning products;
7. Apply new technology and scientific research in contributing to the development of Multi-hazard Early Warning Systems (MHEWS).

Background knowledge and skills

- Knowledge of available meteorological and hydrological information, products and services to support disaster management, the civil protection community and other users;
- Knowledge of methodologies for understanding and development of user requirements;
- Knowledge of risk assessment and how it applies to various sectors;
- Understanding of how meteorological and hydrological risks may have an impact on various sectors as a function of vulnerability and exposure;
- Skill in adapting current meteorological and hydrological products and services to value-added services for disaster management and other users;
- Knowledge of the strengths and limitations of NWP models;
- Knowledge of developments and innovations in NWP and how they may apply to meteorological and hydrological impact-based services.

COMPETENCY 3: DEVELOP AND MANAGE RELATIONSHIPS WITH USERS INVOLVED IN DISASTER PREVENTION AND MITIGATION, AND OTHER STAKEHOLDERS

Competency description

Relationships with users in the emergency management and related communities are developed and maintained to support the ready identification of user needs and requirements and changes to these over time. Relationships with users are formalized through appropriate agreements where necessary.

Performance criteria

1. Establish and maintain working relationships at strategic, operational and technical levels with the emergency management community;
2. Develop and implement partnership agreements at operational and technical levels with relevant agencies;
3. Build and maintain relationships with the media to facilitate communication of warnings and information prior to, during and after high-impact meteorological and hydrological events;
4. Build and maintain relationships between the NMHS and relevant agencies to improve emergency planning, preparedness for and response to high-impact meteorological and hydrological events, including specific urban needs where appropriate;
5. Contribute to the development of response advice and call-to-action statements on the basis of the potential impact of hazards, in close coordination with relevant agencies as appropriate;
6. Participate in the assessment of the socioeconomic impact of meteorological and hydrological events, in collaboration with relevant experts.

Background knowledge and skills

- Knowledge of methodologies for development of partnerships and memorandums of understanding;
- Knowledge of available meteorological and hydrological information, products and services to support disaster management, the civil protection community and other users;
- Understanding of the priorities and operational systems of relevant agencies;
- Understanding of the principles of communication regarding the development of advice and statements addressing the potential impact of hazards;
- Understanding of the vulnerabilities of various sectors and how these may be affected by meteorological and hydrological events.

COMPETENCY 4: COMMUNICATE METEOROLOGICAL AND HYDROLOGICAL INFORMATION AND IMPACT ASSESSMENTS TO INTERNAL AND EXTERNAL USERS, AND ENGAGE IN OUTREACH ACTIVITIES

Competency description

User requirements are fully understood and are addressed by communicating concise and relevant meteorological information and impact assessments in a manner that can be clearly understood by users. Preparedness of user communities is addressed through training and other outreach initiatives.

Performance criteria

1. Contribute to dissemination of warnings through utilization of current and emerging communication technologies;

2. Communicate meteorological and hydrological information to users, in particular disaster management decision-makers and the media, including the scope and limitations of forecasts and warnings, the concept of forecast uncertainty, and information on potential impacts;
3. Contribute to the development of a communication strategy to ensure credibility of, and effective response to, warnings of high-impact meteorological and hydrological events;
4. Promote community awareness and preparedness for high-impact meteorological and hydrological events through public education and outreach.

Background knowledge and skills

- Knowledge of protocols for presenting and communicating warning information to emergency management partners and the media, including information on likely impacts and mitigation activities if relevant;
- Knowledge of standards, procedures and dissemination platforms for the presentation of forecasts and warnings to end users across all relevant media, including impact information as required;
- Knowledge of the authoritative sources of meteorological, hydrological, impact and mitigation information concerning hazardous phenomena;
- Awareness of the application of meteorology and hydrology to human activities for specific users;
- Awareness of the use of meteorological and hydrological information and related user needs;
- Awareness of social science research and findings relevant to the communication of warnings and impact-based meteorological and hydrological information;
- Appreciation of the strengths and weaknesses of the communication media employed.

COMPETENCY 5: ENSURE THE QUALITY OF METEOROLOGICAL AND HYDROLOGICAL INFORMATION AND SERVICES

Competency description

The quality of meteorological and hydrological forecasts, warnings, impact assessments, and related products is maintained through the application of quality management systems processes where appropriate.

Performance criteria

1. Apply the organization's quality management system and procedures;
2. Monitor and assess the effectiveness of warnings of high-impact meteorological and hydrological events through user-based feedback;
3. Work with disaster management agencies and others to strengthen the role of NMHSs as the single authoritative voice for warnings of high-impact meteorological and hydrological events;
4. Contribute to the development of documentation and archiving systems for meteorological and hydrological hazard and impact data, including quality assurance and data management;
5. Collaborate with disaster management agencies and others in the development of post-event assessments of high-impact meteorological and hydrological events;
6. Contribute to outreach and training initiatives particularly those relevant to DPM activities.

Background knowledge and skills

- Knowledge of quality management system processes;

- Knowledge of methodologies for the development, delivery and assessment of user-feedback surveys;
- Knowledge of procedures in documentation and archiving systems;
- Knowledge of verification processes;
- Knowledge of operating and contingency procedures of NMHSs and other relevant agencies;
- Understanding metrics and methods used in developing post-assessments/case studies and verification.

2.2 COMPETENCY STANDARDS FOR AERONAUTICAL METEOROLOGICAL PERSONNEL

The following guidance supplements the competency standards for aeronautical meteorological personnel endorsed by the World Meteorological Congress at its nineteenth session, in May/June 2023, and laid out in the *Technical Regulations* (WMO-No. 49), Volume I, Part V.

The competency standards listed below apply to aeronautical meteorological forecasters and observers, taking into consideration the following conditions:

(a) The area and airspace of responsibility;
(b) The impact of meteorological and/or other relevant environmental phenomena and parameters on aviation operations;
(c) Compliance with aviation user requirements, international regulations, local procedures and priorities.

Regional variations

The importance of the conditions above is emphasized. There will be considerable variation in the legitimate functions of aeronautical meteorological offices and centres worldwide, and it is not possible to write a document that exactly matches the functions of every office or centre. Therefore, the performance criteria should be applied in a way that is consistent with these variations. For example, it is recognized that aeronautical meteorological offices in the tropics will not be responsible for forecasting blowing snow (performance criterion 2.1). The conditions (a), (b) and (c) provide for this.

It is intended that the responsibility for meeting the top-level competency standards will, in the first instance, rest with the organization to which the aeronautical meteorological personnel belongs. The responsibility of the individual will then be to meet (or exceed) the particular competencies which apply to his or her specific job within the organization (usually specified in terms of a job description).

Note: In this context, the word "organization" is being used to denote the aeronautical meteorological service provider of the WMO Member concerned. The aeronautical meteorological service provider may be a National Meteorological and Hydrological Service (NMHS) or a non-NMHS entity, as designated by the meteorological authority of the WMO Member.

In some organizations, the competencies may be collectively satisfied by a team or by several groups. In such cases, the organization is responsible for ensuring that each individual does his or her part of the job to the required standard so that the top-level competency standards are met.

The role of aeronautical meteorological personnel will continue to change in response to evolving technology and user requirements, and that in itself will also likely require high standards of competency and underlying knowledge definition. The guidelines presented here attempt to anticipate imminent changes as far as possible, but a review cycle of not more than 3–5 years is strongly recommended as part of the overall quality management and risk management approach.

The organization is responsible for managing a programme of competency assessments to ensure that competency standards are maintained. It is important that the programme is integrated into the organization's quality management system.

The level of qualification(s) necessary to underpin the required competencies of operational aeronautical meteorological forecasters is to be consistent with the relevant educational frameworks, background skills and knowledge requirements described in the Basic Instruction Package for Meteorologists (BIP-M). Information on the BIP-M is described in the *Technical Regulations* (WMO-No. 49), Volume I, Part V. Qualifications and Competencies of Personnel Involved in the Provision of Meteorological, Climatological, Hydrological, Marine and Related Environmental Services.

The aeronautical meteorological service provider is expected to record evidence that the aeronautical meteorological personnel responsible for the provision of its services have completed the necessary formal learning or courses of study to demonstrate they possess the background skills and knowledge as described in the relevant competency framework.

The WMO Aviation Training Repository[4] is a resource designed to provide aeronautical meteorology training and guidance material sourced from around the world. The repository's content covers both operational and non-operational aspects of aeronautical meteorology, including quality management, regulatory issues, conferences, seminars and workshops, as well as source material in different languages. The repository has played a key role in assisting organizations with changes such as the implementation of a competency assessment for aeronautical meteorological personnel. The repository includes frequently asked questions and discussion forums, where registered users can ask questions, participate in discussions and share resources and expertise.

2.2.1 Aeronautical Meteorological Forecaster

Competency standards

An aeronautical meteorological forecaster should be able to perform the tasks specified under the following top-level competency standards:

1. Analyse and continually monitor meteorological and/or other relevant environmental situations;
2. Forecast meteorological and/or other relevant environmental phenomena and parameters;
3. Warn of hazardous meteorological and/or other relevant environmental phenomena;
4. Ensure the quality of meteorological and/or other relevant environmental information and services supplied to users;
5. Communicate meteorological and/or other relevant environmental information to internal and external users.

Notes:

1. Other relevant environmental situations, phenomena, parameters and information in this context may include, for example, the presence of volcanic ash, the release of radioactive material or toxic chemicals into the atmosphere and space weather.
2. An aeronautical meteorological forecaster in this context may be, for example, a person responsible for providing aeronautical meteorological service at an aerodrome meteorological office (which may or may not be located at an aerodrome), a meteorological watch office, a world area forecast centre, a volcanic ash advisory centre, a tropical cyclone advisory centre or a space weather centre.

[4] https://aviationtraining.wmo.int

COMPETENCY 1: ANALYSE AND CONTINUALLY MONITOR METEOROLOGICAL AND/OR OTHER RELEVANT ENVIRONMENTAL SITUATIONS

Competency description

Observations and forecasts of meteorological phenomena, in particular significant weather, and/or other relevant environmental phenomena and parameters are continually monitored during hours of operation to determine the need for issuance, cancellation or amendment/update of forecasts, warnings and alerts according to documented thresholds and regulations.

Performance criteria

1. Analyse and diagnose[5] meteorological and/or other relevant environmental situations as required in forecast, warning and alert preparation;
2. Monitor meteorological phenomena, in particular significant weather, and/or other relevant environmental phenomena and parameters, and validate current forecasts, warnings and alerts based on these parameters;
3. Appraise the need for amendments to forecasts and updates of warnings and alerts against documented criteria and thresholds.

Background knowledge and skills

- Mechanisms generating different types of cloud and precipitation, and local mechanisms enhancing cloud and precipitation;
- Topographic influences on cloud, precipitation, fog and visibility, in typical wind and moisture regimes;
- Interpretation of:
  - Radar, lidar, wind profiler and satellite imagery to identify fog and stratus, gravity waves in cirrus cloud and jet streams, inference of icing potential in layer cloud, and of volcanic ash and wind shear;
  - Numerical weather prediction (NWP) guidance and other forms of objective guidance, to be incorporated into forecasts, warnings and alerts;
  - Observed parameters when variations result from differences between automatic sensor technologies and manual observing techniques;
- The International Standard Atmosphere (ISA);
- Meteorological and/or other relevant environmental monitoring and observing technologies, and forecasting techniques in use at the service provider;
- Common terms relevant to aeronautical meteorology, including:
  - (Special) Visual and instrument Flight rules and conditions;
  - Flight Information Region (FIR) and, where used, Functional Airspace Block (FAB);
  - Final approach, missed approach;
  - Cruising and transition level, transition layer, transition altitude, flight level;
  - Minimum safe altitude (MSA), indicated altitude, true altitude;
  - Category I, II and III aerodrome operations, Aeronautical Information Publication (AIP);
  - NOTAMs/ASHTAMs;
  - ATIS/VOLMET;
- International Civil Aviation Organization (ICAO) location indicators and/or WMO synoptic station numbers, particularly for aerodromes or stations that lay within and near the area of responsibility.

[5] "Analysis" may be defined as answering the question "what is happening?", and "diagnosis" as answering "why is it happening?"

COMPETENCY 2: FORECAST METEOROLOGICAL AND/OR OTHER RELEVANT ENVIRONMENTAL PHENOMENA AND PARAMETERS

Competency description

Forecasts of meteorological and/or other relevant environmental phenomena and parameters are prepared and issued in accordance with documented requirements, priorities and deadlines.

Performance criteria

1. Forecast the following meteorological and/or other relevant environmental phenomena and parameters:
   - Temperature and relative humidity;
   - Wind, including temporal and spatial variability (wind shear, directional variability and gusts);
   - QNH;
   - Cloud (type, amount, height of cloud base and vertical extent);
   - Precipitation (type, amount, intensity and temporal variations, onset and cessation or duration) and associated visibility;
   - Fog or mist, including onset and cessation or duration, and associated reduced visibility;
   - Other types of obscuration, including dust, smoke, haze, sandstorms, dust storms, blowing snow and associated visibility;
   - Hazardous meteorological and/or other relevant environmental phenomena listed under Competency 3 below;
   - Wake vortex advection and dissipation, as required;

2. Ensure that forecasts are prepared and issued in accordance with ICAO Annex 3 to the Convention on International Civil Aviation – *Meteorological Service for International Air Navigation* (ICAO Annex 3), ICAO *Procedures for Air Navigation Services – Meteorology* (ICAO PANS-MET, Doc 10157), regional and national formats, codes and technical regulations on content, accuracy and timeliness;

3. Ensure that forecasts of meteorological and/or other relevant environmental phenomena and parameters are consistent (spatially and temporally) across boundaries of the area of responsibility as far as practicable, while maintaining meteorological integrity. This will include monitoring forecasts, warnings and alerts issued for other locations or regions as well as liaising with adjacent locations or regions as required.

Background knowledge and skills

- The formation and dissipation, characteristics, occurrence and effects of fog and other forms of obscuration and low-level cloud, and associated diagnostic and prognostic parameters;
- Formation mechanisms and characteristics of other aeronautical meteorological phenomena, such as dust storms, sandstorms, dust devils and funnel clouds (tornadoes or waterspouts);
- Local topography and its effects on weather, such as gap flows, downslope windstorms, orographic turbulence, sea breezes and upslope fog;
- Ability to interpret all observational products (for example, Aerodrome Routine Meteorological Reports (METAR)) and encode forecast products (for example, Terminal Aerodrome Forecasts (TAF)) into Traditional Alphanumeric Codes (TAC) or other required formats;
- Aerodrome climatology, including frequency of occurrence of significant cloud, thunderstorms, precipitation, strong winds, low-level wind shear, reduced visibility, fog and other phenomena;

- Local forecasting guides and techniques, including diagnostic and prognostic parameters, for forecasting significant cloud, thunderstorms, turbulence, aircraft icing, precipitation, strong winds, low-level wind shear, reduced visibility, fog and other phenomena;
- International, national and local aeronautical forecast, warning and monitoring procedures, directives and instructions;
- Local diagnostic and forecast tools and aeronautical forecast preparation systems, including basic operating system functions, data processing and visualization technologies;
- Relevant ICAO and WMO documents, including ICAO Annex 3, ICAO PANS-MET (Doc 10157), the ICAO *Manual of Aeronautical Meteorological Practice* (Doc 8896) and the *Manual on Codes* (WMO-No. 306);
- ICAO, WMO and national aeronautical meteorological codes and forms of data representation;
- Aviation user requirements, including:
  - The effects on aircraft performance of air density, humidity, icing, low-level wind shear, turbulence and wind, and the meteorological factors related to fuel consumption;
  - The requirements for en route wind, temperature and significant weather forecasts and aerodrome forecasts for pre-flight planning and in-flight re-planning;
  - Meteorological aspects of flight planning; definitions; procedures for meteorological services for international air navigation; types of meteorological information required for Air Traffic Services (ATS), aerodrome control towers, approach/area control and flight information centres;
  - Low-visibility runway operating procedures;
  - Effects of unfavourable meteorological and/or other relevant environmental conditions on aviation operations, including air traffic disruption, holding and diversions;
  - Meteorological effects on aerodrome ground services, such as snow clearance, the effect of wet runways, and the effect of thunderstorms and strong winds on apron operations;
  - Aerodrome operating minima, the need for alternates and impacts on fuel consumption;
  - Altimeter setting procedures.

COMPETENCY 3: WARN OF HAZARDOUS METEOROLOGICAL AND/OR OTHER RELEVANT ENVIRONMENTAL PHENOMENA

Competency description

Warnings are issued in a timely manner when hazardous meteorological and/or other relevant environmental phenomena are occurring, expected to occur or when parameters are expected to reach documented threshold values. They are updated or cancelled according to documented warning criteria.

Performance criteria

1. Forecast the following hazardous meteorological and/or other relevant environmental phenomena, including spatial extent, onset and cessation, duration, and intensity and its temporal variations:
   - Thunderstorms, particularly organized systems, including associated turbulence, in-flight icing, hail, heavy precipitation with poor visibility, electrical phenomena, downburst and microburst or gust front and tornadic activity (funnel cloud as tornado or waterspout);
   - Turbulence (moderate or greater) including type (orographic, mechanical, convective and clear air turbulence (CAT));
   - Moderate and severe low-level wind shear;
   - Aircraft icing (moderate or greater) including accumulation rate (if known), spatial extent, type (rime or opaque, glaze or clear, freezing rain, hoar frost, mixed ice, ingested high-altitude ice crystals);

- Height of cloud base and/or surface visibility below aerodrome minima, affecting take-off, landing and approach procedures;
- Hazardous phenomena affecting aerodromes such as strong surface winds including cross-winds and squalls, frost, freezing precipitation, snowfall, lightning and wake vortices;
- Sandstorms and dust storms;
- Volcanic ash on the basis of observations, reports and/or advisory products;
- Tropical cyclones;
- Radioactive cloud;

2. Ensure that warnings are prepared and issued in accordance with thresholds for hazardous meteorological and/or other relevant environmental phenomena, and with ICAO Annex 3, *ICAO PANS-MET (Doc 10157)*, regional and national formats, codes, and technical regulations on content, accuracy and timeliness;

3. Ensure that warnings of hazardous meteorological and/or other relevant environmental phenomena are consistent (spatially and temporally) across boundaries of the area of responsibility as far as practicable, while maintaining meteorological integrity. This will include monitoring forecasts and warnings issued for other locations and regions as well as liaising with adjacent locations or regions as required.

Background knowledge and skills

- Knowledge of volcanic eruptions, volcanic ash cloud displacement, dispersion and/or re-suspension;
- Areas of likely volcanic activity, especially within the region of responsibility (for offices with responsibility for issuing volcanic ash advisories and warnings and offices located close to or downwind of volcanoes);
- Meteorological hazards to aviation operations, including thunderstorms and associated phenomena, aircraft icing, turbulence, low visibility, low-level cloud, tropical cyclones, wind shear and volcanic ash;
- The generation mechanisms of low-level jet streams, boundary layer turbulence and gusts, and their effects on aircraft performance;
- Ability to interpret all observational products (for example, METAR), and encode forecast products (for example, TAF) into TAC or other required formats;
- Aerodrome climatology, including occurrence of significant cloud, thunderstorms, precipitation, strong winds, low-level wind shear, reduced visibility, fog and other phenomena;
- Local forecasting guides and techniques, including diagnostic and prognostic parameters, for forecasting significant cloud, thunderstorms, turbulence, aircraft icing, precipitation, strong winds, low-level wind shear, reduced visibility, fog and other phenomena;
- International, national and local aeronautical forecast, warning and monitoring procedures, directives and instructions;
- Local diagnostic and forecast tools and aeronautical forecast preparation systems, including basic operating system functions, data processing and visualization technologies;
- The significance of warning thresholds on aviation operations, and the ability to describe the likely impact of warnings of hazardous meteorological and/or other relevant environmental phenomena on these aviation operations;
- Relevant ICAO and WMO documents, including ICAO Annex 3, ICAO PANS-MET (Doc 10157), the ICAO *Manual of Aeronautical Meteorological Practice* (Doc 8896) and the *Manual on Codes* (WMO-No. 306);
- ICAO, WMO and national aeronautical meteorological codes and forms of data representation;
- Aviation user requirements, including:
  - The effects on aircraft performance of air density, humidity, icing, low-level wind shear, turbulence and wind, and the meteorological factors related to fuel consumption;
  - The requirements for en route wind, temperature and significant weather forecasts and aerodrome forecasts for pre-flight planning and in-flight re-planning;

  - Meteorological aspects of flight planning; definitions; procedures for meteorological services for international air navigation; types of meteorological information required for ATS, aerodrome control towers, approach and area control, and flight information centres;
  - Low-visibility runway operating procedures;
  - Effects of unfavourable meteorological and other relevant environmental conditions on aviation operations, including air traffic disruption, holding and diversions;
  - Meteorological and other environmental effects on aerodrome ground services, such as volcanic ash and snow clearance, the effect of wet runways, and the effect of thunderstorms and strong winds on runway and apron operations;
  - Aerodrome operating minima, the need for alternates and impacts on fuel consumption;
  - Altimeter setting procedures.

COMPETENCY 4: ENSURE THE QUALITY OF METEOROLOGICAL AND/OR OTHER RELEVANT ENVIRONMENTAL INFORMATION AND SERVICES SUPPLIED TO USERS

Competency description

The quality of meteorological and/or other relevant environmental forecasts, warnings, alerts and related services is ensured at the required level by the application of documented quality management processes.

Performance criteria

1. Apply the organization's quality management system and procedures;
2. Assess the impact of known observational error characteristics (for example, bias and achievable accuracy of observations and sensing methods) on forecasts, warnings and alerts;
3. Validate meteorological and/or other relevant environmental data and information, forecasts, warnings and alerts (timeliness, completeness, accuracy) using real-time checks;
4. Monitor the functioning of operational systems and take remedial actions when necessary.

Background knowledge and skills

- International, national and local forecast, warning and monitoring procedures, directives and instructions;
- Local diagnostic and forecast tools and forecast preparation systems, including basic operating system functions, data processing and visualization technologies;
- Applicable forecast verification scheme(s) and verification statistics;
- Quality management systems;
- Aviation safety management systems, as required;
- Standards (as defined in ICAO Annex 3 and PANS-MET (Doc 10157)) and quality management system procedures (as defined in ISO 9001 standards and national regulations):
  - Procedures for checking, identifying and correcting errors and omissions;
  - Methods for identifying significant differences between factual and forecast data;
  - Knowing when to ignore information and where to go to resolve points of contention;
  - Desirable accuracy of forecasts as stipulated in ICAO PANS-MET (Doc 10157) and national regulations;
  - Priorities and schedules;
  - Actions to be taken in the event of recurrent discrepancies, inconsistencies and malfunctions;
  - Fall-back procedures in the case of computer or other such system failure;
  - Contingency arrangements in case of emergencies such as fire alarms, bomb alerts and natural disasters.

COMPETENCY 5: COMMUNICATE METEOROLOGICAL AND/OR OTHER RELEVANT ENVIRONMENTAL INFORMATION TO INTERNAL AND EXTERNAL USERS

Competency description

User requirements are fully understood and are addressed by communicating concise and complete forecasts, warnings and alerts in a manner that can be clearly understood by the users.

Performance criteria

1. Ensure that all forecasts, warnings and alerts are disseminated through the authorized communication means and channels to designated user groups;
2. Explain[6] meteorological and/or other relevant environmental data and information to users in a clear and concise manner using suitable terminology, and provide briefings and consultations that meet specific user needs.

Background knowledge and skills

- Ability to carry out a routine, high-quality self-briefing, which may include a shift handover briefing, of the recent and current weather situation, and to integrate all available data to produce a consolidated diagnosis;
- Ability to explain the meteorological and procedural reasons behind a forecast, warning or alert decision;
- Likely impact of forecasts of meteorological and/or other relevant environmental parameters and phenomena on aviation operations;
- Use and interpretation of information issued by World Area Forecast Centres (WAFCs), Volcanic Ash Advisory Centres (VAACs), Tropical Cyclone Advisory Centres (TCACs) and other designated centres;
- Means of dissemination of meteorological data and information to users;
- Use of aeronautical meteorological telecommunications.

Regional variations

- Locally agreed and documented criteria and thresholds;
- The range of meteorological and/or other relevant environmental phenomena;
- Risk assessment and estimation of forecast uncertainties;
- Types and use of forecast guidance;
- Designated offices responsible for advice on volcanic ash, tropical cyclones and other phenomena;
- Regional and local regulations;
- Boundaries of forecast areas;
- Extent, scope and exclusions of quality management system implementation;
- Communication language(s);
- Communication technology for forecast, warning and alert transmission, and for flight briefing.

2.2.2 Aeronautical Meteorological Observer

Competency standards

An aeronautical meteorological observer should be able to perform the tasks specified under the following top-level competency standards.

1. Continually monitor the meteorological and/or other relevant environmental situation;

[6] In accordance with any language proficiency requirements stipulated by the national regulator.

2. Observe and record meteorological and/or other relevant environmental phenomena and parameters;
3. Ensure the quality of the observing system performance and of meteorological and/or other relevant environmental information supplied to users;
4. Communicate meteorological and/or other relevant environmental information to internal and external users.

Notes:

1) Other relevant environmental situations, phenomena, parameters and information in this context may include, for example, the presence of volcanic ash.
2) An aeronautical meteorological observer in this context may be, for example a person responsible for providing an aeronautical meteorological service at an aeronautical meteorological station or a State volcano observatory.

COMPETENCY 1: CONTINUALLY MONITOR THE METEOROLOGICAL AND/OR OTHER RELEVANT ENVIRONMENTAL SITUATION

Competency description

Meteorological and/or other relevant environmental phenomena and parameters are continually monitored during hours of operation to identify the significant and evolving meteorological and/or other relevant environmental phenomena that are affecting or will likely affect the area of responsibility (typically, but not exclusively, the aerodrome and its vicinity).

Performance criterion

Analyse and describe the current local meteorological and/or other relevant environmental conditions.

Background knowledge and skills

- Key characteristics of the troposphere and tropopause;
- Properties of air pressure, temperature, density and water vapour;
- Atmospheric stability, inversions;
- Generation mechanisms of wind;
- Fog and cloud formation and dissipation;
- Precipitation types and intensity;
- The general circulation of the Earth's atmosphere;
- The International Standard Atmosphere (ISA);
- Characteristics, occurrence and effects of meteorological and/or other relevant environmental hazards to aviation, including but not limited to low cloud, low visibility, thunderstorms and associated phenomena, aircraft icing, freezing precipitation, turbulence, tropical cyclones, wind shear and volcanic ash;
- Interpretation of surface-weather maps, satellite and radar imagery, and seamless prediction system outputs;
- Region-specific meteorological and/or other relevant environmental phenomena and likely weather sequences that are expected to affect the station;
- Nowcasting for severe weather and/or other relevant environmental phenomena;
- Local topography and climatology, including local reference points;
- ICAO location indicators and WMO synoptic station numbers, particularly for aerodromes and stations that lay within and close to the area of responsibility.

COMPETENCY 2: OBSERVE AND RECORD METEOROLOGICAL AND/OR OTHER RELEVANT ENVIRONMENTAL PHENOMENA AND PARAMETERS

Competency description

Observations of meteorological and/or other relevant environmental phenomena and parameters, and their significant changes, are recorded according to documented thresholds and regulations.

Performance criteria

1. As applicable, perform and record routine and non-routine (special) observations of the following:
   - Surface wind direction and speed, including spatial and temporal variations;
   - Visibility for aeronautical purposes, including spatial and temporal variations;
   - Runway visual range (RVR), including spatial and temporal variations;
   - Present weather phenomena (as defined in ICAO Annex 3);
   - Cloud amount, cloud type and height of cloud base, including spatial and temporal variations;
   - Vertical visibility;
   - Air temperature and dewpoint temperature;
   - Atmospheric pressure; determining QFE and QNH;
   - Supplementary information concerning significant meteorological and/or other environmental conditions, particularly those in the approach and climb-out areas such as wind shear;

2. Interpret meteorological and/or other environmental parameters derived from automatic observing systems, such as lidar and weather radar, to ensure that observations remain representative of local conditions when differences occur between automatic sensor technologies and manual observing techniques;

3. Ensure that observations are prepared and issued in accordance with ICAO Annex 3, ICAO PANS-MET (Doc 10157), regional and national formats, codes and technical regulations on content, representativeness and timeliness.

Background knowledge and skills

- Procedures for performing routine and non-routine (special) aeronautical meteorological observations and reports;
- The impact of meteorological and/or other relevant environmental conditions on aircraft performance and airport operations;
- Strengths and weaknesses of manual observations and automatic observing systems;
- Observer directives, procedures and instructions;
- Validated sources of meteorological and/or other relevant environmental information;
- Quality management systems;
- Aviation safety management systems, as required;
- Relevant ICAO and WMO documents, including ICAO Annex 3, ICAO PANS-MET (Doc 10157), the ICAO *Manual of Aeronautical Meteorological Practice* (Doc 8896), the ICAO *Manual on Automatic Meteorological Observing Systems at Aerodromes* (Doc 9837) and the *Manual on Codes* (WMO-No. 306);
- ICAO definitions of relevance to meteorology;
- WMO Traditional Alphanumeric Codes (TAC), national aeronautical meteorological codes and other forms of data representation.

COMPETENCY 3: ENSURE THE QUALITY OF THE OBSERVING SYSTEM PERFORMANCE AND OF METEOROLOGICAL AND/OR OTHER RELEVANT ENVIRONMENTAL INFORMATION SUPPLIED TO USERS

Competency description

The quality of meteorological and/or other relevant environmental observations is ensured at the required level by the application of documented quality management processes.

Performance criteria

1. Apply the organization's quality management system and procedures;
2. Check and confirm the quality of meteorological and/or other relevant environmental observations before issuance, including relevance of content, time of validity and location of phenomena;
3. In accordance with prescribed procedures:
    - Identify errors and omissions in meteorological and/or other relevant environmental observations;
    - Correct and report errors and omissions;
    - Make and disseminate corrections in a timely manner.

Background knowledge and skills

- Standards (as defined in ICAO Annex 3 and ICAO PANS-MET (Doc 10157)) and quality management system procedures (as defined in ISO 9001 standards and national regulations):
- Procedures for checking, identifying and correcting errors and omissions (in automatically- and manually-derived data);
- Methods for identifying significant differences between observational and forecast data;
- Knowing when to ignore information and where to go to resolve points of contention;
- Desirable accuracies of measurement and observation as in ICAO PANS-MET (Doc 10157) and national regulations;
- Priority tasks and time constraints;
- Action to be taken in the event of recurrent discrepancies, inconsistencies and malfunctions;
- Fall-back procedures in the case of computer or other such system failure;
- Contingency arrangements in case of emergencies such as fire alarms, bomb alerts and natural disasters.

COMPETENCY 4: COMMUNICATE METEOROLOGICAL AND/OR OTHER RELEVANT ENVIRONMENTAL INFORMATION TO INTERNAL AND EXTERNAL USERS

Competency description

All meteorological and/or other relevant environmental data and information are concise, complete and communicated in a manner that will be clearly understood by the users.

Performance criteria

1. Ensure that all observations are disseminated through the authorized communication means and channels to designated user groups;
2. Present[7] meteorological and/or other relevant environmental data and information in a clear and concise manner using suitable terminology that will be clearly understood by the users;

[7] In accordance with any language proficiency requirements stipulated by the national regulator.

3. Alert forecasters to observed or imminent significant changes in meteorological and/or other relevant environmental conditions within the area of responsibility.

Background knowledge and skills

- Knowing how meteorological and/or other relevant environmental information is disseminated within and beyond the area of responsibility;
- Use of aeronautical meteorological telecommunications;
- Air Traffic Service meteorological requirements applicable to the area of responsibility;
- Flight planning meteorological requirements applicable to the area of responsibility;
- Specifications related to flight documentation, briefing and consultations appliable to the area of responsibility.

Regional variations

- The range of significant meteorological and/or other relevant environmental phenomena;
- Extent of automation of observing and sensing systems;
- Thresholds for significant changes in meteorological and/or other relevant environmental conditions;
- Local climatology;
- Extent, scope and exclusions of quality management system implementation;
- Regional regulations;
- Communication language(s);
- Available communication technologies.

2.3 EDUCATION AND TRAINING PROVIDERS

Introduction

The organizational training function within a National Meteorological and Hydrological Service (NMHS) or related agency may be accomplished by a variety of skilled personnel, including training managers, trainers, training developers and training support staff. Third-party organizations, such as universities, international and regional institutions and centres and private-sector companies may also provide education and training for those services.

This section sets out a competency framework for personnel involved in training. Even though it is not necessary for each person to have the full set of competencies, any institution providing education and training for current and future meteorologists and hydrologists should have staff somewhere within the organization who together cover all the competencies.

The application of the competency framework will depend on the following circumstances, which will be different for each organization:

(a) The organizational context and priorities, and stakeholder requirements;
(b) The way in which internal and external training resources are used;
(c) The available resources (financial, human and technological), facilities and capabilities, and the organizational structures, policies and procedures;
(d) National and institutional legislation, rules and procedures.

The performance criteria and knowledge requirements that support the competencies should be customized to fit the particular context of an organization. However, the general criteria and requirements provided here will apply in most circumstances.

The WMO competency requirements for education and training providers are supported by guidance material and trainer resources to help develop the competencies through self-study and curriculum planning for targeted courses. *Guidelines for Trainers in Meteorological, Hydrological*

and Climate Services (WMO-No. 1114) provides a high-level overview of the background knowledge required to meet each of the competency requirements in the framework. The WMO Trainer Resources Portal provides many more detailed resources, templates and examples in support of each competency. We suggest that Members use these resources and also the CALMet Commons portal for discussions and questions about the development of the competencies.

Competency requirements

1. Analyse the organizational context and manage the training processes;
2. Identify learning needs and specify learning outcomes;
3. Determine a learning solution;
4. Design and develop learning activities and resources;
5. Deliver training and manage the learning event;
6. Assess learning and evaluate the learning process.

COMPETENCY 1: ANALYSE THE ORGANIZATIONAL CONTEXT AND MANAGE THE TRAINING PROCESSES

Competency description

The organizational context is analysed and training plans, policies and processes are developed and monitored for effectiveness.

Performance criteria

1. Analyse the current and evolving organizational and learning contexts, taking into account (a) the organizational requirements, (b) how resources are made available and applied, (c) how strategic training plans are developed, and (d) how training procedures are implemented to comply with training plans, policies and processes;
2. Develop and implement a strategic training plan and an operational training plan;
3. Implement training procedures in accordance with training plans, policies and processes;
4. Monitor and update training plans, policies and processes to meet evolving needs and technological advances.

Knowledge requirements

To be able to understand, explain and critically evaluate:

- Factors causing change within an organization;
- Role of plans, policies and processes in supporting organizational change;
- Technologies required to support training;
- Role of quality assurance, financial management and promotion in managing the training process;
- Organizational, technological and research trends affecting the provision of training.

Personnel who should demonstrate this competency:

- Senior staff who have overall responsibility for training;
- Training managers;
- Trainers who would benefit from having some awareness of the context in which they are operating;
- People who make decisions about overall human resources development strategies.

COMPETENCY 2: IDENTIFY LEARNING NEEDS AND SPECIFY LEARNING OUTCOMES

Competency description

A systematic approach is used to identify organizational and/or individual learning needs which are then specified in terms of a set of learning outcomes.

Performance criteria

1. Apply a systematic approach to specifying job competencies and performing learning needs analysis;
2. Base the identification of learning needs on job tasks or the existing competency framework;
3. Identify organizational and/or individual performance gaps that are due to learning deficits;
4. Specify learning needs that take account of organizational and individual requirements, the views of stakeholders and external factors;
5. Set learning outcomes in collaboration with stakeholders so that, if the outcomes are achieved, learners will be able to perform the job at the required level.

Knowledge requirements

To be able to understand, explain and critically evaluate:

- Why learning needs occur and the benefits of learning needs analysis;
- Sources of performance gaps not related to knowledge, skills or behaviour (organization, motivation, management, tools and procedures);
- How to carry out competency definition and learning needs analysis;
- Sources of data and techniques used to identify learning needs;
- Ways of classifying learning outcomes.

Personnel who should demonstrate this competency:
- Training managers;
- Trainers who would benefit from knowing how learning needs are identified within their organization;
- Line managers who carry out their own learning needs analysis before seeking the assistance of the learning professionals in addressing those needs.

COMPETENCY 3: DETERMINE A LEARNING SOLUTION

Competency description

The learning solution is determined and a plan is prepared for implementing the chosen solution.

Performance criteria

1. Assess learning solutions in terms of costs, organizational and learner characteristics, resource implications and the extent to which they satisfy all the required learning outcomes;
2. Choose a learning solution that meets requirements and fits constraints;
3. Consider a wide range of potential solutions, including using a mixture of formal, semi-formal and informal learning methods;
4. Prepare a plan to implement the chosen solution, including time frame, costs, location and technology, personnel, targeted learners and evaluation criteria.

Knowledge requirements

To be able to understand, explain and critically evaluate:

- How the nature of the learning outcomes and organizational requirements help determine a learning solution;
- Types of formal, semi-formal and informal learning methods that might form part of a learning solution;
- Strengths, weaknesses and appropriate uses of learning methods that are part of a learning solution;
- Key components of an implementation plan.

Personnel who should demonstrate this competency:

- Senior trainers;
- Instructional designers or other education specialists;
- Trainers who would benefit from awareness of different learning solutions and of the factors taken into account in choosing those solutions.

COMPETENCY 4: DESIGN AND DEVELOP LEARNING ACTIVITIES AND RESOURCES

Competency description

The design and development of learning activities and resources are grounded in evidence-based learning theory, support the learning process and address the specified learning outcomes.

Performance criteria

1. Design learning activities on the basis of established instructional theory and the characteristics of learners in the workplace;
2. Take account of the strengths and limitations of the learning activities that could be part of the learning experience;
3. Use learning activities that include authentic tasks, build upon the prior knowledge of learners and provide opportunities for practising the required skills;
4. Prepare presentations and learning resources;
5. Choose the technology and software required for learning solutions;
6. Follow a structured development process when preparing learning resources.

Knowledge requirements

To be able to understand, explain and critically evaluate:

- Characteristics of learners in the workplace and various categorizations of learning styles;
- Characteristics of trainer-centred and learner-centred instruction;
- How to plan a learning session and the sequencing of learning;
- Instructional strategies and applications of instructional theory;
- Strengths and limitations of various learning methods;
- How to design presentations, slides and other learning resources;
- How to develop self-paced learning resources;
- Development processes for instructional resources;
- Use of software packages and technology;
- How people acquire knowledge and build skills.

Personnel who should demonstrate this competency:

- Senior trainers who lead the design process;
- Instructional designers or other education specialists;
- Trainers who would benefit from an awareness of the issues related to instructional design.

COMPETENCY 5: DELIVER TRAINING AND MANAGE THE LEARNING EVENT

Competency description

Classroom and distance-learning courses are delivered in an environment that fosters and sustains learning.

Performance criteria

1. Create an environment conducive to learning;
2. Ensure learning activities are engaging and effective;
3. Clearly communicate the purpose and expected outcomes of learning activities;
4. Apply technologies that aid the learning process;
5. Give feedback and manage and mitigate disruptions to learning.

Knowledge requirements

To be able to understand, explain and critically evaluate:

- What preparation and decisions are needed before a learning event;
- How to create an environment that supports learning;
- How to develop mutual trust and respect between trainers and learners;
- How to give presentations and conduct learning exercises;
- How to listen, question and give feedback;
- How to deal with conflict.

Personnel who should demonstrate this competency:

- All trainers and training managers.

COMPETENCY 6: ASSESS LEARNING AND EVALUATE THE LEARNING PROCESS

Competency description

Learning is assessed against the required learning outcomes, and training activities, events and programmes are monitored and evaluated to improve learning processes.

Performance criteria

1. Provide clear assessment policies and guidelines;
2. Use formative assessment to promote deep learning;
3. Assess learning against specified performance outcomes;
4. Collate, analyse and use data on all aspects of the training;
5. Evaluate training at the required level using established models;
6. Improve training on the basis of the results of the evaluation.

Knowledge requirements

To be able to understand, explain and critically evaluate:

- Purposes and characteristics of assessment and evaluation;
- Advantages and limitations of assessment strategies;
- How to design good assessment items;
- Application of the Kirkpatrick Model and other evaluation methods;
- How to conduct the evaluation process;
- How to evaluate a training department and training programmes.

Personnel who should demonstrate this competency:

- Training managers and senior trainers;
- Trainers involved in assessment procedures;
- Managers of staff identified as having a learning need;
- Human resources personnel.

2.4 COMPETENCY REQUIREMENTS FOR OPERATING AND EXPLOITING THE WMO INFORMATION SYSTEMS

The WMO Information System (WIS) cuts across all WMO-related disciplines. Many of the competencies required for operating or participating in WIS are general competencies related to operation and maintenance of information and communication technological systems. Details of WIS competencies can be found in the *Manual on the WMO Information System* (WMO-No. 1060), Volume I, Appendix E. The *Guide to the WMO Information System* (WMO-No. 1061), Volume I contains further information on WIS competencies and learning guides. However, some competencies, especially those related to practices associated with specific WMO Programmes, are defined in the programme-related publications. These include, but are not limited to, the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), the *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485) and the *Manual on the Global Observing System* (WMO-No. 544).

As recommended by the *Technical Regulations* (WMO-No. 49), Volume I, Part V, centres should ensure that they have access to an adequate number of people who among them have the required levels of the WIS competencies that are defined in that volume (see section 1.4.2).

COMPETENCIES

Seven competencies across four basic functional areas are identified as follows:

Infrastructure

1. Manage the physical infrastructure;
2. Manage the operational applications;

Data

3. Manage the data flow;
4. Manage data discovery;

External interactions

5. Manage interaction among WIS centres;

6. Manage external user interactions;

Overall service

7. Manage the operational service.

COMPETENCY 1: MANAGE THE PHYSICAL INFRASTRUCTURE

Competency description

Prepare, plan, design, procure, implement and operate the physical infrastructure, networks and applications required to support the WIS centre.

Many of the skills required here are generic information and communication technology (ICT) skills and will have already been acquired as part of prior education and training or will be provided by hardware and system suppliers.

Performance components

Management of information technology operations

1a. Maintain the system in optimal operational condition by setting and meeting service levels, including:
- Configuration;
- Preventive and corrective maintenance and servicing;
- Equipment replacement or upgrade;
- Networking and processing capacity;
- System monitoring and reporting procedures, and corrective actions;

1b. Provide contingency planning and operation backup and restoration;

Management of facilities

1c. Manage physical site security;
1d. Manage physical site environmental control.

Knowledge and skill requirements

- General ICT skills;
- Operation, configuration and maintenance of equipment and applications;
- Recognized IT service management frameworks;
- Current technologies and emerging trends;
- Service-level agreements.

Learning outcomes

Staff will be able to:

- Maintain the system in optimal operational condition;
- Plan for upgrades and operation backup and restoration;
- Maintain site security and environmental control.

Staff will learn:

- WIS specific systems;
- WIS site security policies;
- Service-level agreements for the centre.

Learning activities

To learn how to perform the required tasks staff may:

- Attend training sessions run by providers of systems and other tools or by other training providers;
- Respond to typical monitoring reports;
- Apply WIS site security measures and respond to typical incidents;
- Apply WIS site environmental control measures and respond to typical incidents.

Assessment

Staff must be able to:

- Configure and maintain system components;
- Respond to monitoring reports;
- Apply WIS site security measures and respond to typical incidents;
- Apply WIS site environmental control measures and respond to typical incidents.

Key learning resources

- Manufacturers' handbooks and guides;
- Documentation of centre's facilities;
- WIS/Global Telecommunication System (GTS) manuals and guides;
- Tools to monitor system security;
- WIS security policies;
- WIS environmental control policies.

COMPETENCY 2: MANAGE THE OPERATIONAL APPLICATIONS

Competency description

Prepare, plan, design, procure, implement and operate the applications required to support the WIS functions.

Many of the skills required here are generic ICT skills and will have already been acquired as part of prior education and training or will be provided by suppliers of applications.

Performance components

2a. Meet service levels by maintaining applications in optimal operational condition through:
    - Configuration of applications;
    - Monitoring and responding to applications' behaviour;
    - Preventive and corrective maintenance;
- Replacement or upgrade of applications;

2b. Provide contingency planning and application backup and restoration;
2c. Ensure data integrity and completeness in the event of system failure;
2d. Ensure system security.

Knowledge and skill requirements

- General ICT skills;
- Operation, configuration and maintenance of applications;
- Recognized IT service management frameworks;
- Current technologies and emerging trends;
- WIS functions and requirements;
- WIS security policies.

Learning outcomes

Staff will be able to:

- Operate, configure and maintain applications;
- Monitor applications and take corrective action;
- Apply and test WIS security protocols.

Staff will learn:

- WIS applications specific to the centre;
- WIS system security policies and procedures.

Learning activities

To learn how to perform the required tasks staff may:

- Attend training sessions run by providers of systems and other tools or by other training providers;
- Initiate monitoring and reporting procedures and respond to typical monitoring reports;
- Apply WIS site security measures and respond to typical incidents.

Assessment

Staff must be able to:

- Configure and maintain system components;
- Respond to monitoring reports;
- Apply site security measures and respond to typical incidents.

Key learning resources

- Documentation of centre's applications;
- WIS/GTS manuals and guides;
- Tools to monitor system security;
- WIS security policies.

COMPETENCY 3: MANAGE THE DATA FLOW

Competency description

Manage the collection, processing and distribution of data and products through scheduled and on-demand services.

Performance components

3a. Ensure collection and distribution of data and products as per data policy;
3b. Publish data and products;
3c. Subscribe to data and products;
3d. Encode, decode, validate and package data and products;
3e. Create, update and maintain data flow catalogues;
3f. Manage connectivity between centres;
3g. Control the data flow to meet service levels.

Knowledge and skill requirements

- System and network monitoring and viewing tools;
- Data formats and protocols;
- Message and file switching systems.

Learning outcomes

Staff will be able to:

- Transfer data and products between their centre, other WIS centres and external users;
- Request data and respond to data requests using ad hoc and routine delivery mechanisms;
- Maintain quality standards (service levels) by monitoring, and responding to, traffic flow, missing data and products, errors and service messages;
- Apply relevant data policies to data and products;
- Identify appropriate formats for data and product exchange;
- Write and read data in WIS formats using their centre's tools.

Staff will learn:

- Data representations used in WIS and when to apply them;
- WMO data policies and how they apply to data in WIS;
- The structure of the WIS and GTS and how to use reference documents to identify and interpret the routing plans and protocols they will need to use;
- The interfaces of their centre's WIS applications, the information they use to modify their behaviour, and the tools available to control the operation of the applications to achieve service levels;
- How to use a WIS centre interface to find and request data for delivery by ad hoc request and by subscription;
- How WIS handles backup and how GTS handles alternative routings to maintain continuity of data flows.

Learning activities

To learn how to perform the required tasks staff may:

- Connect to a WIS centre to search for information, select a dataset and download a copy from the cache;
- Using a WIS centre interface, create, modify and delete a subscription for routine delivery of a dataset;
- Use the software tools of their centre's WIS application to exchange information between computers;
- Assess data flows by analysing monitoring reports from their applications;
- Investigate how data policy (including WMO Resolutions 40 (Cg-XII) and 25 (Cg-XIII)) is applied to data published by their centre;
- Use tools provided at their centre to view information in different formats and convert data between these formats.

Assessment

Staff must be able to:

- Go to a WIS centre, find data, download them immediately, subscribe for regular delivery and cancel the subscription;
- Use a GTS switch to move data between training computers and control the flow.

Key learning resources

Data policies

- Resolution 40 (Cg-XII) – WMO policy and practice for the exchange of meteorological and related data and products including guidelines on the relationships in commercial meteorological activities;
- Resolution 25 (Cg-XIII) – Exchange of hydrological data and products;
- Resolution 60 (Cg-17) – WMO policy for the international exchange of climate data and products to support the implementation of the Global Framework for Climate Services;
- The centre's data policies.

GTS data exchange

Manual on the Global Telecommunication System (WMO-No. 386), Attachments II-5, II-6, II-7, II-15 and II-16.

Data representations

- *Manual on Codes* (WMO-No. 306), Volume I.1; Volume I.2 and Volume I.3;
- Guidance on migration to table driven code forms;
- Tools used at the centre to read, write, convert, validate and display information in Table Driven Code Forms;
- Sample data for reading and writing in Table Driven Code Forms.

WIS discovery, access and retrieval

- *Manual on the WMO Information System* (WMO-No. 1060), Part I, 1.7 and Appendix D (WIS-TechSpec-2, -10, -11 and -12);
- *Guide to the WMO Information System* (WMO-No. 1061);
- User account at a Global Information System Centre (GISC) and PC with Internet connection.

Managing GTS data exchange

- *Manual on the Global Telecommunication System* (WMO-No. 386);
- *Weather Reporting* (WMO-No. 9), Volume C1;
- GTS routing tables;
- Training environment on message and file switch;
- World Weather Watch quantity monitoring statistics.

Security of data exchange

- *Guide to Virtual Private Networks (VPN) via the Internet between GTS centres* (WMO-No. 1116);
- *Guide to Information Technology Security* (WMO-No. 1115).

Network management

- Network management tool and associated documentation;
- System error reports and event viewing tools.

COMPETENCY 4: MANAGE DATA DISCOVERY

Competency description

Create and maintain discovery metadata records describing services and information, and upload them to the WIS Discovery Metadata Catalogue.

Each datum and product record held within WIS must have metadata associated with it so that it can be found and understood. These metadata records are held in a catalogue for discovery, access and retrieval (DAR).

Performance components

4a. Create and maintain discovery metadata records describing products and services;
4b. Add, replace or delete metadata records within the catalogue;
4c. Ensure that all information and service offerings from a WIS centre have complete, valid and meaningful discovery metadata records uploaded to the catalogue.

Knowledge and skill requirements

- Knowledge of WMO and ISO documentation sufficient to create complete and valid metadata;
- Metadata entry and management tools;
- Policies;
- Discovery metadata concepts and formats;
- Written English.

Learning outcomes

Staff will be able to:

- Use standard WIS tools to create discovery metadata from descriptions supplied by users;
- Add, replace or delete metadata records within the catalogue.

Staff will learn:
- The role of metadata in discovery, access and retrieval of data and products;
- Approved metadata formats;
- How to identify content that is mandatory, acceptable or inapplicable;
- Use of metadata creation tools;
- How to access and modify a catalogue;
- How data flow within, to and from their centre;
- About the tools that allow users to input descriptions.

Learning activities

To learn how to perform the required tasks staff may:

- Create metadata records based on sample descriptions for a range of data and products typical of their WIS centre;

- Insert such records into a catalogue, replace them with records that have been changed and delete them.

Assessment

Staff must be able to demonstrate:

- Successful creation of metadata records for typical products;
- Competence in publishing and deleting metadata catalogue records.

Key learning resources

- *Manual on the WMO Information System* (WMO-No. 1060), Part IV, 4.10, and Appendix D (WIS-TechSpec-9), and Part V and Appendix C;
- WIS metadata guidance;
- Metadata entry and management tools;
- Samples of how to complete typical metadata records;
- Metadata policies and WIS metadata guidelines;
- ISO 19100 series: ISO standards on geographic information.

COMPETENCY 5: MANAGE INTERACTION AMONG WIS CENTRES

Competency description

Manage relationships and compliance between the participants' centre and other WIS centres.

Performance components

5a. Exchange information with other centres on operational matters;
5b. Facilitate registration of new WIS centres;
5c. Facilitate registration of new data and products by other WIS centres;
5d. Create and respond to WIS service messages, including GTS.

Knowledge and skill requirements

- Knowledge of current exchanges and requirements for notification of operational changes;
- Procedures and practices for registration of other centres and their data and products;
- Service-level agreements;
- Written English.

Learning outcomes

Staff will be able to:

- Facilitate registration of new WIS centres and their data and products;
- Keep other WIS centres informed of the status of services, incidents and requests;
- Monitor and respond to service-level reports;
- Manage subscriptions.

Staff will learn:

- About current exchanges and requirements for notification of operational changes;
- What type of data, products and services are available at their centre;

- Procedures and practices for registration of other centres and their data and products;
- Procedures and practices for notifying other centres about operational changes and service availability.

Learning activities

To learn how to perform the required tasks staff may carry out the above activities with the help of software, tools and guidance as used in their operational environment, either in a classroom or under supervision on the job.

Assessment

Staff must be able to:

- Respond to a request for registration of a new centre and its data and products;
- Prepare notifications of typical operational scenarios;
- Respond to typical notifications from other WIS centres.

Key learning resources

- *Manual on the Global Telecommunication System* (WMO-No. 386);
- *Manual on the WMO Information System* (WMO-No. 1060), Part II; Part IV, 4.5, 4.7, 4.8, 4.9 and 4.14, and Appendix D (WIS-TechSpec-4, -6, -7, -8 and -13);
- *Guide to the WMO Information System* (WMO-No. 1061);
- *Weather Reporting* (WMO-No. 9), Volume C1;
- *Exchanging Meteorological Data* (WMO-No. 837).

Local resources

- Service-level agreements (as used by the participants' centre);
- Frequently Asked Questions (FAQ) documents (for the user);
- WIS software user guides;
- Guidelines for services available at WIS centre;
- Data policy and associated guidance material;
- First-line support procedures and guides;
- User database (for contact information);
- Case tracking and customer management;
- WIS user management;
- WIS subscription management;
- Monitoring dashboard for WIS components.

COMPETENCY 6: MANAGE EXTERNAL USER INTERACTIONS

Competency description

Ensure that users, including other centres, data providers and subscribers, can publish and access data and products through WIS.

Performance components

6a. Register data providers and subscribers and maintain a service agreement;
6b. Set and register access criteria;
6c. Provide systems and support for users to publish and access data and products;

6d. Manage user relations to ensure a high satisfaction level.

Knowledge and skill requirements

- Data policies;
- External WIS interface;
- WIS registration and monitoring tools and policies;
- User support documentation and help files;
- Written English.

Learning outcomes

Staff will be able to:

- Register new WIS users and providers, setting roles, access authorizations and levels;
- Create and amend WIS user subscriptions;
- Use WIS tools to assist users and providers in resolving problems;
- Create and respond to WIS service messages, including GTS;
- Undertake first-line investigation and diagnosis;
- Manage incidents and requests: log them, categorize and prioritize them, escalate as appropriate and close them when the user is satisfied;
- Keep users informed of the status of services, incidents and requests;
- Gather information and report on user and provider satisfaction;
- Assist users in uploading and accessing data;
- Identify potential problems in services and implement improvements.

Staff will learn:

- What type of data, products and services are available at their centre;
- How WIS applications, including DAR, should be used;
- How to apply data policies;
- How to interact effectively with users and providers.

Learning activities

To learn how to perform the required tasks staff may:

- Register users (data providers and subscribers) and set access authorizations and levels using the same software, tools and guidance as in their operational environment;
- Role play user interactions.

Assessment

Staff must be able to:

- Register typical data providers and users;
- Ensure that users are able to upload and access data;
- Respond to typical incidents.

Key learning resources

- *Manual on the Global Telecommunication System* (WMO-No. 386);
- *Manual on the WMO Information System* (WMO-No. 1060), Part II; Part IV, 4.5, 4.7, 4.8, 4.9 and 4.14, and Appendix D (WIS-TechSpec-4, -6, -7, -8 and -13);
- *Guide to the WMO Information System* (WMO-No. 1061);

- *Weather Reporting* (WMO-No. 9), Volume C1;
- *Exchanging Meteorological Data* (WMO-No. 837).

Local resources

- Service-level agreements (as used by their centre);
- FAQ documents (for the user);
- WIS software user guides;
- Guidelines for services available at WIS centre;
- Data policy and associated guidance material;
- First-line support procedures and guides;
- User database (for contact information);
- Case tracking and customer management;
- WIS user management;
- WIS subscription management;
- Monitoring dashboard for WIS components.

COMPETENCY 7: MANAGE THE OPERATIONAL SERVICE

Competency description

Ensure the quality and continuity of the service.

This is essentially a management role ensuring that the WIS system operates as required, now and in the future. Some of the skills required are generic management skills, rather than WIS specific, and would be taught or learned elsewhere.

Performance components

7a. Coordinate all WIS functions and activities of the centre;
7b. Ensure and demonstrate compliance with regulations and policies;
7c. Monitor and meet quality and service performance standards;
7d. Ensure service continuity through risk management and planning and implementation of service contingency, backup and restoration. Ensure data continuity in the event of system failure;
7e. Plan and coordinate the delivery of new functionalities.

Knowledge and skill requirements

- General management skills;
- Overview of local and external WIS operations and associated service agreements;
- WIS regulations and policies;
- Functional specifications;
- Written English.

Learning outcomes

Staff will be able to:

- Ensure that the WIS centre meets quality and service performance standards;
- Identify the challenges and issues to be addressed;
- Foster compliance with WIS framework.

Staff will learn:

- Functions and responsibilities of the WIS centre;
- WIS quality and service performance standards;
- Methods to manage quality, risk and operational service;
- How to monitor quality and service performance standards;
- How to analyse, demonstrate and report quality and service performance at the WIS centre;
- How to maintain troubleshooting, backup and restoration procedures;
- How to plan and coordinate the delivery of new functionalities and improvements;
- How to integrate new technologies and developments;
- How to update the regulatory documents;
- How to maintain service agreements;
- How to plan monitoring resources;
- How to align budget restrictions with human resources demands.

Learning activities

To learn how to perform the required tasks staff may:

- Monitor quality and service performance standards;
- Analyse quality and service performance in the WIS centre;
- Demonstrate and report quality and service performance;
- Maintain troubleshooting, backup and restoration procedures;
- Plan and coordinate the delivery of new functionalities;
- Keep timely records, as required.

Assessment

Staff must be able to:

- Demonstrate successful WIS service;
- Plan replacement and upgrade of equipment and applications to meet new functionalities and requirements.

Key learning resources

- *Technical Regulations* (WMO-No. 49), Volume I;
- Resolution 40 (Cg-XII) – WMO policy and practice for the exchange of meteorological and related data and products including guidelines on the relationships in commercial meteorological activities;
- Resolution 25 (Cg-XIII) – Exchange of hydrological data and products;
- Resolution 60 (Cg-17) – WMO policy for the international exchange of climate data and products to support the implementation of the Global Framework for Climate Services;
- *Manual on the Global Telecommunication System* (WMO-No. 386);
- *Manual on the WMO Information System* (WMO-No. 1060), Part IV, 4.16, WIS-TechSpec-15;
- *Guide to the WMO Information System* (WMO-No. 1061);
- WIS demonstration procedures and guidelines;
- Monitoring reports;
- Audit reports.

2.5 MARINE SERVICES PERSONNEL

The competency frameworks for Marine Services currently apply to marine weather and ice forecasters. Those responsible for marine observations should refer to section 2.7 Instrumentation, calibration, meteorological observations, and observing programme and network management. Those with responsibilities focused on customer relations and communications and/or new product development or improvements should, in addition to

this section, also refer the following sections of this compendium: 2.1.3 Personnel working in the development and delivery of meteorological and hydrological products and services, and 2.1.4 Public weather service advisers supporting disaster prevention and mitigation and other user activities.

2.5.1 Marine weather forecasters

This section lays out the minimum competency requirements[8] to effectively perform the duties of a marine weather forecaster. The competency framework identifies the knowledge, skills and behaviour that should be demonstrated. Implicit in the background knowledge and skills required of marine weather forecasters is the recommendation that they should have successfully completed the Basic Instruction Package for Meteorologists (BIP-M) or relevant parts thereof. It should, however, be recognized that national qualification requirements for marine weather forecasters may be set at a higher level certified, for example, by a degree.

The marine environment includes open and coastal seas (including the surf zone), estuaries, large lakes, rivers and their interfaces with the land and the atmosphere. It is understood that there will be considerable variation in the legitimate functions of Marine Meteorological Services worldwide. Consequently, it is not possible to write a document that exactly matches every office's function. Once this generic competency framework is adopted, a Marine Meteorological Service will need to define how the competencies relate to its own national operations. That is, the Marine Meteorological Service will have to adapt the competencies, associated supporting knowledge and performance criteria to its specific functions and region. Therefore, the performance criteria should be applied bearing in mind the following conditions:

(a) The area of responsibility (see the *Manual on Marine Meteorological Services* (WMO-No. 558), Volumes I and II;
(b) The impact of meteorological phenomena, variables and parameters on marine operations;
(c) Compliance with marine user requirements, international regulations and local procedures and priorities.

Competency requirements

The role of marine weather forecasters will continue to change in response to evolving technology and user requirements. Thus, any change will require high standards of competency and underlying knowledge and skills with a focus on continuous improvement. This framework is presented in an attempt to anticipate as far as possible those changes in the future. The adoption of a quality management approach is strongly recommended.

A marine weather forecaster should be able to perform the tasks detailed under the following high-level competencies:

1. Analyse and monitor continually the marine weather situation;
2. Forecast marine weather phenomena, variables and parameters;
3. Warn of hazardous marine meteorological phenomena;
4. Ensure the quality of marine meteorological information and services;
5. Communicate meteorological information to internal and external users.

Notes:

1) As this competency framework is generic and recommended for all providers of marine weather forecast and warning services, no priority is stated for either the phenomena or the parameters. Priorities should be established by the Marine Meteorological Service.
2) Performance criteria items marked with an "*" indicate that additional details are provided in 2.5.2 Ice forecasters.

[8] Approved by the Seventeenth World Meteorological Congress (2015)

COMPETENCY 1: ANALYSE AND MONITOR CONTINUALLY THE MARINE WEATHER SITUATION

Competency description

Continuously monitor the latest observations, advisories, forecasts and warnings of marine weather parameters and variables, and significant weather phenomena. Determine the need for issuance, cancellation or amendment/update of advisories, forecasts and warnings according to documented thresholds and regulations.

Performance criteria

1. Maintain a weather watch over the marine weather situation, evolving significant weather phenomena and, where available, advisories issued by other meteorological services, and model guidance;
2. Compare current forecasts and warnings with observed conditions;
3. On the basis of the weather watch, appraise the need for amendments to forecasts and updates of warnings against established and documented criteria.

Background knowledge and skills

- Knowledge of marine meteorological products (routine and non-routine), their issue times and the priorities applied in the region;
- Knowledge of non-routine weather conditions that trigger gale warnings, special marine warnings, storm warnings, wave warnings, surf warnings and advisories;
- Knowledge of meteorological analysis techniques (subjective and objective);
- The ability to interpret:
  - Radar and satellite imagery to identify fog, rapid cyclogenesis, frontogenesis, severe convective systems, tropical cyclones, thunderstorms, squalls, sea ice* and other potentially dangerous phenomena;
  - Numerical weather prediction (NWP) guidance (including Ensemble Prediction Systems (EPS)), marine meteorological products and other types of objective guidance, and their assimilation in the preparation of forecasts and warnings;
  - Observed variables and parameters, when there are differences between automatic sensor technologies and manual observing techniques, and their impact on forecast and warning products;
  - Coded real-time raw data including buoy and ship reports.
- Knowledge of relevant observing systems, platforms, and sensors that may include remote sensing (satellite altimeters, scatterometers, microwave sensors, radar, lightning detection systems); in-situ sensors (anemometers, tide gauges, moored wave buoys, drifting buoys, bottom pressure sensors); human observing procedures (ship, shore) and how their advantages and limitations vary with respect to prevailing seasonal and meteorological conditions;
- Knowledge of bathymetry, local topography, coastal geomorphology, marine climatology and local weather systems and their potential impact on winds, waves and other phenomena, such as abnormal water level or currents, in the forecast area of responsibility;
- The ability to perform manual and subjective analyses (including techniques for analysis in data-sparse areas);
- The ability to perform analysis on weather-related images;
- The ability to perform statistical data analyses;
- The ability to apply statistical analysis and other informational techniques to data that have a geographical or geospatial aspect.

COMPETENCY 2: FORECAST MARINE WEATHER PHENOMENA, VARIABLES AND PARAMETERS

Competency description

Forecasts of meteorological parameters and phenomena are prepared and issued in accordance with documented requirements, priorities and deadlines.

Performance criteria

1. Analyse and diagnose the marine weather situation as required for the preparation and issue of forecasts;
2. Prepare forecasts for the following weather phenomena, parameters and variables, including spatial extent, onset and cessation, duration, intensity and temporal variations, where applicable;

*For high seas, coastal forecast requirements:

- Wind including directional variability, speed and wind gusts;
- Sea state;
- Damaging large waves or multiple swell systems;
- Precipitation and associated horizontal visibility;
- Fog or mist, and associated horizontal visibility;
- Other types of obscuration to visibility, including smoke, dust, haze, sandstorms, dust storms, blowing snow, volcanic ash and rock, and associated horizontal visibility;
- Sea-ice state;*
- Synoptic situation for tropical, subtropical, temperate and polar climate zones as required;
- Thunderstorms, heavy precipitation with poor horizontal visibility, downburst and microburst, squalls or gust front, hail, tornadic and waterspout activity;
- Freezing spray or precipitation, snowfall;
- Icing on vessels or structures;
- Tropical cyclones, hurricanes, typhoons and their movement;
- Icebergs and their movement;*
- Other international and national forecast requirements, as listed under Regional Variations.

3. Ensure that forecasts are prepared and issued in accordance with the *Manual on Marine Meteorological Services* (WMO-No. 558), Volumes I and II, and/or national standard operating procedures (SOPs) including format, codes and technical regulations on content, accuracy and timeliness;

4. Ensure that forecasts of weather parameters and phenomena are consistent (spatially and temporally) across boundaries of the area of responsibility as far as practicable, while maintaining meteorological integrity. This will entail monitoring forecasts and warnings issued for other regions, and liaising with adjacent regions as required.

Background knowledge and skills

- Knowledge of methods for predicting meteorological and oceanographic conditions, and their applications, including those required by the application regional variations;
- Knowledge of forecasting models (deterministic models and EPS) including wave models;
- Knowledge of remote-sensing applications;
- Knowledge of forecast preparation systems (including use of software);
- Knowledge of local and regional areas of responsibility, in particular forecast boundaries and associated observation sites;
- Knowledge of forecast issue times and work priorities;
- Knowledge of types and characteristics of wave and swell; generation and decay of wave and swell; and shallow water wave characteristics;

- Knowledge of tropical cyclones, hurricanes and typhoons and their impact on marine activities;
- Knowledge of sea and tidal currents, sea level (including storm surges and tsunami) and drifting of objects or pollutants;
- The ability to forecast sea-ice extent, thickness, concentration, stage of development, drift, deformation, growth and melting;*
- The ability to forecast icebergs and their movement, as required.

COMPETENCY 3: WARN OF HAZARDOUS MARINE METEOROLOGICAL PHENOMENA

Competency description

Warnings are issued in a timely manner when hazardous conditions are expected to reach documented threshold values and are updated, amended or cancelled, as appropriate, according to documented criteria.

Performance criteria

1. Forecast and issue warning for the following hazardous weather phenomena, variables and parameters, including spatial extent, onset and cessation, duration, intensity and its temporal variations:
    - Tropical cyclones, hurricanes and typhoons;
    - Wind hazards;
    - Thunderstorms, heavy precipitation with poor horizontal visibility, downbursts, microbursts, squalls or gust front, severe hail and tornadic and waterspout activity;
    - Ice accretion:
        - Freezing spray or precipitation and icing on vessels or structures;
        - Snowfall;
    - Restricted visibility (less than 1 nautical mile):
        - Reduced horizontal visibility caused by precipitation, fog, dust, smoke, haze, sandstorms, dust storms and blowing snow;
        - Reduced horizontal visibility caused by volcanic activity;
    - Unusual and hazardous sea-ice conditions:*
        - Exceptional and rapidly changing sea-ice conditions;
        - Icebergs;
    - Storm-induced abnormal (sea) water levels:
        - Sea level and storm surge;
        - Harbour seiches;
    - Unusual and hazardous wave or current conditions;

Note: Forecasts for the occurrence of phenomena that cause obscuration to visibility (for example, volcanic eruptions with emission of ash and rock) may be the responsibility of other jurisdictions; in such cases, the Marine Meteorological Services are not required to provide forecasts.

2. Ensure that warning products are prepared and issued in accordance with thresholds for hazardous weather, as specified in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volumes I and II, and/or national SOPs, including formats, codes and technical regulations on content, accuracy and timeliness;

3. Ensure that warnings of hazardous weather phenomena are consistent (spatially and temporally), across boundaries of the area of responsibility as far as practicable, while maintaining meteorological integrity. This will include monitoring forecasts/warnings issued for other regions, and liaison with adjacent regions as required.

Background knowledge and skills

- Knowledge of SOPs for warnings;
- Knowledge of marine warning criteria and associated amendment criteria;
- Ability to utilize outputs of forecasting models (deterministic models and EPS);
- Knowledge of local and regional areas of responsibility and warning boundaries.

COMPETENCY 4: ENSURE THE QUALITY OF MARINE METEOROLOGICAL INFORMATION AND SERVICES

Competency description

Forecasts, warnings and related products are provided within a quality management framework.

Performance criteria

1. Apply the organization's quality management system and procedures as required;
2. Assess the impact of known observational error characteristics (for example, bias, achievable accuracy and limitations of observations and sensing methods) on forecasts and warnings;
3. Verify and validate marine meteorological data, products, forecasts and warnings (timeliness, completeness and accuracy) using real-time verification tools;
4. Monitor the functioning of operational systems, gather and assess customer comments, suggestions and complaints, and take remedial actions when necessary;
5. Identify and evaluate weather forecasting and warning problems and determine appropriate corrective and preventive action for continuous improvement.

Background knowledge and skills

- Knowledge of quality management principles, practices and procedures;
- Knowledge of SOPs for forecasts and warnings;
- The ability to utilize verification techniques and statistics;
- Knowledge of contingency plans;
- Knowledge of stakeholder needs;
- Knowledge of relevant stakeholder operations and need for and applications of forecasts, including:
  - Stakeholder operations (for example, procedures, tactics, planning processes and cycles);
  - Stakeholder limitations, including operating limits, legal constraints and geopolitical limits;
  - Stakeholder expectations;
  - General knowledge of stakeholder terminology such as nautical terms, acronyms, abbreviations and technical terms related to forecast variables (for example, state of the sea, currents, waves, swell, tides), and awareness of measurement units preferred by the customer;
  - Knowledge of stakeholder communication and security systems, if required;
  - Knowledge of the impact of weather variables, parameters and phenomena on stakeholder operations and activities.

COMPETENCY 5: COMMUNICATE METEOROLOGICAL INFORMATION TO INTERNAL AND EXTERNAL USERS

Competency description

Marine weather forecasts and warnings are communicated in a timely and clear manner to meet user community needs.

Performance criteria

1. Ensure that all forecasts and warnings are disseminated via the authorized communication channels to user groups;
2. Provide marine weather briefings as necessary, and provide consultation to meet specific user needs;
3. Make use of forecasts and warnings of meteorological parameters, variables and phenomena to describe their impact on marine operations, safety of life and property, including the coastal environment and population.

Background knowledge and skills

- Knowledge of primary users and operations and weather sensitivities;
- Knowledge of available communication systems, techniques and methodologies;
- Ability to ask users the appropriate questions so as to better understand their needs;
- Ability to utilize cross-boundary consistency techniques – national and international – as well as inter-disciplinary and inter-agency checks as needed;
- Ability to communicate effectively, orally, graphically and in writing (level of details to meet the identified needs of specific users);
- Ability to communicate at an acceptable level of language proficiency.

Regional variations

Regional variations referred to within this section may include but are not limited to the following:

- Agreed and documented criteria and thresholds;
- The range of weather and sea phenomena including but not restricted to:
  - Tsunamis;
  - Tides, sea level and storm surge;
  - Sea currents and drifting of objects and pollutants;
  - Sea-surface temperature and salinity where required;
  - Volcanic ash cloud dispersion;
  - Volcanic ash deposition;
  - Significant debris following tropical cyclones and tsunamis;
  - Surf zone hazards;
- Appreciation of the types and use of forecast guidance;
- Designated offices responsible for advice on volcanic ash, tropical cyclones, hurricanes, typhoons, sea ice, icebergs and tsunamis;
- Regional regulations;
- Boundaries of forecast and warning areas;
- Communication language(s);
- Communications technology for forecast and warning transmission, and for weather briefing;
- Forecast database(s) used – gridded, text, graphical, digital, and so forth.

2.5.2 Ice forecasters

Introduction

This section outlines the minimum competency requirements to effectively perform the duties of an ice forecaster (IF)[9] for all operational ice services and institutes in the world, typically organized under meteorological, scientific or coast guard institutions. Through several decades, some ice services have operated with two distinct categories of staff: ice analysts and ice forecasters. This framework considers ice analysis competencies as a substantial subset of the ice forecasting competencies. The individual ice services will define how the ice forecaster competency framework addresses regional needs and requirements for ice analysis and forecasts. The competency framework identifies the knowledge, skills and behaviours that should be demonstrated within the ice forecaster profile. The national ice services issuing ice information are responsible for sea-ice covered regions over the global ocean, including bergy waters, interior lakes and rivers, and their interaction with the land and the atmosphere.

National ice services typically issue a variety of products for marine use to address the requirements of the International Convention on Safety Of Life At Sea (SOLAS) (1974) and/or national requirements. There will be considerable variation in the legitimate functions of ice services worldwide. Therefore, the performance criteria should be applied in a way that is consistent with these variations.

Each ice service will define how the competencies relate to their own national operations, practice and user requirements. That is, the ice services will have to adapt the competencies, associated underpinning knowledge and performance criteria that are specific to their functions and regions. The specific performance criteria for a given ice service's program should reflect the roles and responsibilities of the office's service and be applied bearing in mind the following conditions:

The area of responsibility defined by the national ice service;

(1) The impact of sea ice, river ice, lake ice and/or icebergs at sea on life and properties;
(2) Compliance with user requirements, national and international regulations, recognized standards and local priorities.

Competency requirements

Ice analyses and forecasts are used by many and often very different users, such as cargo shipping operators, icebreaking services, the fishing industry, patrols and surveillance, the tourism sector, indigenous peoples, and modelling and research communities. In general, it is important for the ice forecaster to know the user community at national and international levels.

Forecasts of ice conditions and parameters are prepared and issued in accordance with documented requirements, priorities and deadlines. Ice forecasters demonstrate a good working knowledge of the weather producing processes, characteristics and behaviour of synoptic and mesoscale weather systems, and sea-ice physics and dynamics, and use this knowledge in forecasting ice movement, development, melting and decay.

The role of ice forecasters will continue to change in response to evolving technology and user requirements. As such, any change will require high standards of competency and underlying knowledge and skills with a focus on continuous improvement.

An ice forecaster should be able to perform the tasks detailed under the following high-level competencies:

Analyse and routinely monitor ice conditions and parameters.

[9] Approved by the WMO Executive Council at its seventy-sixth session (2023)

(1) Forecast ice conditions and parameters;
(2) Warn of hazardous ice conditions and parameters prone to damage vessels and equipment and threaten the safety of marine navigation and fishing activities;
(3) Ensure the quality of ice information and services;
(4) Communicate ice information to internal and external users.

Regional variations

National ice centres will typically apply and address regional variations in ice cover and user needs in their production environment.

These may include but are not limited to the following:

- Agreed and documented criteria and thresholds;
- The range of environmental factors, including but not restricted to:
  - Ice types;
  - Ice-related hazards;
  - Permanent/semi-permanent local occurrences (e.g. gyres and polynyas);
  - Tides, sea level and storm surge;
  - Sea currents and drifting of ice;
  - Sea-surface temperature and salinity, where required;
- Appreciation of the types and use of forecast guidance;
- Local climatology;
- Designated offices responsible for advice on meteorology, sea ice, lake and river ice, icebergs, oceanography;
- Regional regulations;
- Boundaries of forecast and warning areas;
- Communication language(s);
- Communications technology for forecast and warning transmissions, and for ice briefings;
- Forecast database(s) utilized –gridded/text/graphical/digital, etc.;
- Extent of automation of the observing and sensing system.

COMPETENCY 1: ANALYSE AND ROUTINELY MONITOR ICE CONDITIONS AND PARAMETERS

Competency description

Integrate multiple remote sensing sources, meteorological and oceanographic data, and auxiliary data sources to continually monitor ice conditions. Use applicable geographical information systems and local standard operating procedures to produce timely and accurate sea-ice analyses. Determine the need for the issuance, cancellation or amendment/update of forecasts and warnings according to documented thresholds and regulations.

Performance criteria

(1) Use effectively suitable near-real-time satellite data, relevant derived products and in situ observations when monitoring and analysing ice conditions;
(2) Compare current forecasts and warnings against current ice conditions;
(3) Based on the monitoring/analysis of the ice conditions and parameters, warnings issued by other ice services, and model guidance, appraise the need for amendments to forecasts and updates of warnings against established and documented criteria.

Background knowledge, skills and abilities

- Knowledge of the ice products (routine and non-routine), their issue times and the priorities applied in the region;
- Knowledge of potential ice hazard conditions and events for specific regions;
- Knowledge of non-routine weather conditions and local effects that trigger ice-pressure warnings, rapid closing of coastal leads warnings and special ice warnings;
- Knowledge of meteorological and ice analysis techniques (subjective and objective);
- Knowledge of sea-ice physics;
- Knowledge of relevant observing systems, platforms and sensors that may include remote sensing (satellite altimeters, microwave sensors); radar, in situ sensors (moored wave buoys, drifting buoys, bottom pressure sensors, ice thickness sensors); human observing procedures (ship, shore) and how their advantages and limitations vary with respect to prevailing seasonal and meteorological/ice conditions;
- Knowledge of bathymetry, coastal geomorphology, marine climatology, oceanic currents, any local marine phenomena, local weather systems and their potential impacts on ice movement, development, melt and decay in the area of responsibility;
- The ability to perform manual/subjective analysis (including techniques for analysis in data sparse areas);
- The ability to perform analysis on ice-related images;
- The ability to translate information from automated products into routine ice products;
- The ability to apply statistical analysis, geographical information system processes and other informational techniques to data which have a geographical or geospatial aspect.

COMPETENCY 2: FORECAST ICE CONDITIONS AND PARAMETERS

Competency description

Forecasts of ice conditions and parameters are prepared and issued in accordance with documented requirements, priorities and deadlines. Demonstrate a good working knowledge of the weather producing processes, characteristics and behaviour of synoptic and mesoscale weather systems and sea-ice physics and dynamics. Use this knowledge in forecasting ice movement, development, melt and destruction.

Performance criteria

(1) Analyse and diagnose ice conditions and parameters as required for the preparation and issue of forecasts;
(2) Prepare forecasts for relevant ice conditions and parameters, such as (not limited to):
    (a) Ice concentration;
    (b) Ice floe size;
    (c) Ice stage of development;
    (d) Ice movement;
    (e) Ice freeze up time;
    (f) Ice break up time;
    (g) Ice deformation;
    (h) Iceberg movement and decay;

(3) Ensure that forecasts are prepared and issued in accordance with national standard operating procedures (SOPs) including format, codes and technical regulations on content, consistency, accuracy and timeliness;
(4) Ensure that forecasts of ice conditions and parameters are consistent (spatially and temporally) across boundaries of the area of responsibility as far as practicable, while maintaining scientific integrity. This will include monitoring forecasts/warnings issued for other regions and liaising with adjacent regions as required.

Background knowledge, skills and abilities

- Knowledge of methods for predicting meteorological, oceanographic and ice conditions and their application (including those required by the application of regional variations);
- Knowledge of the performance of forecasting models (deterministic models and ensemble prediction systems), including weather, ocean, ice and wave models;
- Knowledge of remote sensing applications;
- Knowledge of uncertainties and confidence in derived or automated products used for input into routine ice products;
- Knowledge of forecast preparation systems (including the use of the software);
- Knowledge of areas of responsibility (local and regional), and in particular forecast boundaries and associated observation sites;
- Knowledge of forecast issue times and work priorities;
- Knowledge of the types and characteristics of wave and swell, the generation and decay of wave and swell, and shallow water wave characteristics;
- Knowledge of sea ice and freshwater ice physics and dynamics;
- Knowledge of sea/tidal currents and sea level;
- The ability to forecast sea-ice extent, thickness, concentration, stage of development, drift, deformation, growth and melting and floe size;
- The ability to forecast icebergs and their movement/decay.

COMPETENCY 3: WARN OF HAZARDOUS ICE CONDITIONS AND PARAMETERS

Competency description

Warnings are issued in a timely manner when hazardous conditions are expected to reach documented threshold values and updated, amended or cancelled, as appropriate, according to documented criteria. These conditions and parameters are in general prone to damage vessels and equipment and pose threats to the safety of marine navigation and fishing activities.

Performance criteria

(1) Warn for the following hazardous ice conditions and parameters, including their spatial extent, onset/cessation, duration, intensity and their temporal variations:
   (a) Ice pressure warnings;
   (b) Rapid closing of coastal lead warnings;
   (c) Special ice warnings;
   (d) Icebergs;

(2) Ensure that warning products are prepared and issued in accordance with thresholds for hazardous ice conditions and parameters as per national SOPs, including formats, codes and technical regulations on content, accuracy and timeliness;

(3) Ensure that warnings of hazardous ice conditions and parameters are consistent (spatially and temporally), across boundaries of the area of responsibility as far as practicable, while maintaining meteorological integrity. This will include monitoring forecasts/warnings issued for other regions and liaising with adjacent regions as required.

Background knowledge, skills and abilities

- Knowledge of SOPs for warnings;
- Knowledge of ice warning criteria and associated amendment criteria;
- Ability to utilize and clearly communicate forecasting model (deterministic model and ensemble prediction system) outputs;
- Knowledge of areas of responsibility (local and regional) and warning boundaries;
- Ability to use relevant warning communication systems.

COMPETENCY 4: ENSURING THE QUALITY OF ICE INFORMATION AND SERVICES

Competency description

Forecasts, warnings and related products are provided within a quality management framework.

Performance criteria

(1) Apply the organization's quality management systems and quality control procedures as required;
(2) Apply international standards on ice terminology;
(3) Assess the impact of known observational error characteristics (e.g. bias, achievable accuracy and limitations of observations and sensing methods) on forecasts and warnings;
(4) Verify and validate ice data, products, forecasts and warnings (timeliness, completeness, and accuracy), using real-time verification tools;
(5) Monitor the functioning of operational systems, gather and assess customer comments, suggestions and complaints, and take remedial actions when necessary;
(6) Identify and evaluate ice forecasting- and warning-related problems and determine appropriate corrective and preventive actions for continuous improvement.

Background knowledge, skills and abilities

- Knowledge of quality management principles, practices and procedures;
- Knowledge of SOPs for forecasts and warnings;
- The ability to utilize verification techniques and statistics;
- Knowledge of contingency plans;
- Knowledge of relevant stakeholder operations and needs for and applications of forecasts, including:
  - Stakeholder operations (e.g., procedures, tactics, planning processes and cycles);
  - Stakeholder limitations, including operating limits, legal constraints, geopolitical limits;
  - Stakeholder desired outcomes from operation;
- General knowledge of stakeholder terminology such as nautical terms, acronyms, abbreviations, technical terms related to forecast variables (e.g., ice concentration, stage of development, thickness, movement, deformation; freeze up; state of the sea; currents; waves; swell; tides) and awareness of customer-preferred measurement units;
- Knowledge of stakeholder communication and security systems, if required;
- Knowledge of the impact of ice conditions and parameters on stakeholder operations/activities.

COMPETENCY 5: COMMUNICATE ICE INFORMATION TO INTERNAL AND EXTERNAL USERS

Competency description

Ice forecasts and warnings are communicated in a timely and clear manner to meet user community needs. Participate in professional consultations and seek to understand user needs.

Performance criteria

(1) Ensure that all forecasts and warnings are disseminated via the authorized communication channels to user groups;
(2) Provide ice briefings as necessary and provide consultations to meet specific user needs;

(3) Make use of forecasts and warnings of meteorological parameters, variables and phenomena to describe their impact on marine operations and the safety of life and property, including the coastal environment and population.

Background knowledge, skills and abilities

- Knowledge of primary users and operations and their ice-related sensitivities;
- Knowledge of available communication systems, techniques and methodologies;
- Ability to ask users the appropriate questions to better understand their needs and address them or refer them to the appropriate authority;
- Ability to utilize cross-boundary consistency techniques – national and international, as well as interdisciplinary/inter-agency checks as needed;
- Ability to communicate effectively, orally, graphically and in writing (providing the level of detail to meet the identified needs of specific users).

2.6 PROVISION OF CLIMATE SERVICES

One of the purposes of WMO, as laid down in its Convention, is to promote the standardization of meteorological and related observations, including those that are applied to climatological studies and practices. Provision of climate services requires competencies for transformation of climate data (including in situ, remotely-sensed, reanalysis and model output) into climate products and services. Such services require professionals at the managerial level, trainers, information technology (IT) specialists, communicators and administrators, and those specifically involved in the delivery of climate services. The WMO Executive Council, at its sixty-eighth session, approved the competency framework for climate services[10] to help National Meteorological and Hydrological Services (NMHSs) and other institutions to deliver high-quality climate services in compliance with WMO standards and regulations, specifically those defined by the Commission for Climatology (CCl) and the Global Framework for Climate Services (GFCS).

WMO Technical Regulations and Guides, such as the *Guide to Climatological Practices* (WMO-No. 100) and the Guidelines for the Assessment of Competencies for Provision of Climate Services (in preparation), describe in more detail the practices, procedures and specifications that Members are expected to follow or implement in establishing and conducting their arrangements in compliance with the Technical Regulations, and in otherwise developing their meteorological and climatological services.

The list of the competencies to be met and the associated performance criteria would be determined by the infrastructural and human capacity of each institution. The competencies falling in the areas of quality of climate information and services as well as communication of climatological information with users are considered cross-cutting and should be met, at least at basic levels, by all institutions providing climate services.

The WMO competency framework is conditioned by:

(a) The organizational mandate, mission, priorities and stakeholder requirements;
(b) The way in which internal and external personnel are engaged in the provision of climate services;
(c) The available resources and capabilities (financial, human, infrastructural and technical);
(d) National and institutional legislation and rules, organizational structures, policies and procedures;
(e) WMO guidelines, policies and procedures for climate data and products;
(f) The dominant weather and climate influences and extremes experienced.

[10] Resolution 5 (EC-68) – Competencies for provision of climate services

Competency requirements

This competency framework is divided into the following top-level competencies, with related performance criteria and suggested learning outcomes:

1. Create and manage climate datasets;
2. Derive products from climate data;
3. Create and interpret climate forecasts, climate projections and model output;
4. Ensure the quality of climate information and services;
5. Communicate climatological information to users.

COMPETENCY 1. CREATE AND MANAGE CLIMATE DATASETS

Competency description

Climate data, metadata and climate data products are gathered and stored in datasets, quality controlled and assessed for homogeneity.

Performance criteria

1. Conduct climate data preservation and rescue procedures;
2. Assess the location and characteristics of the observation sites against the requirements for a climate observation reference network;
3. Collect and store climate data and metadata in relational databases;
4. Apply quality control processes to climate data and resulting time series;
5. Assess climate data homogeneity and adjust inhomogeneous time series;
6. Create, archive and document climate datasets;
7. Apply spatial and temporal interpolation to ensure data continuity.

Learning outcomes

- 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;
- Characterize 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 explains them using a climate classification;
- Demonstrate computer literacy and the ability to 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;
- Demonstrate the ability to use digitizing devices such as scanners and digital cameras to produce soft copies of climate records;
- Demonstrate the ability to key climate data into a computer from images or paper copies and use real-time quality control techniques to avoid errors;
- Understand the use of various units of measurement and be able to convert these to ensure that parameters within one time series are in the same unit for that parameter;
- Use librarian and archival techniques to organize and preserve hard and soft copies of climate data and metadata;
- 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 evidences;
- Design a database of climate data and metadata using a climate data management system, including raw, quality controlled and homogenized 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.

COMPETENCY 2: DERIVE PRODUCTS FROM CLIMATE DATA

Competency description

Climate data products for science and user applications are derived from different sources of climate data (such as observed and reconstructed time series, reanalysis, satellite and modelled data) applying statistics that describe their spatial and temporal characteristics.

Performance criteria

1. Identify and retrieve climate data from different sources to generate climate products;
2. Compute basic climate products, normals and averages, or anomalies defined in relation to a reference period;
3. Compute climate indices for the monitoring of climate change, climate variability and climate extremes;
4. Compute sector-specific climate indices and other sector-oriented climate products;
5. Apply statistical and geostatistical analysis to monitor the spatial distribution and temporal evolution of climate;
6. Create value-added products, such as graphics, maps and reports to explain climate characteristics and evolution, according to the needs of specific sectors such as health, agriculture, water, energy and disaster management.

Learning outcomes

- Characterize the climate of the area of study and describe its variability and recent changes;
- 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 organization, including local, regional and global networks;
- Retrieve climate data from original sources inside and outside the organization, and organize, store and document them;
- List different sources of sectorial data inside and outside the organization, including local, regional and global networks;
- Retrieve sectorial data from original sources inside and outside the organization, and organize, store and document them;
- Prepare climate and sectorial datasets for own usage, considering the necessary spatial and temporal coverage;
- Demonstrate knowledge of descriptive statistics and their adaptation to climate analysis, including measures of centrality and dispersion, data centring and standardization;

- 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;
- Demonstrate knowledge of inferential and multivariate statistics, including hypothesis testing, fitting and exploiting probability distributions, correlation and regression models, principal components analysis and clustering methods;
- Demonstrate knowledge of geostatistics, especially the techniques involved in data interpolation (for example, Krigging);
- Demonstrate computer literacy and the ability to 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 (RClimdex, Climpact) and other climate products;
- Explain the meaning and applications of widely used climate indices, such as those included in the RClimdex and Climpact packages;
- Make use of climate data, climate indices, other climate-related information and sectorial 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.

COMPETENCY 3: CREATE AND INTERPRET CLIMATE FORECASTS, CLIMATE PROJECTIONS AND MODEL OUTPUT

Competency description

Climate data, climate data products and climate models output are used to create sub-seasonal and seasonal climate forecasts and future climate projections.

Performance criteria

1. Locate, select and retrieve climate forecasts and climate models output generated by Regional Climate Centres (RCCs), Global Producing Centres (GPCs) and other institutions;
2. Create sub-seasonal, seasonal and longer scale forecast products;
3. Create future climate projections using climate models over selected domain for different scenarios and parametrization;
4. Apply statistical and geostatistical analysis, including downscaling, to monitor the spatial distribution and temporal evolution of model output;
5. Evaluate the performance of climate models output and quantify the associated uncertainties;
6. Create value-added products, such as graphics, maps and reports to communicate climate forecasts and climate model information.

Learning outcomes

- 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 measure 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 demonstrate proficiency in the use of spatio-temporal statistical tools;
- 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.

COMPETENCY 4: ENSURE THE QUALITY OF CLIMATE INFORMATION AND SERVICES

Competency description

Climate information and services are defined and routinely updated. Best practices are followed and guidelines and quality management procedures for climate information are established and routinely maintained. Monitoring processes for climate services are documented and used in quality control activities.

Performance criteria

1. Define and apply quality management procedures for climate services;
2. Recruit competent personnel and design the organization workforce to develop and deliver climate services;
3. Ensure that the institution meets the competency framework at its infrastructural capacity level and has a strategy for sustainable capabilities;
4. Provide training to personnel so that they can fulfil their job requirements and expand their capabilities;
5. Conduct refresher courses at regular intervals to update knowledge;
6. Define and implement a catalogue of climate datasets, products and services to meet user requirements at the national and regional level;
7. Monitor the functions of climate services, including validation of data, products and services;
8. Evaluate the impact and benefits of climate services for customers, by gathering customers' comments, suggestions and complaints;
9. Make decisions about service improvement based on evaluation results;
10. Build partnerships with science and service providers and end user stakeholders to improve products and service delivery.

Learning outcomes

- 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;

- Demonstrate ability to work with varied technical knowledge and methodologies across a multidisciplinary team required to deliver climate services;
- Identify education and training systems for developing knowledge and skills for climate services;
- Identify stakeholder needs and characteristics, including:
  - Stakeholder operations, including procedures, tactics, communications, planning processes and cycles;
  - Stakeholder limitations, including operating limits, legal constraints, geopolitical limits and level of climate knowledge;
  - Stakeholder time frames and frequency of engagement;
  - Stakeholder expectations;
  - Stakeholder's terminology;
  - Stakeholder climate impact;
- Use methods of identifying changing user requirements, service delivery techniques and technologies;
- Apply programme evaluation approaches;
- Evaluate results to define improvements and contingency plans.

COMPETENCY 5: COMMUNICATE CLIMATOLOGICAL INFORMATION TO USERS

Competency description

Climate science, data and products are disseminated to policymakers, clients, stakeholders and the general public.

Performance criteria

1. Prioritize the communication of climatological information according to social, political and economic relevance;
2. Establish effective communication channels with users of climate services and build outreach capacities, such as Regional Climate Outlook Forums;
3. Conduct and evaluate customer needs analysis on a regular basis;
4. Review climate services and their communication on the basis of user feedback;
5. Develop and deliver, in partnership with users, specific applications to facilitate understanding and use of climate products and services;
6. Comply with the interfacing requirements of the GFCS and the integration within the WMO Information System (WIS).

Learning outcomes

- Identify climatological similarities and differences across the area of study, relate them to climate controlling factors and explain them using a climate classification;
- Characterize 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;
- Make use of appropriate channels of communication, including management of social media and liaison with media agents;

- Carry out a survey of users' needs in terms of climatological information and revise it on the basis of users' input;
- Find out from users how they use climate information in order to ascertain whether it has to be revised or whether they need assistance in using it;
- Formulate climatological information in a language that is both scientifically sound and adapted to the foreseen 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.

2.7 INSTRUMENTATION, CALIBRATION, METEOROLOGICAL OBSERVATIONS, AND OBSERVING PROGRAMME AND NETWORK MANAGEMENT

The following frameworks were approved by the Commission for Instruments and Methods of Observation (CIMO) and by the Executive Council at its seventieth session in 2018.

2.7.1 Competency framework for personnel performing meteorological observations

The provision of the meteorological observations function within an NMHS or related agencies may be accomplished by a variety of skilled personnel, including meteorologists, climatologists, geographers, meteorological instrument technicians and meteorological technicians. It can also be accomplished by a range of other people not directly within the sphere of the NMHS, such as farmers, police, clerical workers, or private citizens. Third-party (for example, universities, international and regional institutions and research centres) and private-sector organizations might also contribute to this function.

This section sets out a competency framework for personnel (primarily professional meteorological observers) involved in the provision of meteorological observations function, but it is not necessary that each person has the full set of competencies as set out in the framework. However, within specific application conditions (as set out below), which might be different for each organization or region, it is expected that any institution providing meteorological observation services will have staff members somewhere within the organization who together demonstrate all the competencies. The performance components as well as the knowledge and skill requirements that support the competencies should be customized based on the particular context of an organization. However, the general criteria and requirements provided here will apply in most circumstances.

It is recommended that professional meteorological observers performing meteorological observations should have successfully completed the Basic Instruction Package for Meteorological Technicians (BIP-MT) (detailed information on BIP-MT is given in *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I.

Application conditions

The application of the competency framework will depend on the following circumstances, which will be different for each organization:

(a) The organizational context, priorities and stakeholder requirements;
(b) The way in which internal and external personnel are used to provide meteorological observation services;
(c) The available resources and capabilities (financial, human, technological, and facilities), and organizational structures, policies and procedures;

(d) National and institutional legislation, rules and procedures;
(e) WMO guidelines, meteorological observation procedures and ISO requirements;
(f) Regional variations:
    (i) The range of weather phenomena experienced in the region;

    (ii) Local climatology;

    (iii) Extent of automation of observing and sensing systems;

    (iv) Available communication technologies.

Meteorological observations: High-level competencies

1. Monitor the meteorological situation
2. Perform a surface observation
3. Perform a balloon-borne upper-air observation
4. Utilize remote-sensing technology in making observations
5. Monitor the performance of instruments and systems
6. Maintain the quality of observational information
7. Maintain a safe work environment

COMPETENCY 1: MONITOR THE METEOROLOGICAL SITUATION

Competency description

Appraise meteorological conditions to identify the significant and evolving situation that is affecting or will likely affect the area of responsibility throughout the watch period.

Performance components

(a) Assess the evolving local meteorological situation;
(b) Understand the potential influence of the evolving meteorological situation on subsequent observations;
(c) Identify meteorological symptoms that may lead to the onset of significant weather.

Knowledge and skill requirements

(a) Understanding of general meteorology as described in BIP-MT, including physical meteorology, dynamic meteorology, synoptic and mesoscale meteorology, climatology, meteorological instruments and methods of observations;
(b) Identification of clouds and other meteors using the *International Cloud Atlas: Manual on the Observation of Clouds and Other Meteors* (WMO-No. 407) as guidance;
(c) Meteorological factors leading to the evolution of significant weather;
(d) Standard operating procedures (SOPs) and prescribed practices for monitoring weather conditions.

COMPETENCY 2: PERFORM A SURFACE OBSERVATION

Competency description

Perform surface observations of meteorological variables and phenomena, and their significant changes, according to prescribed practices.

Performance components

(a) Observe and accurately record:
- Precipitation
- Atmospheric pressure
- Temperature
- Humidity
- Wind
- Cloud
- Present and past weather
- Visibility
- Solar radiation
- Sunshine duration
- Evaporation
- Soil temperature
- State of the ground
- Other specialized observations as required (for example, soil moisture, sea state, atmospheric composition, wind shear, leaf wetness, phenology);

(b) Encode and transmit surface observations using prescribed codes and methods.

Knowledge and skill requirements

(a) Understanding of general meteorology as described in BIP-MT including physical meteorology, dynamic meteorology, synoptic and mesoscale meteorology, climatology, meteorological instruments and methods of observations;
(b) Cloud classification as defined in the *International Cloud Atlas: Manual on the Observation of Clouds and Other Meteors* (WMO-No. 407);
(c) Past and present weather identification;
(d) SOPs and prescribed practices for performing surface observations;
(e) On-site instrumentation and systems (including software);
(f) Care in handling instruments;
(g) Accuracy in reading instruments and in recording observations;
(h) Use of meteorological codes to record observations (for example, according to *Manual on the Global Data-processing and Forecasting System* (WMO–No. 485) and *Manual on Codes* (WMO-No. 306), several volumes/years).

COMPETENCY 3: PERFORM A BALLOON-BORNE UPPER-AIR OBSERVATION

Competency description

Perform a balloon-borne upper-air observation, according to prescribed practices and procedures.

Performance components

(a) Prepare and deploy balloons and their payloads:
- Balloon shed safety check;
- Balloon preparation and filling;
- Instrument ground check;
- Balloon release;

(b) Track balloon flight;
(c) Compute and record:
- Upper-air pressure, temperature and humidity;
- Upper-air wind speed and direction;
- Other specialized upper-air observations as required (for example, ozone);

(d) Encode and transmit upper-air observations using prescribed codes and methods.

Knowledge and skill requirements

(a) Hydrogen safety and generation;
(b) Understanding of general meteorology as described in BIP-MT, including physical meteorology, dynamic meteorology, synoptic and mesoscale meteorology, climatology, meteorological instruments and methods of observations;
(c) SOPs and prescribed practices for performing upper-air observations;
(d) On-site instrumentation and systems (including software);
(e) Care in handling instruments;
(f) Accuracy in reading instruments and in recording observations;
(g) Use of meteorological codes to record observations.

COMPETENCY 4: UTILIZE REMOTE-SENSING TECHNOLOGY IN MAKING OBSERVATIONS

Competency description

Make observations utilizing remote-sensing technology, for example, satellite, weather radar, radar wind profiler, wind lidar, ceilometer, microwave radiometer, lightning detection system, and the like.

Performance components

(a) Interpret information derived from remote-sensing technology in making observations (for example, ceilometer for cloud base height in synoptic observations and meteorological aerodrome reports);
(b) Cross-check observations obtained from alternative observing techniques (for example, remote sensing versus in situ measurements) to ensure consistency (for example, compare visibility information recorded by visibility meters with satellite imagery (fog, sandstorms) and manual observations).

Knowledge and skill requirements

(a) Understanding of the physical principles of operation, the particular technical configuration and the limitations of surface-based and space-based remote-sensing technology being utilized (for example, weather radar, wind lidar, ceilometer, lightning detection system, radar wind profiler, microwave radiometer);
(b) Knowledge of the use of different meteorological and oceanographic information derived from remote-sensing technology (for example, imagery from different channels of satellites, wind field from Doppler weather radars).

COMPETENCY 5: MONITOR THE PERFORMANCE OF INSTRUMENTS AND SYSTEMS

Competency description

Monitor the status and performance of observational instrumentation and communications systems.[11]

[11] See also competency 2 under 2.7.2.

Performance components

(a) Regularly inspect meteorological instruments (for example, raingauges, wet bulb thermometers), automated observing systems (for example, AWS, weather radar fault status), communications systems and backup systems (for example, power);
(b) Conduct routine maintenance tasks as prescribed (for example, change wet bulb wick or recorder charts, clean pyranometer dome or ceilometer window);
(c) Conduct first-in fault diagnosis and alert technical staff;
(d) Undertake action under guidance from remote technical staff;
(e) Record interventions and irregularities in a maintenance log or metadata repository.

Knowledge and skill requirements

(a) SOPs and prescribed practices for carrying out inspection of instruments and communications systems, and the like;
(b) Accuracy requirements for instrumentation and measurements (for example, as specified in the present Guide and other WMO or International Civil Aviation Organization (ICAO) regulatory and guidance materials);
(c) On-site instrumentation and systems (including software);
(d) Care in handling instruments;
(e) Accuracy in reading instruments and recording observations;
(f) Use of meteorological codes to record observations;
(g) Hazard awareness in the vicinity of instruments and communications systems (for example, near electrical cables, working at heights, electromagnetic radiation);
(h) Prescribed contingency plans (for example, failure of power and communications systems, damage to infrastructure during severe weather events).

COMPETENCY 6: MAINTAIN THE QUALITY OF OBSERVATIONAL INFORMATION

Competency description

Maintain the quality of meteorological observations at the required level by applying documented quality management processes.

Performance components

(a) Monitor all observations to check for errors and inconsistencies, correct errors or flag data in accordance with prescribed procedures and take follow-up action;
(b) Record corrections, flags and follow-up actions in metadata repository;
(c) Check observational messages for format and content before issuance and make corrections if required;
(d) Ensure all observations are successfully sent and received.

Knowledge and skill requirements

(a) Understanding of general meteorology as described in BIP-MT, including physical meteorology, dynamic meteorology, synoptic and mesoscale meteorology, climatology, meteorological instruments and methods of observations;
(b) Standard operating procedures and prescribed practices for treating suspect observations;
(c) Accuracy requirements for measurements (for example, as specified in the present Guide and other WMO or ICAO regulatory and guidance materials);
(d) On-site instrumentation and systems (including software);
(e) Use of meteorological codes to record observations;
(f) Prescribed contingency plans (for example, data transmission failure, power failure).

COMPETENCY 7: MAINTAIN A SAFE WORK ENVIRONMENT

Competency description

Perform all observing tasks in a safe and healthy working environment, at all times complying with occupational safety and health regulations and procedures.

Performance components

(a) Safely handle, store and dispose of hydrogen and the chemicals used for generating hydrogen;
(b) Safely handle, store and dispose of mercury, and equipment containing mercury;
(c) Safely handle, store and dispose of other toxic or dangerous substances, and equipment containing these substances (such as wet-cell batteries);
(d) Perform safely in the proximity of electrical hazards;
(e) Safely perform all observing tasks while minimizing exposure to hazardous environmental conditions (severe weather, lightning, flood, hurricane, fires, and the like);
(f) Safely perform all observing tasks in the presence of safety hazards (working at heights, in the proximity of microwave radiation, compressed gases, and the like);
(g) Maintain a register of hazards and hazard management.

Knowledge and skill requirements

(a) Occupational safety and health requirements and procedures (for example, hydrogen, mercury, chemical, electrical safety and working at height);
(b) Hazard identification and mitigation;
(c) Hazard register summarizing all potential hazards and control measures in the workplace to enhance occupational safety.

2.7.2 Competency framework for personnel installing and maintaining instrumentation

The provision of instrument installation and maintenance services within an NMHS or related services might be accomplished by a variety of skilled personnel, including meteorologists, instrument specialists and technicians, engineers and IT personnel. Personnel in third-party organizations (for example, private contractors, communication service providers and instrument maintenance agents) and other providers might also supply installation and maintenance services for various meteorological observing instruments.

This section sets out a competency framework for personnel involved in the installation and maintenance of meteorological observing instruments,[12] but it is not necessary that each person has the full set of competencies. However, within specific application conditions (see below), which will be different for each organization, it is expected that any institution providing the instrument installation and maintenance services will have staff members somewhere within the organization who together demonstrate all the competencies. The performance components as well as the knowledge and skill requirements that support the competencies should be customized based on the particular context of an organization. However, the general criteria and requirements provided here will apply in most circumstances.

It is recommended that professional meteorological observers performing meteorological observations should have successfully completed the Basic Instruction Package for

[12] In this section, the competency refers to the performance required for effective installation and maintenance of minor pieces of observing instruments. The competencies for large meteorological observing infrastructures such as those including radars and wind profilers are covered under observing programme and network management competencies.

Meteorological Technicians (BIP-MT) (detailed information on BIP-MT is given in *Guide to the Implementation of Education and Training Standards in Meteorology and Hydrology* (WMO-No. 1083), Volume I.

Application conditions

The application of the competency framework will depend on the following circumstances, which will be different for each organization:

(a) The organizational context, priorities and stakeholder requirements;
(b) The way in which internal and external personnel are used to provide the instrument installation and maintenance services;
(c) The available resources and capabilities (financial, human, technological, and facilities), and organizational structures, policies and procedures;
(d) National and institutional legislation, rules and procedures;
(e) WMO guidelines, recommendations and procedures for instrument installation and maintenance services.

Instrumentation: High-level competencies

1. Install instruments and communications systems
2. Maintain instrument and system performance
3. Diagnose faults
4. Repair faulty instruments and systems
5. Maintain a safe work environment

COMPETENCY 1: INSTALL INSTRUMENTS AND COMMUNICATIONS SYSTEMS

Competency description

Install, test and commission meteorological observing instruments and communications systems.

Performance components

(a) Assemble and test instruments before transport to site;
(b) Transport instruments to site;
(c) Install instruments and communication systems (including simple site preparation);
(d) Coach observing and technical staff in the operation and maintenance of the instruments (including provision of SOPs), standard operating instructions, system manuals, wiring diagrams, and the like;
(e) Thoroughly test on-site instrument and communications performance, prior to operational cutover;
(f) Complete site classification for variable(s) concerned, prepare and submit instrument and variable metadata to WIGOS via the Observing Systems Capability Analysis and Review Tool (OSCAR);
(g) Switch instrument(s) to operational mode.

Knowledge and skill requirements

(a) Understanding of general meteorology as described in BIP-MT;
(b) Detailed understanding of meteorological instruments and methods of observation;
(c) Use of meteorological codes to record observations (for example, according to *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485) and *Manual on Codes* (WMO-No. 306), several volumes/years));

(d) WMO Information System (WIS) set-up;
(e) Careful handling of instruments, including during transportation;
(f) Electronics and information and communication technologies (ICTs);
(g) Correct and safe use of mechanical and electrical tools;
(h) SOPs, practices and quality management systems;
(i) Occupation safety and health requirements for instruments and systems.

COMPETENCY 2: MAINTAIN INSTRUMENT AND SYSTEM PERFORMANCE

Competency description

Perform preventive maintenance on instruments and communications systems in accordance with SOPs to ensure quality and availability of observational information.[13]

Performance components

(a) Schedule and carry out preventive maintenance and site inspection following prescribed procedures (for example, change wet bulb wick or recorder charts, clean pyranometer dome or ceilometer window, change anemometer bearings, and carry out preventive maintenance on more sophisticated pieces of equipment such as radars and AWSs as specified in the SOPs);
(b) Ensure availability of prescribed spare parts inventories;
(c) Monitor data availability and the performances of instruments and communications systems;[14]
(d) Routinely verify correct functioning of instruments, following prescribed procedures;
(e) Perform on-site calibration checks to ensure that instrument performance is within tolerance, following prescribed procedures;
(f) Provide guidance and refresher training, remotely if necessary, to on-site staff, to maintain compliance with prescribed methods of operating the instruments, for making observations and with procedures for the reduction of observations;
(g) Inspect the exposure of instruments and remove any obstacles nearby if necessary;
(h) Record maintenance and site inspection[15] events, calibrations, sensor/instrument replacements in the maintenance log or metadata repository.

Knowledge and skill requirements

(a) Understanding of general meteorology as described in BIP-MT;
(b) Detailed understanding of meteorological instruments and methods of observation and particular familiarity with those employed at the site;
(c) Care in handling instruments;
(d) Accuracy in reading instruments;
(e) Maintenance and site inspection manuals, SOPs, practices and quality management systems;
(f) Electronics and ICTs;
(g) Measurement uncertainty of instruments and calibration traceability;
(h) Occupation safety and health requirements for instruments and systems.

[13] See also competency 5 under 2.7.4.
[14] See also competency 5 under 2.7.1.
[15] For site inspection tasks, refer to the *Guide to Instruments and Methods of Observation* (WMO-No. 8), particularly Volume I, Chapter 1, 1.3.5.1 and Volume V, Chapter 1, 1.10.1; also to *Guide to the Global Observing System* (WMO-No. 488), particularly Chapter 3, 3.1.3.8 and 3.1.3.11; and *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), particularly Chapter 3, 3.4.8.

COMPETENCY 3: DIAGNOSE FAULTS

Competency description

Diagnose faults in the performance of the observation system (instruments, communications, power supply and auxiliary infrastructure).

Performance components

(a) Detect abnormality in data acquisition and system operation;
(b) Inspect observational instruments, communications systems, power supply facilities and auxiliary infrastructure for faults;
(c) Provide guidance, remotely if necessary, to on-site staff to identify and diagnose minor faults;
(d) Record all faults and their occurrence time in a maintenance log or metadata repository;
(e) If repair is required, order delivery of requisite spare parts.

Knowledge and skill requirements

(a) Understanding of general meteorology as described in BIP-MT;
(b) Detailed understanding of meteorological instruments and methods of observation and particular familiarity with those employed at the site;
(c) Use of meteorological codes to record observations (for example, according to *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485) and *Manual on Codes* (WMO-No. 306), several volumes/years);
(d) WIS set-up;
(e) SOPs, practices and quality management systems;
(f) Ability to interrogate the system both on site and remotely;
(g) Electronics and ICTs;
(h) Occupation safety and health requirements for instruments and systems;
(i) Contingency planning to ensure continuity of observations (for example, in the event of power, sensor or system failure, backup sensors and communications systems).

COMPETENCY 4: REPAIR FAULTY INSTRUMENTS AND SYSTEMS

Competency description

Repair faulty instruments and systems in the observing network.

Performance components

(a) Provide guidance, remotely if necessary, to on-site staff to repair minor faults;
(b) Assess spare parts requirements and ensure availability;
(c) Repair faulty components following prescribed procedures and processes;
(d) Perform tests after repair to ensure compliance with performance requirements;
(e) Record repair actions taken and time of resuming data acquisition in a maintenance log or metadata repository.

Knowledge and skill requirements

(a) Understanding of general meteorology as described in BIP-MT;
(b) Detailed understanding of meteorological instruments and methods of observation;

(c) Use of meteorological codes to record observations (for example, according to the *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485) and the *Manual on Codes* (WMO-No. 306);
(d) WIS set-up;
(e) Care in handling instruments including during transportation;
(f) Instrument and system design and operation;
(g) Repair manuals, standard operating procedures and practices, and quality management systems;
(h) Ability to interrogate the system both on site and remotely;
(i) Electronics and ICTs;
(j) Occupation safety and health requirements for instruments and systems.

COMPETENCY 5: MAINTAIN A SAFE WORK ENVIRONMENT

Competency description

Perform all tasks in a safe and healthy working environment, at all times complying with occupational safety and health regulations and procedures.

Performance components
(a) Conduct hazard identification and risk assessment;
(b) Raise safety awareness among other employees and visitors to the site;
(c) Continuously monitor the workplace for occupational safety and health hazards and correct or mitigate non-conformances;
(d) Secure remote sites to ensure public safety;
(e) Make use of personal protective equipment;
(f) Safely handle, store and dispose of all hazardous chemicals (for example, mercury, hydrogen and the chemicals used for generating hydrogen, and batteries);
(g) Perform safely in the proximity of electrical hazards, microwave radiation, weather-related hazards and when working at heights or in confined spaces;
(h) Maintain a register of hazards and hazard management.

Knowledge and skill requirements

(a) *ISO 31000:2018, Risk Management – Guidelines*;
(b) Safety procedures in handling hazardous materials (for example, mercury, hydrogen and the chemicals used for generating hydrogen, and batteries);
(c) Safety procedures for electrical hazards, microwave radiation, weather-related hazards and when working at heights or in confined spaces;
(d) General occupational safety and health requirements;
(e) Hazard identification, mitigation and registration.

2.7.3 Competency framework for personnel performing instrument calibrations

The provision of instrument calibration services within an NMHS or related services might be accomplished by a variety of skilled personnel, including meteorologists, instrument specialists, technicians and engineers. Third-party organizations (for example, private contractors, calibration service providers and laboratories) might also provide calibration services for various meteorological observing instruments.

This section sets out a competency framework for personnel working in calibration laboratories and/or providing centralized calibration services for meteorological observing instruments, but it is not necessary that each person has the full set of competencies. However, within specific application conditions (see below), which will be different for each organization, it is expected that any institution providing the instrument calibration services will have staff members somewhere within the organization who together demonstrate all the competencies.

The performance components as well as the knowledge and skill requirements that support the competencies should be customized based on the particular context of an organization. However, the general criteria and requirements provided here will apply in most circumstances.

Application conditions

The application of the competency framework will depend on the following circumstances, which will be different for each organization:

(a) The organizational context and priorities, and stakeholder requirements;
(b) The way in which internal and external personnel are used to provide the instrument calibration services;
(c) The available resources and capabilities (financial, human, technological, and facilities), and organizational structures, policies and procedures;
(d) National and institutional legislation, rules and procedures;
(e) WMO guidelines, recommendations and procedures for instrument calibration services.

Calibration: High-level competencies

1. Calibrate instruments
2. Check instrument performance
3. Manage the laboratory work programme
4. Manage the laboratory infrastructure
5. Develop and maintain standard operating procedures
6. Manage the archiving[16] of data and records
7. Maintain a safe work environment and laboratory security

COMPETENCY 1: CALIBRATE INSTRUMENTS

Competency description

Execute calibrations in accordance with standard calibration procedures, from item handling to editing of calibration certificates.

Performance components

(a) Execute routine calibrations on a day-to-day basis in accordance with standard calibration procedures;
(b) Compute the calibration uncertainty in conformity with the SOPs;
(c) Prepare a draft of calibration certificate (not including approval or issuance);
(d) Handle calibration items appropriately;
(e) Conduct intermediate checks of working standards in calibration laboratory;
(f) Participate in internal and external audits.

Knowledge and skill requirements

(a) Laboratory facilities and standards (including software);
(b) SOPs for performing calibration and computation of calibration uncertainty;
(c) Care in handling instruments;

[16] "Archiving", in this context, is the function of storing, keeping secure and ensuring discoverability, accessibility and retrievability of data and information.

(d) The basics of metrology and uncertainty computation, including knowledge of VIM, SI, measurement standards and traceability, measurement uncertainty and errors, and calculation of uncertainty using prescribed methods;
(e) The basics of meteorological instrumentation, including understanding of the working principles of common meteorological instruments and their characteristics and accuracy requirements for measurements (for example, as specified in the present Guide and other WMO or ICAO regulatory and guidance materials).

COMPETENCY 2: CHECK INSTRUMENT PERFORMANCE

Competency description

Check instrument performance in the laboratory using measurement standards in accordance with SOPs.

Performance components

(a) Prepare the standards to be used for checking instrument performance;
(b) Handle standards and items appropriately;
(c) Compare the instrument with standards and evaluate its functionality;
(d) Record and analyse the measurement errors;
(e) Prepare instrument performance reports as required.

Knowledge and skill requirements

(a) Handling and use of measurement standards;
(b) SOPs for performing instrument checks;
(c) Care in handling instruments;
(d) The basics of metrology and uncertainty computation, including knowledge of VIM, SI, measurement standards and traceability, measurement uncertainty and errors, and calculation of uncertainty using prescribed methods;
(e) The basics of meteorological instrumentation, including understanding of the working principles of common meteorological instruments and their characteristics and accuracy requirements for measurements (for example, as specified in the present Guide and other WMO or ICAO regulatory and guidance materials).

COMPETENCY 3: MANAGE THE LABORATORY WORK PROGRAMME

Competency description

Develop, prepare, organize and manage the calibration activities of the calibration laboratory.

Performance components

(a) Manage the work of the calibration laboratory, including quality and technical aspects (covering traceability of standards, uncertainty budget evaluation) in accordance with *ISO/IEC 17025 – General requirements for the competence of testing and calibration laboratories*;
(b) Plan and organize the regular calibrations (either internal or external, as required) of reference standards following SOPs and/or relevant WMO guidance;
(c) Prepare, plan, design, procure the physical infrastructure for calibration activities (test chambers, standards, fixed point cells, pressure generators, and the like) and the applications required to conduct calibration activities;

(d) Monitor the quality of the laboratory calibration activities and determine the laboratory's applicable calibration and measurement capability (CMC);
(e) Provide ongoing training to ensure maintenance of competency of the calibration laboratory staff (training, qualification, and the like);
(f) Communicate with customers on calibration issues, including explaining the results of calibrations;
(e) Conduct internal and external audits, and where possible ILCs as recommended by ISO/IEC 17025.

Knowledge and skill requirements

(a) Laboratory facilities and standards (including software);
(b) SOPs for managing the calibration activities of the laboratory;
(c) Advanced metrology and uncertainty computation including, in addition to the basics, detailed knowledge of JCGM 100:2008, *Evaluation of measurement data — Guide to the expression of uncertainty in measurement* (GUM) or equivalent, and application of the GUM framework to measurement uncertainty evaluation;
(d) SOPs for ILCs and assessment of CMC;
(e) Quality-related requirements (for example, ISO 9001, ISO/IEC 17025, good laboratory practice);
(f) Meteorological instrumentation covering the knowledge of the performance characteristics of common meteorological instruments;
(g) Current technologies and emerging trends of laboratory instruments.

COMPETENCY 4: MANAGE THE LABORATORY INFRASTRUCTURE

Competency description

Install and maintain the physical infrastructure for calibration activities (test chambers, standards, fixed-point cells, pressure generators, and the like) and the applications required to conduct calibration activities.

Performance components

(a) Install and set up the physical infrastructure for calibration activities, including software;
(b) Test the equipment to ensure its compliance with the requirements;
(c) Maintain the laboratory infrastructure in optimal operational condition;
(d) Maintain the quality of the laboratory reference standard instruments;
(e) Conduct preventive and corrective maintenance;
(f) Manage site environment (air conditioning, secure electric power, and the like).

Knowledge and skill requirements

(a) Laboratory facilities and standards (including software), and their maintenance;
(b) Asset management;
(c) Care in handling instruments;
(d) SOPs for managing the laboratory infrastructure;
(e) The basics of metrology including knowledge of VIM, SI, measurement standards and traceability;
(f) The basics of meteorological instrumentation and its maintenance.

COMPETENCY 5: DEVELOP AND MAINTAIN STANDARD OPERATING PROCEDURES

Competency description

Develop, assess and maintain SOPs necessary for the achievement of calibrating activities, including computing calibration uncertainties.

Performance components

(a) Develop SOPs taking into account available laboratory facilities and quality management requirements;
(b) Establish uncertainty budget for calibration operating procedures;
(c) Develop calibration certificate templates;
(d) Maintain and upgrade SOPs (including in support of maintenance).

Knowledge and skill requirements

(a) Knowledge of best practices relating to SOPs;
(b) Advanced metrology and uncertainty computation including, in addition to the basics, detailed knowledge of JCGM 100:2008, *Evaluation of measurement data — Guide to the expression of uncertainty in measurement* (GUM) or equivalent, application of the GUM framework to measurement uncertainty evaluation, conducting ILCs and determination of the CMC of the laboratory;
(c) Laboratory facilities and standards (including software);
(d) Quality requirements (for example, ISO 9001, ISO/IEC 17025, good laboratory practice);
(e) Meteorological instrumentation, in particular, those in the national network.

COMPETENCY 6: MANAGE THE ARCHIVING OF DATA AND RECORDS

Competency description

Ensure archiving of calibration activity measurements, calibration certificates and records.

Performance components

(a) Archive calibration activity measurement data and metadata and the associated records;
(b) Archive calibration certificates of calibrated instruments;
(c) Archive calibration certificates of laboratory instruments.

Knowledge and skill requirements

Knowledge of prescribed practices for managing the data and record archiving.

COMPETENCY 7: MAINTAIN A SAFE WORK ENVIRONMENT AND LABORATORY SECURITY

Competency description

Perform all calibration tasks in a safe and healthy working environment, at all times complying with occupational safety and health regulations and procedures, and security requirements.

Performance components

(a) Safely handle, store and dispose of mercury, and equipment containing mercury;
(b) Safely handle, store and dispose of other toxic or dangerous substances, and equipment containing these substances (such as wet-cell batteries);
(c) Perform safely in the proximity of electrical hazards;
(d) Safely perform all calibration tasks in the presence of safety hazards;
(e) Ensure the security (access restrictions, and the like) of the calibration laboratory and instruments under test.

Knowledge and skill requirements

(a) Mercury safety procedures;
(b) Chemical safety procedures;
(c) Electrical safety procedures;
(d) Occupational safety and health requirements;
(e) SOPs for maintaining staff safety and laboratory security.

2.7.4 Competency framework for personnel managing observing programmes and networks

The management of observing programmes and network operation within an NMHS or related services might be accomplished by a variety of skilled personnel, including programme planners and managers, meteorologists, instrument specialists and technicians, engineers and IT personnel. Personnel in third-party organizations (for example, private contractors, communication service providers and instrument maintenance agents) and other providers might also supply consultancy and management services for the observing programme and/or equipment maintenance services for the observing network.

This section sets out a competency framework for personnel involved in the management of observing programmes and networks. It is not necessary that each person has the full set of competencies.[17] However, within specific application conditions (see below), which will be different for each organization, it is expected that any institution managing an observing programme and network operation will have staff members somewhere within the organization or external service providers who together demonstrate all the competencies. The performance components as well as the knowledge and skill requirements that support the competencies should be customized based on the particular context of an organization. However, the general criteria and requirements provided here will apply in most circumstances.

In planning and managing the observing programme and network operation, the relevant regulatory requirements and guiding principles from *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160) should be taken into account (for example, Appendices 2.1 and 2.5). The WMO Rolling Review of Requirements process in combination with OSCAR should be used so that the capabilities of the observing programme can be reviewed and improved to meet the relevant data requirements under various WMO application areas.

Application conditions

The application of the competency framework will depend on the following circumstances, which will be different for each organization:

(a) The organizational context, priorities and stakeholder requirements;
(b) The way in which internal and external personnel are used to provide the observing programme and network management services;

[17] In the present context, "competency" refers to the performance required for effective management of an observing programme involving large meteorological observing networks such as those including radars and wind profilers.

(c) The available resources and capabilities (financial, human, technological, and facilities), and organizational structures, policies and procedures;
(d) National and institutional legislation, rules and procedures;
(e) WMO guidelines, recommendations and procedures for observing programme and network management.

Observing programme and network management: High-level competencies

1. Plan the observing programme
2. Procure equipment
3. Select and acquire sites
4. Install network components
5. Manage the network operation
6. Manage the observing programme

COMPETENCY 1: PLAN THE OBSERVING PROGRAMME

Competency description

Ascertain observation requirements and formulate observing programme development plans that satisfy these requirements taking into account the technical, financial and human resources required for implementation, continuous operation and long-term sustainability.

Performance components

(a) Assess user requirements for observations (Rolling Review of Requirements);
(b) Perform an observation system gap analysis using OSCAR;
(c) Identify the required observational instrumentation to fill the identified gaps;
(d) Design network topology and structure required to fill the identified gaps, taking into account the inclusion of external (so-called third-party) data sources;
(e) Identify the associated human resources required (quantities and competencies) for the sustainable operation of the proposed observing programme;
(f) Identify the required supporting infrastructure (for example site, buildings, communications);
(g) Prepare a fully costed life cycle plan for the sustainable operation of the proposed observing programme;
(h) Document in detail the proposed observing programme and develop the implementation plan;
(i) Check that the final observing programme satisfies the original specified requirements (review and obtain feedback from users);
(j) Develop (or update existing) contingency plan and business continuity plan for the observing programme.

Knowledge and skill requirements

(a) Users' requirements for data under various WMO application areas;
(b) Meteorological instruments and communications systems installed in the observing network, commercially available alternatives and emerging developments;
(c) Programme management, including knowledge of programme planning, organizational structure, design and scheduling of tasks and liaison with stakeholders;
(d) Financial planning and management, including knowledge of different financial accounting models – for example, accrual and cash accounting, asset versus recurrent costing, costs benefits analysis, and whole-life costing;
(e) Understanding of human resource management, including knowledge of planning and developing human resources, and the like;

(f) Contingency planning and existing observing system contingency plans;
(g) Familiarity with WMO regulations, guidelines and activities (for example, *Guide to Instruments and Methods of Observation* (WMO-No. 8), *Guide to the Global Observing System* (WMO-No. 488), *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), the Rolling Review of Requirements, OSCAR and CIMO Testbeds);
(h) Familiarity with the Implementation Plan for the Evolution of Global Observing Systems and any national observing system strategies;
(i) ISO 9001 (Quality Management Systems).

COMPETENCY 2: PROCURE EQUIPMENT

Competency description:

Procure instruments and the associated infrastructure (including communications systems, initial spares and staff training) as specified for the implementation, continuous operation and long-term sustainability of the observing programme.

Performance components:

(a) Confirm procurement scope with the planning team, including availability of funds to meet capital and operational costs;
(b) Conduct market surveys to identify the suitable models of instruments meeting observation requirements;
(c) Conduct engineering design and/or draw up functional specifications of the instruments to be procured;
(d) Initiate tender or purchasing processes for equipment and infrastructure (obtain the necessary approvals) and prepare and issue procurement documents:
    – Tender evaluation;
    – Purchase recommendation;
    – Appoint supplier;
(e) Conduct factory acceptance tests;
(f) Conduct site acceptance tests (if required);
(g) Authorize payments subject to satisfactory fulfilment of the contract terms.

Knowledge and skill requirements

(a) Observing programme, including meteorological instruments and communications systems installed in the observing network;
(b) Observing technology options (as described in the present Guide);
(c) ICT options;
(d) National and organizational procurement rules and guidelines;
(e) Project management (especially with significant procurement projects);
(f) *ISO 31000:2018, Risk management – Guidelines*;
(g) Occupational safety and health requirements for instruments and systems.

COMPETENCY 3: SELECT AND ACQUIRE SITES

Competency description:

Select, acquire and commission observing sites for installation of instruments and communications systems.

Performance components:

(a) Identify suitable sites for long-term observations that meet observational requirements (for example, conduct site survey to ensure representative measurements of the required variables can be taken to satisfy the data requirements of relevant WMO application areas);
(b) Detailed site planning and site acquisition (ensure reliable power supply and communications; ascertain best form(s) of communications (satellite, copper cable, optical fibre, microwave link, General Packet Radio Service, private wire); road access, site exposure, granting of site lease, acquisition of formal land allocation notification, and the like);
(c) Prepare site or enclosure (for example, civil works: clear and level the site, establish power and communications; ensure fencing of site and road access);
(d) Provide site plan, layout diagrams of observing equipment, power supply, communication links, and the like;
(e) Conduct joint site inspection and acceptance tests;
(f) Confirm site conditions, for example, flatness of site, earthing conditions (< 10 ohms) for lightning protection, low electromagnetic wave background for lightning location detector, quality of power supply, communications bandwidth, roadways and fencing;
(g) Complete the handover of site (for example, obtain site acceptance certificates);
(h) Prepare and submit site metadata to WIGOS via OSCAR.

Knowledge and skill requirements

(a) *Guide to Instruments and Methods of Observation* (WMO-No. 8) (for example, Volume I, Chapter 1, in particular 1.3, and Annex 1.D – Siting classification for surface observing stations on land (WMO/ISO); Annex 1.F – Station exposure description);
(b) WIGOS, in particular OSCAR requirements and data submission process;
(c) ICTs;
(d) Site leasing process and negotiation skills;
(e) Project management;
(f) Occupational safety and health requirements.

COMPETENCY 4: INSTALL NETWORK COMPONENTS

Competency description

Install, test and commission major components [18] of observing networks (for example, weather radars, vertical wind profilers).

Performance components

(a) Assemble, test and calibrate network components (for example, instruments, communications, support systems) before transport to site;
(b) Transport network components to site or coordinate delivery by supplier;
(c) Install network components and carry out user acceptance tests;
(d) Ensure training is conducted to meet user or operational requirements (including SOPs and instructions, systems manuals, wiring diagrams, and the like);
(e) Complete site classification for variable(s) concerned; prepare and submit instrumentation metadata to WIGOS via OSCAR;
(f) Switch network components to operational mode.

[18] This indicates components that comprise a significant investment for an organization and so require a structured project management approach, as opposed to the implementation of minor pieces of observing infrastructure, the competencies for which are covered under 2.7.2.

Knowledge and skill requirements

(a) Understanding of general meteorology as described in BIP-MT, including meteorological codes, and WIS set-up;
(b) The observing programme, including existing network components or new components to be installed in the observing network;
(c) Careful handling of network components, including during transportation;
(d) Electronics and ICTs;
(e) Correct and safe use of mechanical and electrical tools;
(f) SOPs, practices and quality management systems;
(g) Occupation safety and health requirements.

COMPETENCY 5: MANAGE THE NETWORK OPERATION

Competency description

Manage the observing network (including observations, instrument calibration and maintenance) to ensure its continuous operation and timely delivery of quality observations.

Performance components

(a) Implement network maintenance (preventive, corrective, adaptive), site inspection and instrument calibration programmes[19] to ensure correct and sustainable functioning of all equipment;
(b) Develop and employ quality assurance tools (for regular diagnosis of system functions and parameters) for all instrumentation both in situ and remote sensing;
(c) Develop and maintain a data quality monitoring system (for example, manual and/or automated data quality control systems) to ensure data traceability and metadata accuracy;
(d) Coordinate with external sources (partners, volunteers and other third-party sources such as crowdsourcing) regarding the provision of their data to ensure the quality of data and homogeneity of the integrated network;
(e) Prepare contingency plans for network operation and data acquisition, including periodic testing of effectiveness;
(f) Monitor network performance using appropriate tools and schemes, and devise indicators to measure network performance (for example, data availability, timeliness);
(g) Document all operational procedures (for example, network maintenance, instrument calibration, data quality control algorithms, contingency plans);
(h) Maintain an asset register.

Knowledge and skill requirements

(a) Meteorological instruments and communications systems installed in the observing network;
(b) Familiarity with WMO guidelines and regulations on meteorological observations (for example, *Guide to Instruments and Methods of Observation* (WMO-No. 8), *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160) and the WIGOS Framework Implementation Plan);
(c) Detailed knowledge of operational programme management and organizational structure, and the like;
(d) Contingency plans (to ensure continuity of the observing network);
(e) Asset management standards, for example, *ISO 55000:2014, Asset management – Overview, principles and terminology*, and the Global Forum on Maintenance and Asset Management;

[19] Including for remote-sensing equipment. Note, for example, that detailed guidance on maintenance of radars and wind profilers is given in *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 7, 7.7, and *Operational Aspects of Wind Profiler Radars* (WMO/TD-No. 1196), Section 4, respectively.

(f) Occupation safety and health requirements for the observing network.

COMPETENCY 6: MANAGE THE OBSERVING PROGRAMME

Competency description

Manage the observing programme (technical, financial and human resources, and the like) to ensure observing programme requirements are met safely and sustainably.

Performance components

(a) Develop financial and human resource plans and secure the resources that ensure sustainability of the observing programme;
(b) Regularly evaluate and reassess staff performance and provide ongoing training (in liaison with the training section if necessary) to ensure maintenance of competency of all staff involved in the observing programme;
(c) Coordinate with users and, as required, update data requirements of the observing programme (for example, real-time observations, NWP applications and climate monitoring);
(d) Regularly review short-term and long-term goals of the observing programme, identify areas for its continuous improvement (for example, improved standardization, network optimization and development);
(e) Explore and implement technical solutions to address improvement areas identified taking into account technological change of instrumentation and data communication methods;
(f) Promote awareness and compliance of all staff with occupational safety and health requirements.

Knowledge and skill requirements

(a) Financial planning including knowledge of different financial accounting models (for example, accrual and cash accounting, asset versus recurrent costing, cost–benefit analysis, and whole-life costing);
(b) Detailed knowledge of programme monitoring and evaluation techniques;
(c) Understanding of human resource management, including knowledge of performance management and developing of human resources;
(d) Meteorological instrumentation and ICTs;
(e) Familiarity with WMO regulations, guidelines and activities (for example, *Technical Regulations* (WMO-No. 49), *Guide to the Global Observing System* (WMO-No. 488), *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160) and OSCAR);
(f) Occupation safety and health requirements.

2.8 TROPICAL CYCLONE (TC) FORECASTER COMPETENCY STANDARDS

In 2011, the World Meteorological Congress, at its sixteenth session, recognized the need for the Tropical Cyclone Programme to establish top-level tropical cyclone (TC) forecaster competency standards. In 2014, the Executive Council, at its sixty-sixth session, stressed the need for the development of TC forecaster (TCF) competencies in tropical cyclone basins by regional tropical cyclone committees under the initiative of the Regional Specialized Meteorological Centres (RSMCs). Following those requests, each of the five Tropical Cyclone Programme (TCP) regional bodies developed a TCF competency framework to ensure the quality of tropical cyclone forecasting services and to meet users' requirements.

2.8.1 Tropical Cyclone Forecaster Competency Framework in the Regional Association I Tropical Cyclone Committee region

Introduction

The TCF Competency Framework for Regional Association I (RA I) was elaborated in 2017 and presented at the twenty-second session of the RA I Tropical Cyclone Committee (Seychelles, 25–29 September 2017), where it was adopted. It was thereafter approved by RA I. The differences between the RSMC and the National Meteorological Services (NMSs) in terms of operational structure, responsibilities and activities (as recognized and documented in the RA I Tropical Cyclone Operational Plan) guide the competency framework.

The framework thus considers the competencies needed to deal with variations in activities and services depending on the tasks each Service has to undertake. The RA I TCF competency framework suggests that TCFs be divided into the following two categories:

(1) **RSMC tropical cyclone forecaster** – A meteorological forecaster working at the RSMC who has specialized expertise in tropical cyclone forecasting and provides a range of tropical cyclone forecasts, products and services;

(2) **Forecaster working in a National Forecast Office** – A senior forecaster who is required to interpret information from the RSMC and formulate and communicate tailored forecasts, warnings and impact-based hazard information to national and local stakeholders.

National variation

The context of these competencies may vary from office to office according to:

- National climatology and impacts;
- National geography, especially how it affects hazards, including storm tide, rainfall and wind;
- Observation networks (including surface, upper-air, weather radar, aircraft);
- Variations in products issued and briefing requirements;
- Boundaries of forecast areas;
- Communication language(s);
- Procedures for handling external enquiries;
- Communication technology for warning transmission and for briefings;
- National and international regulations;
- Operational forecast systems, procedures and warning thresholds;
- Risk assessment and estimation of forecast uncertainties;
- Types and use of forecast guidance.

I. RSMC tropical cyclone forecasters

I.1 *Description*

RSMC TC forecasters must be able to assume and handle independently the whole processing chain of cyclone analysis/forecast and related production (that is, without any external support or internal supervision). They must also be able to deal with their own national needs and for that reason, must be able to translate cyclone information and upstream expertise in terms of the impact and the resulting practical consequences on the local weather. Finally, they must be able to transmit their expertise and communicate with respect to all the previous information, both internally and externally, and do so in a way that must be adapted to the kind of audience they are dealing with (other meteorologists, civil protection, emergency management or crisis management partners, media, general public, etc.).

I.2 *Essential prerequisites*

The RSMC TC forecaster must:

- Be a meteorologist (as defined by the WMO classification – corresponding to the former Class 1);
- Have an in-depth knowledge of tropical meteorology;
- Master synoptic analysis and general weather forecasting;
- Be able to interpret data from the numerical weather prediction (NWP) (models);
- Be able to synthesize information from a range of sources;
- Have good written and oral communication skills (including written scientific English).

I.3 *Top-level competencies*

1. Being able to perform a cyclone analysis;
2. Being able to forecast at the most advanced level (including cyclogenesis);
3. Being able to determine potential weather hazards and impacts;
4. Mastering the tools used to elaborate and disseminate all related products (text bulletins or graphic products), including checking to ensure that they have been correctly disseminated;
5. Being able to deliver, in a way adapted to the audience they are dealing with, all relevant TC information to internal and external stakeholders (through bulletins, briefings, interviews, presentations, and so forth).

I.4 *RSMC TC forecaster competencies*

I.4.1 Being able to perform a cyclone analysis

Description

I.4.1.1 Being able to determine the position (and the current motion), the intensity and the structure of a tropical low-pressure system (hereafter referred to as TD – that is, the generic acronym for any tropical disturbance) from all available observational data and by relying on the related analysis or interpretation techniques.

Performance criteria

I.4.1.1.1 Analyse the synoptic-scale environment to assess the likely influence on the disturbance in a range of situations;

I.4.1.1.2 Determine TD centre location and current movement in accordance with standard operating procedures in a range of situations;

I.4.1.1.3 Determine TD intensity in accordance with standard operating procedures in a range of situations;

I.4.1.1.4 Determine TD structure in accordance with standard operating procedures in a range of situations.

Knowledge

- Knowing the classification and the operational procedures in force in the basin (reference document: Operation Plan of the South-West Indian Ocean), and more particularly, the classification of the tropical low-pressure systems in use for the basin, the associated terminology and the naming procedure;

- Knowing the observation means available, in particular the means that are specifically valuable for the monitoring of a TD, as well as the capacities and limitations related to each type of observation;
- Knowing the structure and the dynamics of TDs (theoretical and practical knowledge, conceptual models, etc.);
- Mastering the different analysis or estimation techniques of the intensity of TDs, as well as their capacities and limitations.

Skills

- Visualize the different available observational data or know how to get access to them and master the tools required to deal with them;
- Analyse and interpret the observational data: satellite imagery (conventional or microwave), radar imagery, data retrieved from scatterometer radars, satellite winds and by-products (vertical wind shear, upper divergence, etc.), surface or upper-level observations;
- Be able to apply the Dvorak technique in order to locate the low-level circulation centre of a TD and estimate its intensity;
- Synthesize all the observations and input data in order to determine the best final estimate of intensity;
- Estimate as accurately as possible the essential parameters that characterize the structure of the TD (radius of maximum winds, wind radii by quadrants, diameter of the first closed isobar).

I.4.2 Being able to elaborate a cyclone forecast

Description

I.4.2.1 Being able to optimally work out a cyclogenesis forecast or a track and intensity forecast (possibly a structure change forecast) of a TD from all the available guidance (forecast data provided by numerical models or from guidance tools such as statistical-dynamical models or others).

Performance criteria

I.4.2.1.1 Interpret NWP-predicted synoptic-scale environment to assess the likely influence on the disturbance in a range of situations;

I.4.2.1.2 Determine TD forecast track in accordance with standard operating procedures in a range of situations;

I.4.2.1.3 Determine TD forecast intensity in accordance with standard operating procedures in a range of situations;

I.4.2.1.4 Determine TD forecast structure in accordance with standard operating procedures and timelines in a range of situations.

Knowledge

- Having conceptual knowledge of the factors that can help trigger the cyclogenesis of a TD and being aware of the local climatology of cyclogeneses;
- Having conceptual knowledge both of the factors that can rule or modify the motion of the TDs and of the internal or environmental processes or factors that can have a bearing on their changes in intensity and structure (eyewall replacement cycles, oceanic heat content, vertical windshear, moisture, steering flux, beta effect, Fujiwhara effect, etc.);

- Knowing the strengths and weaknesses of the numerical models as regards the track, intensity or structure forecasts of TDs;
- Knowing the consensus techniques as regards the track forecast of TDs.

Skills

- Interpret the diagnostic and prognostic tools available to monitor tropical waves and be aware of how they can influence or modulate convective activity and disturbed activity;
- Carry out a cyclogenesis prognosis by relying on deterministic and ensemble forecasts and be able to produce the related cyclogenesis risk map;
- Master the tools that make it possible to visualize all the track forecasts from the different numerical models together and to produce the RSMC official forecast;
- Interpret and assess the behaviour of the numerical models and their track and intensity forecasts in light of the analysis of the situation carried out by the cyclone forecaster, in particular through the assessment of the environment of the disturbance and diagnosis of the foreseen evolution;
- Interpret the data from the ensemble forecasts in order to evaluate the forecast uncertainty;
- Elaborate and produce a probabilistic cone of uncertainty for the track and intensity forecast.

I.4.3 Determining the consequences in terms of weather and impact on a given area

DESCRIPTION

I.4.3.1 Whenever a territory happens to be affected or influenced by a TD, being able to determine, in any given area, the impact or influence that the storm is going to exert on the weather conditions and the timing of the degradation of the different associated hazards as well as the level of uncertainty regarding the related forecasts.

Performance criteria

I.4.3.1.1 Forecast extent of cyclonic winds (e.g. gales, storm force, hurricane force) and onset times for key locations using available guidance in a range of situations;

I.4.3.1.2 Forecast rainfall using available guidance in a range of situations and liaise with the relevant organization in charge of hydrology to determine potential flooding;

I.4.3.1.3 Forecast marine hazards – waves and swell – in accordance with standard operating procedures;

I.4.3.1.4 Forecast storm surge potential considering various TC forecast scenarios and confidence levels (worst case, most likely, alternate TD forecast scenario).

Knowledge

- Knowing both the contingency/prevention/emergency plans and local procedures and the related warning thresholds for the different parameters (winds, swell, heavy rains, storm surge);
- Knowing the local modifications and disturbances of the wind and rain fields generated by the orography or the island effect;
- Knowing the potential impacts and the hazardous areas of the territory;
- Knowing the wave formation theory, cyclone swell and storm surge.

Skills

- Be able to run the storm surge model and to estimate the maximum potential storm surge through the developed interface and application;
- Be able to interpret and tailor the forecast data and guidance provided by the numerical models by integrating their limitations (often significant) when forecasting the relevant meteorological parameters related to the significant weather (amounts of rainfall, wind speeds, wave heights);
- Be able to infer, from the track and intensity forecasts of the TD and from the other available guidance elements, a forecast of the evolution of the significant weather (winds, rains, swell, storm surge) that is tailored to the local scale;
- Be able to assess the margins of uncertainty regarding the timing and virulence of the foreseen meteorological phenomena (amounts of rain, wind speed, swell and storm surge), and the likelihood of exceeding certain critical thresholds (including the worst-case scenario);
- Liaise and transmitting the relevant information to the hydrology department in charge of the management of floods.

I.4.4 Elaborating and distributing the whole cyclone production

Description

I.4.4.1 Elaborating graphical products and writing all the text bulletins (bilingual French–English) that make up the cyclone production in accordance with the procedures in force at the RSMC, then making sure they are effectively disseminated before the final deadline.

Performance criteria

I.4.4.1.1 Liaise effectively with internal staff in the elaboration of TD forecast scenarios and in considering the impact on other services;

I.4.4.1.2 Formulate and issue a range of TD-related warning products in consideration of potential impacts and in accordance with standard operating procedures and timelines in a range of situations;

I.4.4.1.3 Determine the appropriate key messages for general and technical audiences in a range of situations.

Knowledge

- Mastering the different software and tools that make it possible to produce cyclone analyses and forecasts, and also the text bulletins and graphical by-products;
- Knowing the related operating procedures;
- Knowing the user needs and significant impact thresholds.

Skills

- Be able to write intelligibly and efficiently the commentaries that appear in technical discussions (in French and in English);
- Be able to optimally manage the available time to respect the disseminating schedules imposed by the operational constraints;
- Be able to compile products and key messages for different audiences.

I.4.5 Communicating the cyclone information to the internal and external users

Description

I.4.5.1 Transmitting the expertise and delivering the information related to the cyclone phenomenon and to its potential consequences in plain language adapted to the user.

Performance criteria

I.4.5.1.1 Logically structure briefings and presentations to contain relevant, timely and understandable information;

I.4.5.1.2 Deliver briefings, presentations and interviews to suit the intended audience, explaining technical information in concise, clear and easy-to-understand language.

Knowledge

- Knowing the basics of efficient communication and, in particular, the mistakes or traps to be avoided regarding crisis communication;
- Mastering the communication equipment or tools used, for briefings in particular.

Skills

- Structure a briefing, a presentation or guidelines in a coherent and efficient way, so as to deliver the essential messages within the time allowed;
- Adapt one's wording to the audience or the user by popularizing it or making it as plain as possible when necessary;
- Be able to give an interview.

II. Forecasters working in a National Forecast Office

II.1 *Description*

These forecasters receive the first-level information provided by the RSMC and must be in a position to understand and interpret the corresponding data and expertise in order to infer from them elaborate forecasts applicable to the scale of their territories or of their areas of responsibility (aeronautic, maritime or land) and adapted to their internal needs.

Relying on the raw data of track, intensity and structure forecasts provided by the RSMC, they will have to be able to infer what the potential impacts and the consequences will be in terms of weather, and they will have to, if need be, warn or inform the authorities, the media and the population about the possible induced meteorological hazards.

The different steps of that process require multiple competencies and skills.

A differentiation, however, is made between:

(a) Forecasters who belong to the NMSs of the countries of the "first circle" (Comoros, France (that is, forecasters of Météo-France working under the supervision of a cyclone forecaster of the RSMC), Madagascar, Mauritius, Mozambique, Seychelles, South Africa) that are directly impacted by tropical cyclones and thus prone to the whole set of related hazards due to their maritime frontage (strong winds, storm surge, heavy rains, etc.).
(b) Forecasters who belong to the NMSs of the countries of the "second circle" (all member states of the Tropical Cyclone Committee from Southern Africa except Mozambique and South Africa).

II.2 *Essential prerequisites*

The forecaster must:

- Have a good understanding of tropical meteorology in their region;
- Be able to use the Internet and software to access TC-related information, including satellite imagery, NWP and observation systems;
- Be able to interpret weather observations and maintain a weather watch;
- Be able to produce local forecasts and understand the concerns of local users;
- Have good written and oral communication skills.

II.3 *Top-level competencies*

1. Access and be able to interpret the cyclone information and expertise provided by the RSMC;
2. Determine the consequences in terms of weather and impact in a given area;
3. Elaborate and disseminate all the relevant forecast products;
4. Communicate the information to internal and external users.

II.4 *Competencies of a forecaster working in a National Forecast Office*

II.4.1 Being able to interpret the cyclone information and expertise provided by the RSMC

Description

II.4.1.1 After accessing the RSMC products (bulletins and other products), the forecaster will have to be able to understand and interpret the associated analyses and forecasts. Relying on that forecasting guidance, he or she will set it in the context of his or her own understanding of the meteorological situation through the available data (observations or forecast data) and in the local context.

Performance criteria

II.4.1.1.1 Access a range of appropriate information, including forecasts from the RSMC;

II.4.1.1.2 Interpret technical forecast guidance in order to assess impact potential on forecasts in the region of responsibility;

II.4.1.1.3 Interpret observational and satellite information appropriately.

Knowledge

Notes:

(a) Specific to forecasters of the NMSs of the "first circle"

(b) Specific to forecasters of the NMSs of the "second circle"

- Knowing the classification and the operational procedures in force in the basin (reference document: Operation Plan of the South-West Indian Ocean), and more particularly, the classification of low-pressure systems in use and the associated terminology;
- Knowing how to quickly get access to the information and forecasts issued by the RSMC, whether they are presented as text bulletins or graphics, via the Global Telecommunication System (GTS), websites or others;

- Understanding[a] or having a basic knowledge[b] of the structure and dynamics of tropical low-pressure systems (hereafter referred to as TD, the generic acronym for any tropical disturbance);
- Knowing the available observational means, in particular those specific to the monitoring of TDs;[a]
- Knowing[a] the broad features of the main techniques used to analyse or assess the intensity of the TDs, without being necessarily in a position to apply them oneself (Dvorak technique in particular);
- Understanding[a] the broad features of the factors that can rule or dictate the motion of TDs and also the internal or environmental processes or factors that can have an influence on the changes in their intensity and structure (eyewall replacement cycle, oceanic heat content, vertical windshear, moisture, steering flow concept, Fujiwhara effect and so forth);

Skills

- Read and interpret[a] the content of the bulletins, advisories and graphical products issued by the RSMC;
- Extract[b] from the bulletins, advisories and graphical products delivered by the RSMC the relevant information (TD centre location, TD intensity, forecast track, extent of the area of strong winds, information about the areas of deep convection);
- Get access to the essential observational data (satellite imagery and by-products, radar imagery – when available, data from scatterometer radars, surface and upper-level observations) and be able to interpret them from a general perspective;
- Interpret available forecast data from numerical weather prediction (models).

II.4.2 Determining the consequences in terms of weather and impact in a given area

Description

II.4.2.1 Whenever one's national territory (or one's area of responsibility) happens to be affected or influenced by a TD, being able to determine, in any given area, the impact that the storm is going to have on the weather conditions and the timing of the degradation of the different associated hazards, as well as the level of uncertainty regarding the related forecasts.

Performance criteria

II.4.2.1.1 Forecast areas likely to be affected by strong winds (e.g. gales, storm force or hurricane force) and onset times using available guidance in a range of situations;

II.4.2.1.2 Forecast rainfall using available guidance in a range of situations and determine potential flooding or liaise with relevant organization(s) in charge of hydrology;

II.4.2.1.3[a] Forecast marine hazards – waves and swell, in accordance with standard operating procedures;

II.4.2.1.4[a] Forecast storm surge potential considering various TC forecast scenarios and confidence levels (worst case, most likely, alternate TC forecast scenario).

Knowledge

- Knowing the prevention plans and national or local procedures as well as the related warning thresholds for the different relevant parameters (winds, rains, swell and storm surge[a]);
- Knowing the local influences that can modify the wind and rain fields (such as disturbances due to orography or high ground, island induced effects, etc.);

- Knowing the potential impacts and the hazardous areas of one's territory and the recent meteorological history (past rainfall for soil moisture).

Skills

- Infer from the track and intensity forecast of the TD provided by the RSMC and from the other available elements supporting the forecast (numerical models in particular) a forecast adapted to the local scale for the evolution of the weather (winds, rains, thunderstorm activity in particular);
- Assess the margins of uncertainty regarding the timing and virulence of the foreseen meteorological phenomena (rainfall amounts, wind speed, swell and storm surge[(a)]) and the likelihood of exceeding critical thresholds (including the worst-case scenario);
- Liaise and transmit the relevant rainfall information to the hydrology department in charge of the management of floods.

II.4.3 Elaborating and distributing all the forecast products

Description

II.4.3.1 Elaborating the graphical products and writing all the text bulletins that make up the production of the forecasting department in accordance with the internal procedures in force, then making sure they are effectively disseminated in due time.

Performance criteria

II.4.3.1.1 Formulate and issue a range of TD-related warning products in consideration of potential impacts and in accordance with standard operating procedures and timelines in a range of situations.

Knowledge

- Mastering the different software and tools that make it possible to produce the forecast or warning bulletins and associated graphical products;
- Knowing the related operating procedures;
- Knowing the user needs and significant impact thresholds.

Skills

- Write intelligibly and efficiently the different forecast bulletins;
- Optimally manage the available time to respect the disseminating schedules imposed by the operational constraints;
- Elaborate and disseminate the warning messages in accordance with the national procedures in force.

II.4.4 Communicating the information to the internal and external users

Description

II.4.4.1 Transmitting the information related to the cyclone phenomenon and to its potential consequences in plain language adapted to the user.

Performance criteria

II.4.4.1.1 Logically structure briefings and presentations to contain relevant, timely and understandable information.

II.4.4.1.2 Deliver briefings, presentations and interviews to suit the intended audience, explaining technical information in concise, clear and easy-to-understand language.

Knowledge

- Knowing the basics of efficient communication and, in particular, the mistakes or traps to be avoided;
- Mastering the communication equipment or tools used, for briefings in particular.

Skills

- Structure a briefing, a presentation or an answer to a user in a coherent and efficient way, so as to deliver the essential messages within the time allowed;
- Adapt one's language to the audience or the user by popularizing it or making it as plain as possible when necessary;
- Be able to give an interview.

2.8.2 Tropical Cyclone Forecaster Competencies in the WMO/Economic and Social Commission for Asia and the Pacific (ESCAP) Panel on Tropical Cyclones

WMO/Economic and Social Commission for Asia and the Pacific (ESCAP) Panel on Tropical Cyclones (PTC) region (Bangladesh, India, Islamic Republic of Iran, Kingdom of Saudi Arabia, Maldives, Myanmar, Pakistan, Qatar, Sultanate of Oman, Sri Lanka, Thailand, United Arab Emirates, and Yemen)

Tropical Cyclone Forecaster Competencies

WMO/ESCAP PTC Tropical Cyclone Forecaster Competencies are a set of proposed competencies aiming to provide a baseline competency standard to effectively address the job performance of the tropical cyclone forecaster (TCF). These competencies, like other WMO competencies being developed, are part of a competency framework that identifies the knowledge, skills and attitudes that must be demonstrated.

They have been devised to be consistent with the actual work in meteorological services (NMSs) and are essential for:

1. Defining what is required to do the job;
2. Developing the most appropriate training for tropical cyclone forecasters;
3. Demonstrating that forecasters working with tropical cyclones can do their job.

The competencies are designed to use and build upon general weather forecasting and forecast preparation skills, general synoptic analysis techniques, analysis skills and the knowledge and interpretation of numerical weather prediction (NWP) model outputs.

The aim of the competency management system is to ensure that individuals (forecasters) are clear about the performance expected from them when forecasting tropical cyclones, have relevant training, development, assessment and re-assessment, and maintain their competency over time.

The competency management system should not only serve as a quality checking system, but also facilitate continuous improvement of the quality of weather service. Results of the competency assessment, together with the gap and training needs identified, would be properly documented and consolidated for the development of a training plan. Thus, it is an integral part of the quality management system (QMS) in view of its linkage to the quality of meteorological service and compliance to international standards. There should a procedure for conducting competency assessment (methodology and tools) under this scheme.

The competency management system should enable the forecasters to perform activities at recognized standards of competency, so that the NMS:

- Reduces risks;
- Improves tropical cyclone forecasts;
- Complies with requirements ;
- Meets quality and safety standards.

The structure of the system can be broadly defined in five steps (plan, design, implementation, assessment/maintenance and verification/audit). Each step contains one or more management principles, and for each principle there is a set of recommended actions.

Step I: PLAN

- Specify all work activities to be included in the competency management system;
- Define the purpose and scope of the competency management system;
- Define roles and responsibilities to be covered by the forecasters under this system.

Step II: DESIGN

- Define the elements of the competency management system;
- Design repeatable processes and procedures that are consistent with the principles in this guidance;
- Define the quality assurance procedures for all system elements;
- Design competency criteria according to the job profile;
- Specify how each competency criterion is met, assessed and recorded;
- Establish the tools used for competency assessment and how often the assessment shall be conducted;
- Establish training needs and assessment requirements for each competency criterion;
- Establish tools and methods of competency management improvement.

Step III: IMPLEMENTATION

- Apply the competency management procedures and methods to selection and recruitment activities;
- Train to the defined competencies associated with the job profile;
- Assess competency;
- Monitor, maintain and develop the competency of staff; and
- Evaluate the impact of any competency shortcomings and take appropriate actions.

Step IV: ASSESS AND MAINTAIN

- The competency assessment should be part of the quality management system;
- Maintain the competency for forecasters and assessors;
- Record information on the operation of the competency management system;
- Monitor changes in the external environment and the operational activities of the organization;

- Ensure that the competency management system conforms with quality management requirements; and
- Review the output and impact of the competency management on the organization's key performance indicators.

Step V: VERIFY AND AUDIT

- Implement a method of systematic verification and auditing of the competency management system;
- Identify the need for changes and implement these changes in periodic intervals (for example, every five years).

WMO/ESCAP PTC consists of a wide variety of NMSs and their differences have guided the development of a competency framework. This has led to a proposed framework to deal with variations in activities and services, taking into account the necessary competencies needed and depending on the tasks each service will undertake. The framework suggests that WMO/ESCAP PTC NMSs be broken up into the following three categories:

1. TCFs suited with the necessary skills and equipment to provide guidance for other services to downscale. This is one of the primary roles of Regional Specialized Meteorological Centre (RSMC) New Delhi.
2. TCFs that downscale the guidance from RSMC New Delhi or other sources to tailor forecasts for their areas of responsibility. This is the role of most of the forecast offices in WMO/ESCAP PTC.
3. TCFs that work from forecasts provided by services that downscale the guidance (primarily the Public Weather Services (PWS) of the countries). The primary role of these TCFs is to interpret the forecasts provided so that they can be used in an advisory capacity by emergency services, local media, etc.

1.0 Category 1. TCFs providing guidance for other services to downscale the format of the framework

The framework is provided under the following headings:

Category: Determine the type of meteorological service and the job responsibility of the TCF within that category.

Unit descriptor: A competency unit relevant to TCFs working within a particular category providing operational tropical cyclone services. Activities include:

- Analysing synoptic environment and determining TC position, intensity and structure;
- Forecasting TC track, intensity and structure;
- Determining potential weather impacts on at-risk areas;
- Formulating policy and issuing TC products;
- Communicating relevant information.

The details of the unit descriptor describe the aspects of competency recommended for an effective TCF. The specific performance criteria and background knowledge and skills for a given category reflect the required roles and responsibilities of the service provided by that tropical cyclone office.

Another important section of the framework is the national variations, which recognize the national requirements among services in WMO/ESCAP PTC which may require specific attention. These may be the result of general geography or social consequences such as communication language, etc.

It is expected that the role of a TCF will change as technology changes and as more is required from users. Therefore, as with other competencies, a process of continuous improvement is expected.

Unit descriptor

1.1 **This competency unit is relevant to TCFs working in a TC warning office. It covers the provision of operational TC services at an unsupervised level.**

It includes:
- TC analysis and continuous monitoring and analysis of the area of responsibility for TC development;
- Forecasting and warning of TC development, changes in intensity and associated hazards;
- Determining the potential weather and storm tide impacts;
- Formulating policy and issuing products; and
- Communicating/delivering briefings, interviews and presentations.

1.2 **Analyse broad-scale environment and determine TC position, intensity and structure**

Description

1.2.1 A range of observational information is analysed to interpret the broad-scale environment, position, intensity and structure of the tropical circulation.

Performance criteria

1.2.2 Analyses the synoptic environment to assess the likely influence on the disturbance in a range of situations;

1.2.3 Determines location of centre and current movement in accordance with standard procedures in a range of situations;

1.2.4 Determines intensity in accordance with standard procedures in a range of situations;

1.2.5 Determines structure in accordance with standard procedures in a range of situations;

Background knowledge and skills

1.2.6 Knowledge of:

- Local cyclone policy and operating procedures;
- Observation networks;
- Capabilities and limitations of different observational data types;
- TC structure dynamics and conceptual models;
- Synoptic factors that affect the intensity, including shear, ocean temperatures, upper-level flow, stability, landfall, vorticity and low to mid-level moisture;
- Strengths and limitations of the Dvorak technique, advanced Dvorak technique (ADT), advanced microwave sounding unit (AMSU) intensity estimation, satellite consensus (SATCON) and other intensity analysis guidance;
- Strength and limitations of radar products for location and intensity estimation.

1.2.7 Skills in:

- Using data viewing software and other applications in the forecast process;
- Interpreting observations, weather radar and satellite-derived information such as scatterometry and cloud drift winds;
- Interpreting satellite imagery, including water vapour, visible, infrared and microwave for TC analysis;
- Using the Dvorak technique for cyclone centre location and intensity estimation;
- Using radar products for cyclone centre location and intensity estimation;
- Estimating the intensity from a number of inputs;
- Interpreting wind shear from shear analyses and prognoses;
- Assessing the environment for motion, intensity and structural changes;
- Interpreting deterministic and probabilistic NWP guidance material;
- Interpreting multi-model ensemble and grand global ensemble techniques.

1.3 Forecast TC track, intensity and structure

Description

1.3.1 A range of information, including NWP and objective aids, in addition to an understanding of conceptual synoptic forecast approaches, is used to forecast the track, intensity and structure in warning products that are issued in accordance with documented procedures.

Performance criteria

1.3.2 Interprets the NWP-predicted broad-scale environment to assess the likely influence on the disturbance in a range of situations;

1.3.3 Determines forecast track in accordance with standard procedures in a range of situations;

1.3.4 Determines forecast intensity in accordance with standard procedures in a range of situations;

1.3.5 Determines forecast structure in accordance with procedures and timelines in a range of situations;

Background knowledge and skills

1.3.6 Knowledge of:

- Local cyclone policy and forecast process;
- Relative strengths and limitations of NWP in predicting cyclone movement, structure and intensity;
- Synoptic factors that affect TC motion and intensity;
- Consensus track forecasting techniques;
- Intensity forecasting methods, including conceptual models of decay;
- Interpretation of satellite, radar and coastal observations for TC track and intensity forecasting.

1.3.7 Skills in:

- Evaluating model predictions against observed conditions to (i) assess the most likely forecast environment for motion and intensity changes, and (ii) identify models with reference to better initial conditions;
- Interpretation of satellite and radar observations for TC track, intensity and structure forecasting;
- Interpreting NWP guidance material, including ensemble output, to determine forecast uncertainty;

- Using software systems (Tropical Cyclone Module) to determine forecast parameters.

1.4 Determine potential weather impacts on at-risk areas

Description

1.4.1 The impacts of high winds, rainfall, waves and storm surge are determined for key locations/areas according to appropriate thresholds, including estimates of uncertainty.

Performance criteria

1.4.2 Forecasts the extent of cyclonic winds (e.g. squall, gales, storm force) and onset times for key locations/areas using available guidance in a range of situations;

1.4.3 Forecasts rainfall using available guidance in a range of situations and liaise with the relevant organization in charge of hydrology to determine potential flooding;

1.4.4 Forecasts waves and swell using standard techniques;

1.4.5 Forecasts storm tide potential considering various track and intensity scenarios and confidence levels (worst case, most likely, alternate track/intensity);

1.4.6 Forecasts coastal inundation (height and area) considering various track, intensity scenarios and confidence level.

Background knowledge and skills

1.4.7 Knowledge of:

- Local cyclone policy and operating procedures;
- Potential impacts in a range of synoptic situations;
- Wave and storm surge theory;
- Local climatology of cyclogenesis, track, intensity and landfall;
- Storm tide and coastal inundation theory and warning techniques;
- The level of threat posed by storm surge heights and coastal inundation.

1.4.8 Skills in:

- Using software to determine range of impacts;
- Interpreting NWP guidance material;
- Assessing rainfall potential including ensemble tropical rainfall potential (eTRaP), consensus model guidance and probabilistic rainfall guidance;
- Determining onset, extent and associated uncertainties of weather phenomena (heavy rain, gale/squally wind, storm surge and coastal inundation) forecasting.

1.5 Formulate policy and issue TC products

Description

1.5.1 Local forecast production systems are used to produce and disseminate a range of products according to local operating procedures.

Performance criteria

1.5.2 Liaises effectively with internal staff in the development of tropical cyclone policy and in considering the impact on other services;

1.5.3 Formulates TC policy in accordance with procedures in a range of situations;

1.5.4 Determines the appropriate key messages for general and technical audiences in a range of situations;

1.5.5 Issues the range of TC products in accordance with procedures and timelines in a range of situations.

Background knowledge and skills

1.5.6 Knowledge of:

- Local cyclone policy and operating procedures;
- User needs and significant impact thresholds;
- Product styles and standards.

1.5.7 Skills in:

- Using appropriate software (TC module) to produce warning products;
- Communicating with colleagues to arrive at policy decisions;
- Internal time management to produce the range of products on time;
- Compiling policy, products and key messages for different audiences;
- Converting technical concepts into concise and easy-to-understand language.

1.6 Communicate relevant TC information to internal and external stakeholders

Description

1.6.1 TCFs are required to communicate information to internal and external users appropriate to their needs.

Performance criteria

1.6.2 Logically structures briefings and presentations to contain relevant, accurate and complete information;

1.6.3 Delivers briefings, presentations and interviews to suit the intended audience, explaining technical information in concise, clear and easy-to-understand language.

Background knowledge and skills

1.6.4 Knowledge of:

- Principles of effective communication, including presentation and interviews;
- Presentation and meeting formats and requirements;
- Legislation, regulations, policies, procedures and guidelines relating to workplace communication in the public sector, such as privacy, confidentiality, freedom of information.

1.6.5 Skills in:

- Compiling policy, products and key messages for different audiences;

- Converting technical concepts into concise and easy-to-understand language;
- Facilitating and engaging in communication exchanges;
- Using equipment for structured briefing presentations and interviews to suit the intended audience, explaining technical information in concise, clear and easy-to-understand language.

2.0 Category 2. TCFs who downscaled the guidance from the RSMC or other sources to tailor forecasts to their areas of responsibility

Unit descriptor

2.1 **This competency unit is relevant to TCFs working either under the supervision of a senior forecaster or in a forecasting office that receives guidance from an RSMC.**

It includes:

- Accessing and interpretation of TC products and services;
- Understanding the forecast process and technical components of the forecast inputs (radar and satellite interpretation (including the Dvorak technique, etc.)), Scatterometer Satellite (Scat Sat), Advanced Scatterometer (Ascat), NWP models, etc., but TCFs are not expected to perform the technical analysis themselves;
- Using technical forecasts to determine potential impacts;
- Producing local forecast products based on technical forecasts from the RSMC;
- Conducting briefings to local user groups – media and emergency services, and providing TC information in response to enquiries;
- Providing support to senior TC forecasters or feedback to the RSMC as appropriate.

2.2 Access and interpret TC products and services

Description

2.2.1 Guidance products from the RSMC and other agencies are appropriately accessed and interpreted. Technical information, including satellite, radar and other observational information, are interpreted in the context of the guidance products.

Performance criteria

2.2.2 Ability to access the range of appropriate information, including forecasts from RSMC and other agencies;

2.2.3 Ability to interpret technical forecast guidance in order to assess impact potential upon forecast region of responsibility;

2.2.4. Ability to interpret observational products and satellite and radar information appropriately.

Background knowledge and skills

2.2.5 Knowledge of:

- Local cyclone policy and operating procedures;
- Observation networks for the area of responsibility;
- Capabilities and limitations of different observational data types;
- TC structure dynamics and conceptual models;
- Synoptic factors that affect intensity, including shear, ocean temperatures, upper-level flow, stability, landfall, vorticity, low to mid-level moisture; divergence and convergence, etc.

- Strengths and limitations of the Dvorak technique, ADT, AMSU intensity estimation, SATCON and other intensity analysis guidance.

2.2.6 Skills in:

- Interpreting official forecast products from official agencies;
- Using data viewing software and other applications in the forecast process;
- Interpreting observations, weather radar, satellite and satellite-derived information at a general level;
- Assessing the environment for impact on the TC at a general level;
- Interpreting NWP guidance material.

2.3 Determine potential weather impacts on at-risk areas

Description

2.3.1 The impacts of high winds, rainfall, waves and storm surge/coastal inundation are determined for key locations/areas according to appropriate thresholds and including estimates of uncertainty.

Performance criteria

2.3.2 Forecasts the extent of cyclonic winds (e.g. squalls, gales, storm force) and onset times for key locations/areas using available guidance in a range of situations;

2.3.3 Forecasts rainfall using available guidance in a range of situations and liaises with the relevant organization in charge of hydrology to determine potential flooding;

2.3.4 Forecasts waves and swell and storm tide/coastal inundation potential using standard techniques and guidance material.

Background knowledge and skills

2.3.5 Knowledge of:

- Local cyclone policy and operating procedures;
- Potential impacts in a range of synoptic situations;
- Wave and storm surge theory and warning techniques;
- The level of threat posed by storm surge heights;
- Rainfall theory and warning techniques;
- Downscaling the RSMC forecast products (rainfall, wind, storm surge, etc.) at key locations/areas.

2.3.6 Skills in:

- Using software to determine range of impacts;
- Interpreting RSMC/NWP guidance material;
- Determining onset, extent and associated uncertainties of weather phenomena (such as rainfall, wind, etc.);
- Storm surge forecasting;
- Flood forecasting.

2.4 Formulate policy and issue forecast products

Description

2.4.1 Local forecast production systems are used to produce and disseminate a range of products according to local operating procedures.

Performance criteria

2.4.2 Liaises effectively with internal staff in the development of tropical cyclone policy and in considering the impact on other services;

2.4.3 Formulates policy in accordance with procedures in a range of situations;

2.4.4 Determines the appropriate key messages for general and technical audiences in a range of situations;

2.4.5 Issues the range of TC products in accordance with procedures and timelines in a range of situations.

Background knowledge and skills

2.4.6 Knowledge of:

- Local cyclone policy and operating procedures;
- User needs and significant impact thresholds;
- Product styles and standards.

2.4.7 Skills in:

- Communicating with colleagues to arrive at policy decisions;
- Using appropriate software to produce notification products;
- Internal time management to produce the range of products on time;
- Compiling policy, products and key messages for different audiences;
- Converting technical concepts into concise and easy-to-understand language.

2.5 Communicate relevant TC information to internal and external stakeholders

Description

2.5.1 TCFs are required to communicate information to internal and external users appropriate to their needs, including responding to enquiries.

Performance criteria

2.5.2 Logically structures briefings and presentations to contain relevant, accurate and complete information;

2.5.3 Delivers briefings, presentations and interviews to suit the intended audience, explaining technical information in concise, clear and easy-to-understand language;

2.5.4 Responds to requests for information appropriately.

Background knowledge and skills

2.5.5 Knowledge of:

- Principles of effective communication, including presentations and interviews;
- Presentation and meeting formats and requirements;
- Legislation, regulations, policies, procedures and guidelines relating to workplace communication in the public sector, such as privacy, confidentiality, freedom of information.

2.5.6 Skills in:

- Compiling key messages for different audiences;
- Converting technical concepts into concise and easy-to-understand language;
- Facilitating and engaging in communication exchanges;
- Using audio/visual equipment for presentations.

3.0 Category 3. TCFs who work from forecasts provided by RSMCs/National Storm Warning Services. In this case, the primary role is coordination with emergency services, local media, etc. (Forecast offices in WMO/ESCAP Panel countries that have trained forecasters)

Unit descriptor

3.1 **This competency unit is relevant to TCFs working in a non-forecasting office that receives information and guidance from a forecast office.**

It includes:

- Accessing and interpreting TC products and services;
- Understanding the forecast process and the technical components of forecast inputs (radar, satellite interpretation including the Dvorak technique, etc.), Scat Sat, Ascat, etc., but TCFs are not expected to perform the technical analysis themselves;
- Using technical forecasts to determine potential local impacts;
- Conducting briefings to local user groups – media and emergency services – and providing TC information in response to enquiries;
- Providing support and/or feedback to the forecast office as appropriate.

3.2 Access and interpret TC products and services

Description

3.2.1 Guidance products from the forecast office and other agencies is appropriately accessed and interpreted. Technical information, including radar, satellite and other observational information, is interpreted in the context of the guidance products.

Performance criteria

3.2.2 Accesses the range of appropriate information, including forecasts from the RSMC and other agencies;

3.2.3 Interprets technical forecast guidance to assess potential local impact;

3.2.4 Interprets observational and satellite information appropriately.

Background knowledge and skills

3.2.5 Knowledge of:

- Local cyclone policy and operating procedures;
- Observation networks for the area of responsibility;
- Capabilities and limitations of different observational data types;
- TC structure dynamics and conceptual models;
- Synoptic factors that affect intensity, including shear, convergence, divergence, ocean temperatures, upper-level flow, stability, landfall, vorticity, low to mid-level moisture, etc.;
- Strengths and limitations of the Dvorak technique, ADT, AMSU intensity estimation, SATCON and other intensity analysis guidance.

3.2.6 Skills in:

- Interpreting official forecast products from official agencies;
- Using data viewing software and other applications in the forecast process;
- Interpreting observations, weather radar, satellite and satellite-derived information at a general level;
- Assessing the local environment for impact on the TC at a general level.

3.3 Determine potential weather impacts

Description

3.3.1 The impacts of high winds, rainfall, waves and storm surge are interpreted for key locations according to appropriate thresholds and including estimates of uncertainty.

Performance criteria

3.3.2 Interprets the extent of cyclonic winds (e.g. squall, gales, storm force) and onset times for key locations/areas using available guidance in a range of situations;

3.3.3 Uses available information to determine potential flooding and gives guidance on the impact of rainfall in a range of situations;

3.3.4 Uses available information to give guidance on the impact of forecast waves, swell and storm tide and coastal inundation potential.

Background knowledge and skills

3.3.5 Knowledge of:

- Local cyclone policy and operating procedures;
- Potential impacts in a range of synoptic situations;
- Wave and storm surge theory and warning techniques;
- The level of threat posed by storm surge heights and coastal inundation;
- Rainfall theory and warning techniques;
- Downscaling the RSMC forecast products (rainfall, wind, storm surge) at the location/area level.

3.3.6 Skills in:

- Using software to determine range of impacts;
- Interpreting forecast office and RSMC/NWP guidance material;
- Determining onset, extent and associated uncertainties of weather phenomena such as rainfall, wind, etc.;

- Downscaling the RSMC forecast products (rainfall, wind, storm surge) at the location/area level.

3.4 Communicate relevant TC information to internal and external stakeholders

Description

3.4.1 TCFs are required to communicate information to internal and external users appropriate to their needs, including responding to enquiries.

Performance criteria

3.4.2 Logically structures briefings and presentations to contain relevant, accurate and complete information;

3.4.3 Delivers briefings, presentations and interviews to suit the intended audience explaining technical information in concise, clear and easy-to-understand language;

3.4.4 Responds to requests for information appropriately.

Background knowledge and skills

3.4.5 Knowledge of:

- Principles of effective communication, including presentation and interviews;
- Presentation and meeting formats and requirements;
- Legislation, regulations, policies, procedures and guidelines relating to workplace communication in the public sector, such as privacy, confidentiality, freedom of information.

3.4.6 Skills in:

- Compiling key messages for different audiences;
- Converting technical concepts into concise and easy-to-understand language;
- Facilitating and engaging in communication exchanges; using equipment for presentations/briefings.

Regional/national variations

Regional/national variations referred to within the document may include but are not limited to the following:

- Agreed and documented criteria and thresholds;
- The range of weather phenomena;
- Appreciation of the types and use of forecast guidance;
- Designated offices responsible for advice on tropical cyclones;
- Regional regulations;
- Boundaries of forecast and warning areas;
- Communication language(s);
- Communications technology for forecast and warning transmission and for weather briefing;
- Forecast database(s) utilized – gridded/text/graphical/digital, etc.

2.8.3 Tropical Cyclone Forecaster Competencies in the ESCAP/WMO Typhoon Committee Region

At its sixty-sixth session, the WMO Executive Council stressed the need for regional tropical cyclone committees to develop tropical cyclone (TC) forecaster competencies under the initiative of the Regional Specialized Meteorological Centres (RSMCs) in order to ensure the quality of tropical cyclone forecasting services and to meet users' requirements. The ESCAP/WMO Typhoon Committee, at its forty-seventh session (Bangkok, 2015), requested RSMCs Tokyo and Honolulu to develop draft TC forecaster competencies as part of the Annual Operating Plan of its Working Group on Meteorology (WGM).

At the tenth Integrated Workshop of the Typhoon Committee (Malaysia, October 2015), RSMCs Tokyo and Honolulu reported that they had reviewed (1) the WMO International TC Competencies Regional Association (RA) V (version 1.3), and (2) the TC competencies developed by the Hurricane Committee Task Team submitted to the RA IV Hurricane Committee in 2014, and found that both describe a list of requirements comprehensively enough to be used as a draft of the TC forecaster competencies for the ESCAP/WMO Typhoon Committee. The RSMCs also indicated that all the Typhoon Committee members have dedicated meteorological services, and thus a category for non-forecast offices, namely Category 3 of the Hurricane Committee version, would not need to be included in the Typhoon Committee version. In addition, the fact that some Typhoon Committee members still rely on TC forecasts from the RSMCs or other agencies to issue their TC information should be taken into account; TC competency requirements for such members need to be included.

In accordance with the 2016 Annual Operating Plan (AOP), on 20 October 2016, RSMCs Honolulu and Tokyo circulated the draft of TC forecaster competencies, which was developed largely based on the WMO International TC Competencies Regional Association (RA) V (version 1.3) to solicit the views of the WGM members and invite them to nominate their focal points (see Appendix I). At the eleventh Integrated Workshop of the Typhoon Committee (the Philippines, October 2016), the RSMCs proposed organizing a face-to-face meeting to finalize the draft for approval at the session and invited WGM members to this meeting.

At its forty-ninth session, the Typhoon Committee approved the establishment of a task team to finalize the draft tropical cyclone competency and to discuss how to utilize it for future training activities in the Committee region.

The RSMCs invited all the focal points/alternates to the Tropical Cyclone Forecaster Competency Task Team meeting in the ESCAP/WMO Typhoon Committee Region jointly hosted by RSMCs Tokyo and Honolulu in Guam, United States of America from 11 to 14 March 2017. In addition, as preparatory work, a questionnaire to review their current status and future training needs in light of the draft competency was sent to and responded to by all the focal points. The responses were utilized for discussions during the meeting. The meeting report is available at http://www.jma.go.jp/jma/en/Activities/ESCAP_WMO_Typhoon_Committee_Task_Team_on_TC_Competency.pdf.

RSMCs Tokyo and Honolulu reported the outcome of the task team meeting, including the final draft competency, during the twelfth Integrated Workshop of the Typhoon Committee (Republic of Korea, October 2017). WGM concluded that the final draft of the Tropical Cyclone Forecaster Competency was to be submitted to the Typhoon Committee at its fiftieth session for approval, and the approved tropical cyclone forecaster competency was to be included into the Typhoon Committee Operational Manual (TOM).

The final draft competency prepared by the task team as shown below was approved by the TC at its fiftieth session. The Typhoon Committee encouraged the competency to be used as a guiding document for Members' training activities as appropriate.

TROPICAL CYCLONE FORECASTER COMPETENCY IN THE TYPHOON COMMITTEE REGION

1. Overview

The establishment of formal competencies for tropical cyclone (TC) operations is part of the overall WMO Competency Standards, which are a key element of the broader ambition to implement the WMO Quality Management System (QMS) set out by the World Meteorological Congress at its fourteenth session. The tropical cyclone competency approach is essential for defining what is required to do the job, developing the most appropriate training and demonstrating that forecasters can do the job.

These competencies have been devised to be consistent with the actual work in TC warning offices and other tropical cyclone services.

As well as those listed under particular elements, the following are required:

- General weather forecasting and forecast preparation skills;
- General synoptic analysis techniques (including data limitations);
- Ability to analyse and synthesize a range of data types in order to apply relevant weighting to each data type where appropriate;
- Numerical weather prediction (NWP) – interpretation of model output; knowledge of model strengths and limitations; and model comparisons.

2. Tropical Cyclone Forecaster Competency in the Typhoon Committee region

There are two competency units identified for tropical cyclone forecast services in the ESCAP/WMO Typhoon Committee region. The first unit is applicable to dedicated or specialized forecasters working in TC forecast agencies, such as RSMCs, at a senior or independent, unsupervised level, providing a range of TC forecast services (Category 1). The second unit applies to general forecasters who provide a range of TC forecast services based on information from the "parent" RSMC or other agencies, and/or available data (Category 2).

2.1 Category 1

This competency unit is relevant to dedicated or specialized TC forecasters working in a TC office at an unsupervised level. It includes:

- Analysing broad-scale environment and determining TC position, intensity and structure;
- Forecasting TC track, intensity and structure;
- Determining potential TC-related hazards;
- Formulating and issuing TC-related warning products;
- Communicating relevant TC information to internal and external stakeholders.

2.2 Category 2

This competency unit is relevant to general forecasters who provide a range of TC forecast services based on information from the parent RSMC or other agencies, and/or available data. It includes:

- Accessing, interpreting and adapting TC analysis and forecasts;
- Determining potential TC-related hazards;
- Formulating and issuing TC-related warning products;
- Communicating relevant TC information to internal and external stakeholders.

Performance criteria and background knowledge and skills of each of the above items for Category 1 and 2 are shown in annex. Each Member, including not only its National

Meteorological and Hydrological Service but also all the other government entities in charge of its official TC-related forecast/warning service, is encouraged to meet either Category 1 or Category 2.

3. National variation

The context of these competencies may vary from office to office according to:

- National climatology and impacts;
- National geography, especially as how it affects hazards including storm tide, rainfall and wind;
- Observation networks (including surface, upper-air, weather radar, aircraft);
- Variation in products issued and briefing requirements;
- Boundaries of forecast areas;
- Communication language(s);
- Procedures for handling external enquiries;
- Communication technology for warning transmission and for briefings;
- National and international regulations;
- Operational forecast systems, procedures and warning thresholds;
- Risk assessment and estimation of forecast uncertainties;
- Types and use of forecast guidance.

Analyse broad-scale environment and determine TC position, intensity and structure (for Category 1)

Description

A range of observational information is analysed to interpret the synoptic-scale environment, position, intensity and structure of the tropical circulation.

Performance criteria

- Analyses the synoptic-scale environment to assess the likely influence on the disturbance in a range of situations;
- Determines TC centre location and current movement in accordance with standard operating procedures in a range of situations;
- Determines TC intensity in accordance with standard operating procedures in a range of situations;
- Determines TC structure in accordance with standard operating procedures in a range of situations.

Background

Knowledge

- Standard operating procedures for TC analysis;
- Basic TC climatology and general impacts of El Niño Southern Oscillation (ENSO) on TC behaviour;
- Capabilities and limitations of different observational data types;
- TC structure dynamics and conceptual models;
- Synoptic-scale factors that affect the tropical cyclone intensity including shear, ocean temperatures, upper-level flow, stability, landfall, vorticity and low to mid-level moisture;
- Strengths and limitations of intensity analysis methods including Dvorak technique and others, such as ADT, CLOUD, AMSU intensity estimation, and SATCON.

Skills

- Uses data viewing software and other applications in the forecast process;
- Interprets observations, weather radar and satellite-derived information such as scatterometry and cloud drift winds;
- Interprets satellite imagery, including water vapour, visible, infrared, and microwave for TC analysis;
- Uses Dvorak technique for TC centre location and intensity estimation;
- Estimates intensity from a number of inputs;
- Interprets wind shear from shear analyses and prognoses;
- Assesses the environment for motion and intensity changes;
- Interprets NWP guidance material.

Forecast TC track, intensity and structure (for Category 1)

Description

A range of information, including NWP and objective aids, in addition to an understanding of conceptual synoptic forecast approaches, are used to forecast the track, intensity and structure in warning products that are issued in accordance with documented procedures.

Performance criteria

- Interprets NWP-predicted synoptic-scale environment to assess the likely influence on the disturbance in a range of situations;
- Determines TC forecast track in accordance with standard operating procedures in a range of situations;
- Determines TC forecast intensity in accordance with standard operating procedures in a range of situations;
- Determines TC forecast structure in accordance with standard operating procedures and timelines in a range of situations.

Background

Knowledge

- Standard operating procedures for TC forecasts;
- Relative strengths and limitations of NWP in predicting cyclone movement, structure and intensity;
- Basic concept of rapid intensification/weakening, landfall process, and extratropical transition;
- Verification results of official TC forecasts and NWP guidance;
- Basic theory of TC ensemble forecasts;
- Synoptic factors that affect TC genesis, motion, intensity and structure;
- Track forecasting techniques including consensus and ensemble forecasts;
- Intensity forecasting methods.

Skills

- Evaluates model predictions against observed conditions to assess the most likely forecast environment for motion and intensity changes;
- Evaluates TC genesis potential using observations and NWP guidance including ensembles;
- Interprets NWP guidance material including ensemble output to determine forecast uncertainty;
- Uses software systems to determine forecast parameters.

Access, interpret and adapt TC analysis and forecasts (for Category 2)

Description

Guidance products from RSMC and other agencies are appropriately interpreted and assessed. Technical information including satellite and other observational information is interpreted taking into consideration the guidance products.

Performance criteria

- Evaluates and adapts TC analyses and forecasts based on information from RSMCs or other TC forecast agencies and/or available data;
- Interprets technical forecast guidance in order to assess impact potential upon forecast region of responsibility;
- Interprets observational and satellite information appropriately.

Background

Knowledge

- Standard operating procedures for TC analysis and forecasts;
- Capabilities and limitations of different observational data types;
- TC structure dynamics and conceptual models;
- Synoptic-scale factors that affect tropical cyclone intensity, including shear, ocean temperatures, upper-level flow, stability, landfall, vorticity and low to mid-level moisture;
- Relative strengths and limitations of NWP in predicting cyclone movement, structure and intensity;
- Synoptic factors that affect TC genesis, motion, intensity and structure;
- Track forecasting techniques including consensus and ensemble forecasts;
- Intensity forecasting methods;
- Strengths and limitations of Dvorak technique and other intensity analysis guidance, such as ADT, CLOUD, AMSU intensity estimation and SATCON.

Skills

- Uses data viewing software and other applications in the forecast process;
- Interprets observations, weather radar, satellite and satellite-derived information at a general level;
- Assesses the environment for impact on the TC at a general level;
- Interprets NWP guidance material;
- Interprets official TC forecast products from official agencies.

Determine potential TC-related hazards (for Categories 1 and 2)

Description

Potential TC-related hazards such as high winds, rainfall, waves and storm surge are determined, taking into consideration mesoscale weather phenomena, for key locations, according to appropriate thresholds and including estimates of uncertainty.

Performance criteria

- Forecasts extent of cyclonic winds (e.g. gales, storm force) and onset times for key locations using available guidance in a range of situations;
- Forecasts rainfall using available guidance in a range of situations and liaises with relevant organizations to determine potential flooding and landslides;
- Forecasts waves in accordance with standard operating procedures;
- Forecasts storm tide potential considering various TC forecast scenarios and confidence levels (worst case, most likely, alternate TC forecast scenario).

Background

Knowledge

- Standard operating procedures for TC-related hazards, including wave and storm surge, associated with tropical cyclones;
- Potential TC-related hazards in a range of synoptic and mesoscale situations in consideration of local characteristics, such as shapes of coastlines and topographic effects;
- Basic theory of wave and storm surge.

Skills

- Interprets NWP guidance material and/or guidance material from other centres, such as RSMCs;
- Assesses rainfall potential using probabilistic rainfall guidance, such as eTRaP and consensus model guidance (operational consensus forecast (OCF), precipitation model ensemble (PME));
- Determines onset, duration, coverage and associated uncertainties of weather phenomena;
- Interprets TC storm surge forecast guidance.

Formulate and issue TC-related warning products (for Categories 1 and 2)

Description

Forecast production systems are used to produce and disseminate a range of TC-related waning products according to operating procedures.

Performance criteria

- Liaises effectively with internal staff in the development of TC forecast scenarios and in considering the impact on other services;
- Formulates TC-related warning products, in consideration of potential impacts, in accordance with standard operating procedures in a range of situations;
- Determines the appropriate key messages for general and technical audiences in a range of situations;
- Issues a range of TC-related warning products in accordance with standard operating procedures and timelines in a range of situations.

Background

Knowledge

- Standard operating procedures for warning issuance and contingency plans of relevant Disaster Risk Reduction (DRR) authorities, such as local governments;

- Local characteristics of potential impacts of tropical cyclones;
- Level of threat posed by storm tide;
- User needs and significant impact thresholds;
- Product styles and standards.

Skills

- Uses appropriate software to determine the range of potential impacts and produce warning products;
- Communicates with colleagues to formulate warning products;
- Compiles products and key messages for different audiences;
- Converts technical concepts into concise and easy-to-understand language.

Communicate relevant TC information to internal and external stakeholders (for Categories 1 and 2)

Description

Forecasters are required to communicate information to internal and external users appropriate to their needs.

Performance criteria

- Logically structures briefings and presentations to contain relevant, timely and understandable information;
- Delivers briefings, presentations and interviews to suit the intended audience, explaining technical information in concise, clear and easy-to-understand language;
- Communicates with related internal and external parties, such as DRR emergency managers, RSMCs, other TC forecast centres and weather services in neighbouring areas;
- Responds to requests for information appropriately.

Background

Knowledge

- Principles of effective communication, including presentation and interviews;
- Presentation and meeting formats and requirements;
- Legislation, regulations, policies, procedures and guidelines relating to workplace communication in the public sector, such as privacy, confidentiality, freedom of information.

Skills

- Compiles products and key messages for different audiences;
- Converts technical concepts into concise and easy-to-understand language;
- Facilitates and engages in communication exchanges;
- Uses equipment for presentations.

2.8.4 WMO Regional Association IV (North America, Central America and the Caribbean) Tropical Cyclone Forecaster Competency Framework

1. Summary and purpose of the document

This document was drafted by the Regional Association (RA IV) Hurricane Committee Task Team on Tropical Forecaster Competency Framework as charged by WMO RA IV (North America, Central America and the Caribbean) at its sixteenth session, in Willemstad, Curaçao from 12 to 19 April 2013. The document seeks to outline competency standards and requirements for tropical cyclone competencies for use by RA IV members. It is largely based on practices outlined using the approach taken by the Bureau of Meteorology, Australia (BoM) in the WMO Tropical Cyclone Forecaster Competencies for Regional Association V, developed by Joe Courtney et al. and modified based on the WMO Guide to Competency (WMO-No. 1205) under the leadership of Andrea Henderson (Australian Bureau of Meteorology) of the WMO Commission for Aeronautical Meteorology (CAeM) Expert Team on Education and Training (ET-ETC). The task team also solicited and included the views of Members to accommodate the diverse contexts of RA IV Members.

1.1 RA IV tropical cyclone forecasters

The WMO RA IV Tropical Cyclone Forecaster Competency Framework (RA IV TCF-CF) will contain competencies which aim to provide a baseline competency standard to effectively address the job performance of the tropical cyclone forecaster (TCF) within the RA IV structure. RA IV Member States and Territories should add a third-level competency for national circumstances.

A tropical cyclone forecaster is defined as a meteorologist (Technical Regulations (WMO-No. 49), Volume I) working in a forecast office and performing forecasting duties, with specialized training in tropical meteorology and/or competency in tropical cyclone forecasting.

In the RA IV Hurricane Operational Plan, it is recognized that in RA IV, there exists a well-established structure within a tropical cyclone forecast and warning system. This structure is centred on the US-based National Hurricane Center (NHC), which serves as the WMO Regional Specialized Meteorological Centre (RSMC-Miami) with the responsibility of maintaining a continuous watch on tropical cyclones and areas of disturbed weather within the North Atlantic and eastern North Pacific basins. RSMC-Miami collaborates with RA IV National Meteorological Services (NMSs) with forecast and warning responsibilities. As designated in the RA IV Hurricane Operational Plan, some NMSs provide tropical cyclone forecasts and warnings to countries/territories which do not have an NMS or have an NMS but do not have forecast office responsibilities. Such countries/territories are defined as non-forecast NMSs (NF-NMSs) and coordinate tropical cyclone warnings with the respective NMSs responsible for warnings and forecasts.

1.2 Outline of the framework

The RA IV Hurricane Forecaster Competency framework will be guided by the WMO Guide to Competency (WMO-No. 1205) and, like other WMO competencies being developed, will seek a competency framework that identifies the knowledge, skills and behaviours that must be demonstrated. This document will outline the minimum competencies for TCFs in the respective offices within the RA IV structure.

The competency framework will be devised to be consistent with the actual work in the respective RSMC and NMSs and is essential for:

(1) Defining the associated competency requirements or competency standards, including:
   (a) The top-level competency statement;
   (b) The first- and second-level competency description;
   (c) Performance criteria or components, and
   (d) Background skills and knowledge;

(2) Defining the recommended appropriate training for tropical cyclone forecasters within the RA IV structure; and
(3) Suggesting an assessment process to demonstrate the necessary competencies.

2. Overview, competency requirements for a tropical cyclone forecaster

WMO competency frameworks consist of a preface, followed by a three-section description of each competency.

The preface includes a list of the top-level competencies, as well as additional critical implementation information. This information includes:

(a) A description of the roles or positions to which the competency requirement applies;
(b) A conditional statement which describes conditions that may cause the competencies to vary in different contexts;
(c) A description of the qualifications that are expected to provide essential background knowledge, where applicable.

The RA IV Hurricane Operational Plan recognizes the operational structure of the RSMC and the NMSs, and these differences will guide the competency framework. This has led to a framework to deal with variations in activities and services considering the necessary competencies needed and depending on the tasks each Service will undertake. The RA IV framework suggests that TCF responsibilities be defined in the following three (3) categories:

1. **National Meteorological Centre Forecaster or RSMC Tropical Cyclone (TC) Forecaster (RTCF)** – A meteorological forecaster currently working at a National Meteorological Centre or the RSMC who has specialized expertise in hurricane (tropical cyclone) forecasting and provides a range of tropical cyclone forecasts, products and services.

2. **Regional Office Forecaster (RF)** – A forecaster at an office with regional and or local responsibility for one or more territories who is required to interpret information from a National Meteorological Centre or RSMC and formulate and communicate forecast and impact-based hazard information to regional and local stakeholders as described in their standard operating practices.

3. **Non-forecast Office Personnel (NFP)** – Personnel who are preferably trained forecasters, or at least meteorological technicians, tasked with liaising with an RF or a TCF and able to interpret and communicate impact-based hazard information to local stakeholders.

The competencies are designed to use and build upon general weather forecasting and forecast preparation skills, general synoptic analysis techniques, analysis skills and the knowledge and interpretation of numerical weather prediction (NWP) model output.

The top-level competency statements and the first-level competencies for each category of forecaster are specified in section 3 of this document. Second-level competencies are defined in section 4.

3. Competency framework for RA IV tropical cyclone forecasters

3.1 Top-level competency statements and first-level competencies

The provision of tropical cyclone forecast services within WMO RA IV will be carried out by a variety of skilled meteorologists trained in tropical meteorology and specializing in tropical cyclone forecasting. In accordance with the *Technical Regulations* (WMO-No. 49), Volume I, a meteorologist is defined as a person who has successfully completed the requirements of the Basic Instruction Package for Meteorologists at the university level.

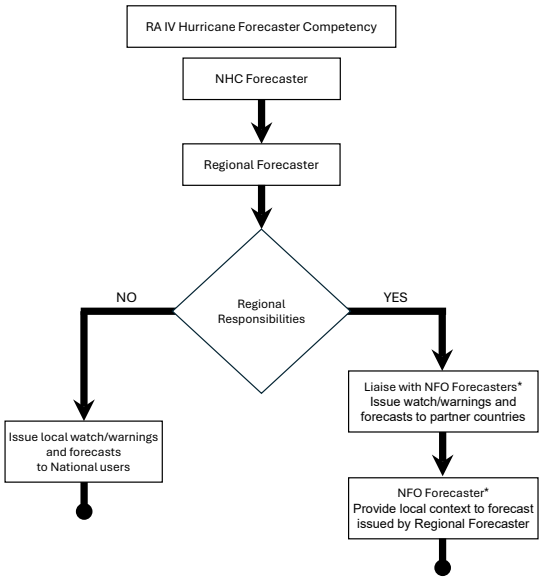


Figure 1. Flow diagram illustrating the TCF structure within RA IV

This document sets out a competency framework for personnel involved in the provision of tropical cyclone forecasting services. It is not necessary that each person have the full set of competencies; however, within specific application conditions (see below), which will be different for each organization, it is expected that any institution providing tropical cyclone forecasting services will have staff members somewhere within the organization who together demonstrate all the competencies. The performance components as well as the knowledge and skill requirements that support the competencies should be customized based on the particular context of an organization. However, the general criteria and requirements provided here will apply in most circumstances.

3.1.1 *RSMC Tropical Cyclone (TC) Forecaster*

An RSMC Tropical Cyclone (TC) Forecaster (RTCF) is a qualified meteorologist and meteorological forecaster, specialized in tropical meteorology and currently working at a National Meteorological Centre or the RSMC, who has specialized expertise in hurricane (tropical cyclone) forecasting, and provides a range of tropical cyclone forecasts, products and services.

An RTCF:

(a) For the area of responsibility;

(b) In consideration of the impact of tropical cyclones and related phenomena and parameters on life and property; and

(c) In compliance with user requirements, international regulations, local procedures and priorities;

must be able to:

(1) Maintain a continuous watch on tropical cyclones and areas of disturbed weather (within the North Atlantic and eastern North Pacific basins);
(2) Forecast the track, intensity and structure of a tropical cyclone and related meteorological phenomena and parameters;

(3) Liaise with national weather offices and regional meteorological services, where necessary, with respect to issuing watches and warnings;
(4) Warn of hazardous phenomena and related impacts associated with tropical cyclones;
(5) Produce and issue TC products;
(6) Ensure the quality of meteorological information and services; and
(7) Communicate hydrometeorological information to national stakeholders and regional meteorological services.

3.1.2 *Regional Office Forecaster*

A Regional Office Forecaster (RF) is a qualified meteorologist and meteorological forecaster stationed at a National Meteorological Service office with national and/or regional responsibility for one or more countries/territories. The RF will issue watches, warnings and forecasts to local authorities, the media and other agencies (either national or regional) as described in their standard operating practices.

An RF:

(a) For the area of responsibility;

(b) In consideration of the impact of tropical cyclone and related phenomena and parameters on life and property; and

(c) In compliance with user requirements, international regulations, regional procedures and national priorities;

must be able to:

(1) Maintain a continuous watch on areas of disturbed weather and liaise with an RTCF on developing and/or developed tropical cyclones;
(2) Formulate specific regional forecasts guided by RSMC information on TC track, TC intensity and structure and related meteorological phenomena and parameters;
(3) Coordinate with RTCF/RSMC on the issuance of TC watches and warnings for tropical cyclones[20] and associated hazardous phenomena;
(4) Interpret RSMC TC products to determine and warn of potential weather and hazardous phenomena impacts on at-risk areas;
(5) Ensure the quality of meteorological information and services; and
(6) Communicate hydrometeorological information to regional and national users.

3.1.3 *Non-forecast Office Personnel*

Non-forecast Office Personnel (NFP) are personnel who are preferably trained forecasters, or at least meteorological technicians, tasked with liaising with an RF and able to receive and interpret the watches, warnings and forecasts; deliver and explain tropical cyclone information; and interpret and communicate impact-based hazard information for disaster managers and other local stakeholders.

A Non-forecast Officer

(a) For the country/territory of responsibility;

(b) In consideration of the impact of tropical cyclone and related phenomena and parameters on life and property; and

(c) In compliance with user requirements, national regulations, local procedures and priorities,

[20] This will include tropical storm and/or hurricane watches/warnings for potential and post-tropical cyclones.

must be able to:

(1) Maintain a continuous watch on areas of disturbed weather and liaise with the RF office on developing and/or developed tropical cyclones;
(2) Interpret forecasts for localized meteorological phenomena and parameters based on RF office information on TC track, intensity and structure;
(3) Interpret the RSMC and the regional TC products and produce locally specific TC products in collaboration with the RF;
(4) Warn of hazardous phenomena and related localized impacts associated with tropical cyclones;
(5) Ensure the quality of meteorological information and services; and
(6) Communicate hydrometeorological information to national users.

4. **Second-level competencies**

The text is structured according to the following format:

4.# **Position title:** RSMC Tropical Cyclone (TC) Forecaster (RTCF), Regional Office Forecaster (RF), and Non-forecast Office Personnel (NFP)

4.#.# **First-level competency standard**

4.#.#.# **Competency descriptions for each standard**

4. #.#.#.# **Performance criteria for each standard**

4. #.#.#.# Background knowledge and skills

Regional variations

4.1 **RSMC Tropical Cyclone (TC) Forecaster (RTCF)**

4.1.1 Maintain a continuous watch on tropical cyclones and areas of disturbed weather (within the North Atlantic and eastern North Pacific basins).

Competency description

4.1.1.1 Observational, numerical prediction model and forecast weather data are continuously monitored to determine the development, position, intensity. structure and dissipation of a tropical cyclone.

Performance criteria

4.1.1.1.1 Continuously monitors the RSMC area of responsibility for indications of tropical cyclone development;

4.1.1.1.2 Analyses and diagnoses[21] the potential of the disturbed area of convective weather to develop into a tropical cyclone;

4.1.1.1.3 Determines the location of the centre and current movement in accordance with standard procedures in a range of situations;

[21] "Analysis" may be defined as answering the question "what is happening?" and "diagnosis" as answering "why is it happening?"

4.1.1.1.4 Determines intensity in accordance with standard procedures in a range of situations;

4.1.1.1.5 Determines structure in accordance with standard procedures in a range of situations;

4.1.1.1.6 Communicates forecast uncertainty and risk of associated tropical cyclone hazards (wind, storm surge and flooding) to national preparedness officials and the general public.

4.1.2 Forecast the track, intensity and structure of tropical cyclone and related meteorological phenomena and parameters.

Competency description

4.1.2.1 Use a range of information, including NWP and objective aids, in addition to an understanding of conceptual synoptic forecast approaches, to forecast the track, intensity and structure in warning products that are issued in accordance with documented procedures.

Performance criteria

4.1.2.1.1 Determines forecast track in accordance with standard procedures in a range of situations;

4.1.2.1.2 Determines forecast intensity in accordance with standard procedures in a range of situations;

4.1.2.1.3 Interprets NWP-predicted broad-scale environment to assess the likely influence on the system in a range of situations;

4.1.2.1.4 Receives and interprets reconnaissance aircraft data;

4.1.2.1.5 Determines forecast structure (including wind radii) in accordance with procedures and timelines in a range of situations.

4.1.3 Liaise with national weather offices and regional meteorological services, where necessary, on the issuance of watches and warnings.

Competency description

4.1.3.1 Furnish tropical cyclone guidance for all countries in the RSMC area of responsibility and be responsible for advisory “packages” when watches/warnings are in effect.

Performance criteria

4.1.3.1.1 Liaises effectively with internal staff and international stakeholders using the policy governing the issuance of TC watches and warnings;

4.1.3.1.2 Coordinates with the national and international services on issuing and discontinuing TC watches and warnings.

4.1.4 Warn of hazardous phenomena and related impacts associated with tropical cyclones.

Competency description:

4.1.4.1 Forecast and warn of the impacts of high winds, rainfall, waves and storm surge according to appropriate thresholds and including estimates of uncertainty.

Performance criteria

4.1.4.1.1 Forecasts the extent of cyclonic winds (e.g. gales, storm force) and onset times for key locations using available guidance in a range of situations;

4.1.4.1.2 Forecasts rainfall using available guidance in a range of situations and liaises with hydrologists to determine potential flooding, landslide and debris flows;

4.1.4.1.3 Forecasts waves and swell using standard techniques;

4.1.4.1.4 Forecasts storm tide potential considering various track and intensity scenarios and confidence levels (worst case, most likely, alternate track/intensity).

4.1.5 Produce and issue TC products.

Competency description

4.1.5.1 Produce and issue analysis and forecast products on developing, existing and dissipating tropical cyclones according to regional operating procedures.

Performance criteria

4.1.5.1.1 Determines the appropriate products and key messages for general and technical users in a range of situations;

4.1.5.1.2 Issues the range of TC products in accordance with procedures and timelines in a range of situations.

4.1.6 Ensure the quality of meteorological information and services.

Competency description

4.1.6.1 Check the effectiveness of the tropical cyclone forecast and warning system and institute or recommend remedial action when indicated.

Performance criteria

4.1.6.1.1 Applies the organization's quality management system and procedures;

4.1.6.1.2 Assesses the impact of known observational error characteristics (e.g. NWP model bias, achievable accuracy of observations and sensing methods) on forecasts and warnings;

4.1.6.1.3 Validates all meteorological and hydrological data, products, forecasts and warnings (timeliness, completeness, accuracy), using real-time checks;

4.1.6.1.4 Monitors the functioning of operational systems and takes remedial actions when necessary.

4.1.7 Communicate hydrometeorological information to national stakeholders and regional meteorological services.

Competency description

4.1.7.1 Forecasters are required to communicate information to internal and external users appropriate to their needs and provide briefings to decision makers, media and other users.

Performance criteria

4.1.7.1.1 Logically structures briefings and presentations to contain relevant, accurate and complete information;

4,1.7.1.2 Delivers briefings, presentations and interviews to suit the intended audience, explaining technical information in concise, clear and easy-to-understand language.

4.1.8 ***Background knowledge and skills***

The RTCF must be a Basic Instruction Pack for Meteorologists (BIP-M)-qualified forecaster with demonstrated ability, especially in all aspects of tropical meteorology, be able to formulate clear advisory messages and speak clearly and distinctly. Academic training at the graduate level in meteorology is highly desirable. The RTCF must be an expert in the scientific method and have a working knowledge of statistical principles and computer techniques. A thorough knowledge of tropical cyclone climatology and forecasting method is mandatory.

4.1.8.1 Knowledge of:

- Regional tropical cyclone policy;
- RSMC operating procedures;
- Regional observation networks;
- The capabilities and limitations of different observational data types;
- Tropical meteorology and tropical cyclones:
  - TC structure dynamics and conceptual models;
  - Synoptic factors that affect intensity, including shear, ocean temperatures, upper-level flow, stability, landfall, vorticity and low to mid-level moisture;
  - Local climatology of cyclogenesis;
  - Strengths and limitations of Dvorak technique, ADT, AMSU intensity estimation, SATCON and other intensity analysis guidance;
- Tropical cyclone forecast process:
  - Synoptic factors that affect TC motion and intensity;
  - Consensus track forecasting techniques;
  - Intensity forecasting methods including conceptual models of decay;
  - Reconnaissance aircraft data (Stepped Frequency Microwave Radiometer (SFMR), flight-level observation data and wind data, dropsonde data and radar);
  - Relative strengths and limitations of NWP models in predicting cyclone movement, structure and intensity;
- Potential impacts in a range of synoptic situations associated with TCs:
  - Wave and storm surge theory;
  - Storm tide theory and warning techniques;
  - The level of threat posed by storm surge heights;
  - The impact of floods, debris flows, and landslides;
- User needs and significant impact thresholds;
- TC text and graphical products and standards;
- The principles of effective communication, including presentation and interviews:
  - Presentation and meeting formats and requirements;
  - Legislation, regulations, policies, procedures and guidelines relating to workplace communication in the public sector, such as privacy, confidentiality, freedom of information.

4.1.8.2 Skills in:

- Observations:
  - Using data viewing software and other applications in the forecast process;
  - Interpreting observations, weather radar and satellite-derived information, such as scatterometry and cloud drift winds;
  - Interpreting satellite imagery, including water vapour; visible; infrared; red–green–blue (RGB), and microwave for TC analysis;
  - Using the Dvorak technique for cyclone centre location and intensity estimation;
  - Estimating intensity from a number of inputs;
  - Interpreting wind shear from shear analyses and prognoses;
  - Assessing the environment for motion and intensity changes;
  - Interpreting NWP guidance material;
- TC forecasting techniques:
  - Evaluating model predictions against observed conditions to assess the most likely forecast environment for motion and intensity changes;
  - Understanding and interpreting reconnaissance aircraft data;
  - Interpreting NWP guidance material, including ensemble output, to determine forecast uncertainty;
  - Using software systems to determine forecast parameters;
- Impact forecasting:
  - Using software to determine range of impacts;
  - Interpreting NWP guidance material;
  - Assessing rainfall potential including eTRaP, consensus model guidance (OCF, PME) and probabilistic rainfall guidance;
  - Determining onset, extent and associated uncertainties of weather phenomena;
  - Storm surge forecasting;
  - Forecasting the onset of floods, debris flows and landslides (or have access to hydrological expertise);
- Watches and warnings:
  - In the use of appropriate software to produce warning products;
  - Internal time management to produce the range of products on time;
  - Compiling products and key messages for different audiences;
  - Converting technical concepts into concise and easy-to-understand language;
- Communication:
  - Compiling policy, products and key messages for different audiences;
  - Converting technical concepts into concise and easy-to-understand language;
  - Facilitating and engaging in communication exchanges;
  - Using equipment for presentations.

4.2 Regional Office Forecaster (RF)

This competency unit is relevant to meteorologists/forecasters at a National Meteorological Service office that has national and/or regional responsibility for one or more countries/territories and receives guidance from an RSMC.

4.2.1 Maintain a continuous watch on areas of disturbed weather and liaise with RTCF on developing and/or developed tropical cyclones.

Competency description:

4.2.1.1 Analyse and monitor continuously the weather situation as well as outputs from the RSMC on the development, position, intensity, structure and dissipation of a tropical cyclone.

Performance criteria:

4.2.1.1.1 Continuously monitors RSMC outputs and areas of potential and developed TCs within the area of responsibility;

4.2.1.1.2 Analyses and diagnoses[22] the potential of the disturbed area of convective weather to develop into a tropical cyclone;

4.2.1.1.3 Monitors the prescribed location of the TC centre and current movement in accordance with standard procedures in a range of situations;

4.2.1.1.4 Monitors changes in intensity in TC activity in accordance with standard procedures in a range of situations;

4.2.1.1.5 Monitors structure in accordance with standard procedures in a range of situations.

4.2.2 Formulate specific regional forecasts guided by RTCF information on TC track, intensity and structure of TC and related meteorological phenomena and parameters.

Competency description

4.2.2.1 With the use information from the RSMC and of a range of information including NWP and objective aids, in addition to an understanding of conceptual synoptic forecast approaches, forecast weather associated with the track, intensity and structure in warning products that are issued in accordance with documented procedures.

Performance criteria

4.2.2.1.1 Provides information on the extent of cyclonic winds (e.g. gales, storm force) and onset times for key locations using available guidance based on the forecast TC track and intensity in accordance with standard procedures in a range of situations;

4.2.2.1.2 Interprets RSMC products and NWP models to assess the likely influence on the disturbance in a range of situations;

4.2.2.1.3 Interprets and utilizes all observational data, including reconnaissance aircraft data, to formulate regional forecasts.

4.2.3 Coordinate with RTCF/RSMC the issuance of TC watches and warnings for tropical cyclones and associated hazardous phenomena.

Competency description

4.2.3.1 Liaise with the RSMC and act as the local and/or regional authority responsible for the issuance of advisories, watches and warnings in effect in the area of responsibility.

Performance criteria

4.2.3.1.1 Liaises effectively with the RSMC on the issuance of TC watches and warnings;

4.2.3.1.2 Liaises effectively with internal staff and regional stakeholders using the standard operating procedures governing the issuance of TC watches and warnings;

4.2.3.1.3 Coordinates with the national and regional services in the area of responsibility on the issuing and discontinuing TC watches and warnings.

4.2.4 Determine and warn of potential weather and hazardous phenomena impacts on at-risk areas.

[22] "Analysis" may be defined as answering the question "what is happening?", and "diagnosis" as answering "why is it happening?"

Competency description

4.2.4.1 Employ regional and local knowledge in coordination with RSMC products to forecast and warn of the impacts of high winds, rainfall, waves and storm surge based on appropriate thresholds and including estimates of uncertainty.

Performance criteria

4.2.4.1.1 Provides information on the impact of TC force winds (e.g. gales, storm force) and onset times for key locations using available guidance and knowledge;

4.2.4.1.2 Forecasts the impact of heavy rainfall using available guidance in a range of situations and liaises with hydrological experts on the potential impacts of flooding, landslides and debris flows;

4.2.4.1.3 Forecasts inundation of waves and swell and storm tide potential using standard techniques and guidance material;

4.2.4.1.4 Determines the appropriate products and key messages (including watches and warnings for regional and technical users in a range of situations);

4.1.5.1.4 Issues a range of regional TC products in accordance with procedures and timelines in a range of situations.

4.2.5 Ensure the quality of meteorological information and services.

Competency description

4.2.5.1 Check the effectiveness of the tropical cyclone forecast and warning system and institute or recommend remedial action when indicated.

Performance criteria

4.2.5.1.1 Applies the organization's quality management system and procedures;

4.2.5.1.2 Assesses the impact of known observational error characteristics (e.g. NWP model bias, achievable accuracy of observations and sensing methods) on forecasts and warnings;

4.2.5.1.3 Validates all meteorological and hydrological data, products, forecasts and warnings (timeliness, completeness, accuracy) using real-time checks;

4.2.5.1.4 Monitors the functioning of operational systems and takes remedial actions when necessary.

4.2.6 Communicate hydrometeorological information to regional and national users.

Competency description

4.2.6.1 Regional forecasters are required to effectively liaise with RSMC forecasters and communicate information to internal and external stakeholders.

Performance criteria

4.2.6.1.1 Informs the RSMC forecaster of regional and local hydrometeorological data that could have an impact on the TC analysis and forecast;

4.2.6.1.2 Logically structures briefings and presentations to contain relevant, accurate and complete information on TC track, intensity, weather and related impacts;

4.2.6.1.3 Delivers briefings, presentations and interviews to suit the intended audience, explaining technical information in concise, clear and easy-to-understand language;

4.2.6.1.4 Responds to requests for information appropriately.

4.2.7 Background knowledge and skills

The RF must be a BIP-M-qualified forecaster with demonstrated ability, especially in all aspects of tropical meteorology, be able to formulate clear advisory messages and speak clearly and distinctly. The RF should have some expertise in the scientific method and have a working knowledge of statistical principles and computer techniques. The RF must be able to interpret and downscale guidance from the RSMC or other sources to tailor forecasts for their area of responsibility. A thorough knowledge of tropical cyclone climatology and forecasting methods is strongly recommended (in Regional NMSs where the RF is the designated "Tropical cyclone specialist", thorough knowledge of tropical cyclone climatology and forecasting methods should be considered mandatory).

4.2.7.1 Knowledge of:

- Regional and local cyclone policy and operating procedures;
- Regional and local observation networks for the area of responsibility;
- The capabilities and limitations of different observational data types;
- Tropical meteorology:
  - TC structure dynamics and conceptual models;
  - Synoptic factors that affect the intensity, including shear, ocean temperatures, upper-level flow, stability, landfall, vorticity and low to mid-level moisture;
  - Strengths and limitations of the Dvorak technique, ADT, AMSU intensity estimation, SATCON and other intensity analysis guidance;
  - Relative strengths and limitations of NWP models in predicting cyclone movement, structure and intensity;
- Potential impacts in a range of synoptic situations associated with TCs:
  - Regional and local geography and areas of vulnerability;
  - Wave and storm surge theory and warning techniques;
  - The level of threat posed by storm surge heights;
  - The impact of floods, debris flows and landslides (knowledge of or in contact with hydrological expertise is strongly recommended);
- Local and regional user needs and significant impact thresholds;
- RSMC product styles and standards;
- Principles of effective communication, including presentation and interviews;
- Presentation and meeting formats and requirements;
- Legislation, regulations, policies, procedures and guidelines relating to workplace communication in the public sector such as privacy, confidentiality, freedom of information.

4.2.7.2 Skills in:

- Observations:
  - Using data viewing software and other applications in the forecast process;
  - Interpreting observations, weather radar and satellite-derived information;
  - Interpreting RSMC official analysis and products from official agencies;
  - Interpreting satellite imagery, including water vapour, visible, infrared, RGB and microwave for TC analysis;
  - Familiarity and utilization of the Dvorak technique for cyclone centre location and intensity estimation;
  - Interpreting NWP guidance material;
- Regional forecast office operations:
  - Interpreting RSMC official forecast products from official agencies;

  - Generating meteorological forecasts based on conceptual models and RSMC guidance;
  - Using data viewing software and other applications in the forecast process;
  - Assessing the local environment for impact on the TC at a general level;
- Impact-based forecasting:
  - Interpreting RSMC/Tropical Cyclone Warning Centre (TCWC)/NWP guidance material;
  - Using software to determine range of impacts;
  - Determining onset, extent and associated uncertainties of weather phenomena;
  - Storm surge/storm tide and wave height forecasting;
  - Forecasting the onset of floods, debris flows and landslides (or have access to hydrological expertise);
- Watches and warnings:
  - Downscaling RSMC products to formulate regional and local advisories, watches and warnings;
  - Internal time management to produce the range of products on time;
  - Compiling products and key messages for different audiences;
  - Converting technical concepts into concise and easy-to-understand language;
- Communication:
  - Compiling key messages for different audiences;
  - Converting technical concepts into concise and easy-to-understand language;
  - Facilitating and engaging in communication exchanges;
  - Using audio/visual equipment for presentations.

4.3 Non-forecast Office Personnel (NFP)

Personnel who are preferably trained forecasters, or at least meteorological technicians, and able to interpret information from RSMC and RF National Weather Service (NWS) offices, formulate appropriate messaging, coordinate with local emergency services and media, etc.

4.3.1 Maintain a continuous watch on areas of disturbed weather and liaise with the RF office on developing and/or developed tropical cyclones.

Competency description

4.3.1.1 Monitor continuously the weather situation, especially during periods of disturbed weather and/or TC activity in the area of responsibility, as well as outputs from the RSMC and RF on the development, position, intensity, structure and dissipation of a tropical cyclone.

Performance criteria

4.3.1.1.1 Access and interpret TC forecast information from the products and services of the RSMC and RF offices;

4.3.1.1.2 Perform a basic analysis to assess the potential of the disturbed area of convective weather to develop into a tropical cyclone;

4.3.1.1.3 Understand the forecast process and technical components of the forecast inputs (satellite interpretation including Dvorak) but are not expected to perform the technical analysis themselves;

4.3.1.1.4 Use technical forecasts to determine potential local impacts;

4.3.1.1.5 Provide support and/or feedback to the RF offices.

4.3.2 Interpret RSMC and RF forecasts for localized meteorological phenomena and parameters based on RTCF and RF office information on TC track, intensity and structure.

Competency description

4.3.2.1 Guidance products from the forecast office and other agencies are appropriately accessed and interpreted. Technical information, including satellite and other observational information, is interpreted in the context of the guidance products.

Performance criteria

4.3.2.1.1 Access the range of appropriate information, including forecasts from the RSMC, RF;

4.3.2.1.2 Interpret technical forecast guidance to assess potential local impact;

4.3.2.1.3 Interpret observational and satellite information appropriately;

4.3.2.1.4 If qualified, use interpreted forecast information to assist the RF forecaster to formulate a local forecast.

4.3.3 Interpret the RSMC and the regional TC products and produce locally specific TC products in collaboration with the RF.

Competency description:

4.3.3.1 Guidance TC products from the RSMC are appropriately accessed and interpreted.

Performance criteria

4.3.3.1.1 Interpret TC products from the RSMC and RF and produce localized products if required;

4.3.3.1.2 Discuss with RF existing and future products in accordance with procedures in a range of situations;

4.3.3.1.3 Determine the appropriate products and key messages for local and technical users in a range of situations.

4.3.4 Warn of hazardous phenomena and related localized impacts associated with tropical cyclones.

Competency description:

4.3.4.1 The impacts of high winds, rainfall, waves and storm surge are interpreted for key locations according to appropriate thresholds and including estimates of uncertainty.

Performance criteria

4.3.4.1.1 Liaise with RF office regarding local vulnerable locations and the need to issue the appropriate alerts;

4.3.4.1.2 Assist in interpreting the extent of cyclonic winds (e.g. gales, storm force) and onset times for key local locations using available guidance in a range of situations;

4.3.4.1.3 Use available hydrological guidance information to determine potential local flooding and give guidance on the impact of rainfall in a range of situations;

4.3.4.1.4 Use available information to give guidance on the local impact of forecast waves, swell and storm tide potential.

4.3.5 Ensure the quality of meteorological information and services.

Competency description

4.3.5.1 Check the effectiveness of the RF forecast and warning system and institute or recommend remedial action where indicated.

Performance criteria

4.3.5.1.1 Apply the organization's quality management system and procedures;

4.3.5.1.2 Validate all meteorological and hydrological data, products, forecasts and warnings (timeliness, completeness, accuracy) using real-time checks;

4.3.5.1.3 Monitor the functioning of operational systems and take remedial actions when necessary.

4.3.6 Communicate hydrometeorological information, watches and warnings and relevant TC information to national stakeholders.

Competency description

4.3.6.1 NFP are required to communicate information nationally to internal and external users appropriate to their needs, including responding to enquiries.

Performance criteria

4.3.6.1.1 Logically structure briefings and presentations to contain relevant, accurate and complete information;

4.3.6.1.2 Deliver briefings, presentations and interviews to suit the intended audience explaining technical information in concise, clear and easy-to-understand language;

4.3.6.1.3 Respond to requests for information appropriately.

4.3.7 Background knowledge and skills

In RA IV, there is a range of National Weather Services which can be categorized as non-forecast offices and fall under the forecast responsibility of a Regional Forecast office (see RA IV Hurricane Plan). Not all these services are designated as forecast offices and not all will have personnel qualified to the level of meteorological forecaster, with BIP-M qualifications. It is strongly recommended that these services work towards employing a trained forecaster, or at least a meteorological technician (qualified at the BIP-MT level, as stated in *Technical Regulations* (WMO-No. 49), Volume I), trained to interpret information from RSMC and RF NWS offices and to formulate appropriate messaging and coordination with emergency services, local media, etc.

4.3.7.1 Knowledge of:

- Local cyclone policy and operating procedures;
- Local observation networks for the area of responsibility;
- The capabilities and limitations of different observational data types;
- Tropical meteorology:
  - TC structure dynamics and conceptual models;

  - Synoptic factors that affect intensity, including shear, ocean temperatures, upper-level flow, stability, landfall, vorticity and low to mid-level moisture;
- Potential impacts in a range of synoptic situations associated with TCs:
  - Wave and storm surge theory;
  - Storm tide theory and warning techniques;
  - The level of threat posed by storm surge heights;
  - The impact of floods, debris flows and landslides;
- Local user needs and significant impact thresholds;
- TC text and graphical products and standards;
- The principles of effective communication, including presentation and interviews:
  - Presentation and meeting formats and requirements;
  - Legislation, regulations, policies, procedures and guidelines relating to workplace communication in the public sector, such as privacy, confidentiality, freedom of information.

4.3.7.2 Skills in:

- Observations:
  - Using data viewing software and other applications in the forecast process;
  - Interpreting observations, weather radar and satellite-derived information;
  - Interpreting RSMC official analysis and products from official agencies;
- Regional forecast office operations:
  - Interpreting RSMC and RF official forecast products from official agencies;
  - Generating meteorological forecasts based on conceptual models and RSMC guidance;
  - Using data viewing software and other applications in the forecast process;
  - Assessing the local environment for impact on the TC at a general level;
- Impact-based forecasting:
  - Interpreting RSMC/TCWC/NWP guidance material;
  - Downscaling guidance to determine the onset, extent and associated uncertainties of weather phenomena;
  - Interpreting storm surge/storm tide and wave height forecast products;
  - Interpreting hydrological guidance to assess the onset of floods, debris flows and landslides (or have access to hydrological expertise);
- Watches and warnings:
  - Downscaling RSMC and RF products to formulate local advisories, watches and warnings;
  - Internal time management to produce the range of products on time;
  - Compiling policy, products and key messages for different audiences;
  - Converting technical concepts into concise and easy-to-understand language;
- Communication:
  - Compiling key messages for different audiences;
  - Converting technical concepts into concise and easy-to-understand language;
  - Facilitating and engaging in communication exchanges;
  - Using audio/visual equipment for presentations.

5. Regional/national variations

The context of these competencies may vary from service to service according to:

- Agreed and documented criteria and thresholds;
- National climatology and impacts;
- National geography, especially how it affects hazards including storm tide, rainfall and wind;
- Observation networks (including surface, upper-air, weather radar, aircraft);
- Variations in products issued and briefing requirements;
- Boundaries of forecast areas;
- Communication language(s);
- Boundaries of forecast and warning areas;

- Communications technology for forecast and warning transmission and for weather briefing;
- Forecast database(s) utilized – gridded/text/graphical/digital, etc.;
- Risk assessment and estimation of forecast uncertainties;
- Types and use of forecast guidance.

6. Glossary

The glossary is adapted from the NHC glossary.

Advisory

Official information issued by tropical cyclone warning centres describing all tropical cyclone watches and warnings in effect, along with details concerning tropical cyclone locations, intensity and movement, and precautions that should be taken. Advisories are also issued to describe: (a) tropical cyclones prior to the issuance of watches and warnings and (b) subtropical cyclones.

Cyclone

An atmospheric closed circulation rotating counterclockwise in the northern hemisphere and clockwise in the southern hemisphere.

Gale warning

A warning of 1-minute sustained surface winds in the range 34 kt (39 mph (63 km/h)) to 47 kt (54 mph or 87 km/h), inclusive, either predicted or occurring and not directly associated with tropical cyclones.

High wind warning

A high wind warning is defined as 1-minute average surface winds of 35 kt (40 mph (64 km/h)) or greater lasting for 1 hour or longer, or winds gusting to 50 kt (58 mph (93 km/h)) or greater, regardless of duration, that are either expected or observed over land.

Hurricane/typhoon

A tropical cyclone in which the maximum sustained surface wind (using the US 1 minute average) is 64 kt (74 mph (119 km/h)) or more. The term “hurricane” is used for northern hemisphere tropical cyclones east of the International Dateline to the Greenwich Meridian. The term “typhoon” is used for Pacific tropical cyclones north of the Equator west of the International Dateline.

Hurricane local statement

A public release prepared by local National Weather Service offices in or near a threatened area giving specific details for its county/parish warning area on (1) weather conditions, (2) evacuation decisions made by local officials, and (3) other precautions necessary to protect life and property.

Hurricane season

The portion of the year having a relatively high incidence of hurricanes. The hurricane season in the Atlantic, Caribbean and Gulf of Mexico runs from 1 June to 30 November. The hurricane season in the Eastern Pacific basin runs from 15 May to 30 November. The hurricane season in the Central Pacific basin runs from 1 June to 30 November.

Hurricane warning

An announcement that sustained winds of 64 knots (74 mph (119 km/h)) or higher are *expected* somewhere within the specified area in association with a tropical, subtropical, or post-tropical cyclone. Because hurricane preparedness activities become difficult once winds reach tropical storm force, the warning is issued 36 hours in advance of the anticipated onset of tropical-storm-force winds. The warning can remain in effect when dangerously high water or a combination of dangerously high water and waves continues, even though winds may be less than hurricane force.

Hurricane watch

An announcement that sustained winds of 64 knots (74 mph (119 km/h)) or higher are *possible* within the specified area in association with a tropical, subtropical, or post-tropical cyclone. Because hurricane preparedness activities become difficult once winds reach tropical storm force, the hurricane watch is issued 48 hours in advance of the anticipated onset of tropical-storm-force winds.

Inundation

The flooding of normally dry land, primarily caused by severe weather events along the coasts, estuaries and adjoining rivers. These storms, which include hurricanes and nor'easters, bring strong winds and heavy rains. The winds drive large waves and storm surge on shore, and heavy rains raise rivers. (A tsunami – a giant wave caused by earthquakes or volcanic eruptions under the sea or landslides into the sea – is another kind of coastal inundation but should not be confused with storm surge.)

Landfall

The intersection of the surface centre of a tropical cyclone with a coastline. Because the strongest winds in a tropical cyclone are not located precisely at the centre, it is possible for a cyclone's strongest winds to be experienced over land even if landfall does not occur. Similarly, it is possible for a tropical cyclone to make landfall and have its strongest winds remain over the water. Compare direct hit, indirect hit and strike.

Major hurricane

A hurricane that is classified as Category 3 or higher.

Maximum sustained surface wind

The standard measure of a tropical cyclone's intensity. When the term is applied to a particular weather system, it refers to the highest one-minute average wind (at an elevation of 10 meters with an unobstructed exposure) associated with that weather system at a particular point in time.

Potential tropical cyclone

A term used in United States National Weather Service (NWS) advisory products to describe a disturbance that is not yet a tropical cyclone, but which poses the threat of bringing tropical storm or hurricane conditions to land areas within 48 hours.

Storm surge

An abnormal rise in sea level accompanying a hurricane or other intense storm, and whose height is the difference between the observed level of the sea surface and the level that would have occurred in the absence of the cyclone. Storm surge is usually estimated by subtracting the normal or astronomic high tide from the observed storm tide.

Storm surge warning

The danger of life-threatening inundation from rising water moving inland from the shoreline somewhere within the specified area, generally within 36 hours, in association with an ongoing or potential tropical cyclone, a subtropical cyclone or a post-tropical cyclone. The warning may be issued earlier when other conditions, such as the onset of tropical-storm-force winds are expected to limit the time available to take protective actions for surge (e.g. evacuations). The warning may also be issued for locations not expected to receive life-threatening inundation but which could potentially be isolated by inundation in adjacent areas.

Storm surge watch

The possibility of life-threatening inundation from rising water moving inland from the shoreline somewhere within the specified area, generally within 48 hours, in association with an ongoing or potential tropical cyclone, a subtropical cyclone or a post-tropical cyclone. The watch may be issued earlier when other conditions, such as the onset of tropical-storm-force winds are expected to limit the time available to take protective actions for surge (e.g. evacuations). The warning may also be issued for locations not expected to receive life-threatening inundation but which could potentially be isolated by inundation in adjacent areas.

Storm tide

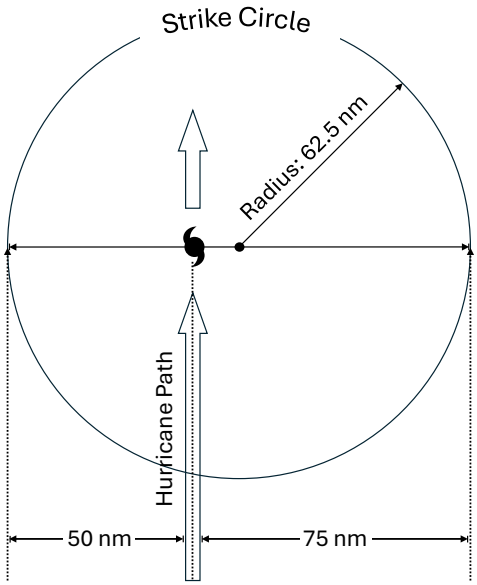
The actual level of seawater resulting from the astronomic tide combined with the storm surge.

Storm warning

A warning of 1 minute sustained surface winds of 48 kt (55 mph or 88 km/h) or greater, either predicted or occurring, not directly associated with tropical cyclones.

Strike

For any particular location, a hurricane strike occurs if that location passes within the hurricane's strike circle, a circle of 125 n mi diameter, centred 12.5 n mi to the right of the hurricane centre (looking in the direction of motion). This circle is meant to depict the typical extent of hurricane force winds, which are approximately 75 n mi to the right of the centre and 50 n mi to the left.



Subtropical cyclone

A non-frontal low-pressure system that has characteristics of both tropical and extratropical cyclones. Like tropical cyclones, they are non-frontal, synoptic-scale cyclones that originate over tropical or subtropical waters and have a closed surface wind circulation about a well-defined centre. In addition, they have organized moderate to deep convection, but lack a central dense overcast. Unlike tropical cyclones, subtropical cyclones derive a significant proportion of their energy from baroclinic sources and are generally cold-core in the upper troposphere, often being associated with an upper-level low or trough. In comparison to tropical cyclones, these systems generally have a radius of maximum winds occurring relatively far from the centre (usually greater than 60 n mi), and generally have a less symmetric wind field and distribution of convection.

Subtropical depression

A subtropical cyclone in which the maximum sustained surface wind speed (using the US 1 minute average) is 33 kt (38 mph or 62 km/h) or less.

Subtropical storm

A subtropical cyclone in which the maximum sustained surface wind speed (using the US 1 minute average) is 34 kt (39 mph or 63 km/h) or more.

Tropical cyclone

A warm-core non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters, with organized deep convection and a closed surface wind circulation about a well-defined centre. Once formed, a tropical cyclone is maintained by the extraction of heat energy from the ocean at high temperature and heat export at the low temperatures of the upper troposphere. In this they differ from extratropical cyclones, which derive their energy from horizontal temperature contrasts in the atmosphere (baroclinic effects).

Tropical depression

A tropical cyclone in which the maximum sustained surface wind speed (using the US 1 minute average) is 33 kt (38 mph or 62 km/h) or less.

Tropical disturbance

A discrete tropical weather system of apparently organized convection – generally 100 to 300 n mi in diameter – originating in the tropics or subtropics, having a non-frontal migratory character and maintaining its identity for 24 hours or more. It may or may not be associated with a detectable perturbation of the wind field.

Tropical storm

A tropical cyclone in which the maximum sustained surface wind speed (using the US 1 minute average) ranges from 34 kt (39 mph or 63 km/h) to 63 kt (73 mph or 118 km/h).

Tropical storm warning

An announcement that sustained winds of 34 to 63 knots (39 to 73 mph or 63 to 118 km/h) are *expected* somewhere within the specified area within 36 hours in association with a tropical, subtropical, or post-tropical cyclone.

Tropical storm watch

An announcement that sustained winds of 34 to 63 knots (39 to 73 mph or 63 to 118 km/h) are *possible* within the specified area within 48 hours in association with a tropical, subtropical, or post-tropical cyclone.

Tropical wave

A trough or cyclonic curvature maximum in the trade-wind easterlies. The wave may reach maximum amplitude in the lower middle troposphere.

2.8.5 WMO tropical cyclone competencies – Region V competency requirements for a tropical cyclone forecaster

OVERVIEW

The establishment of formal competencies for tropical cyclone (TC) operations is part of the overall WMO Competency Standards which are a key element of the broader ambition to implement the WMO Quality Management System (QMS) set out in by the World Meteorological Congress at its fourteenth session.

The competency approach is essential for defining what is required to do the job, developing the most appropriate training and demonstrating that forecasters can do the job. The WMO *Guide to Competency* (WMO-No. 1205) sets out details on competency assessment systems and guidelines on developing an assessment plan.

These competencies have been devised to be consistent with the actual work in TC warning offices and other tropical cyclone services.

As well as those listed under particular elements, the following are required:

- General weather forecasting and forecast preparation skills;
- General synoptic analysis techniques (including data limitations);
- Ability to analyse and synthesize a range of data types in order to apply relevant weighting to each data type, where appropriate;
- Numerical weather prediction (NWP) – interpretation of model output; knowledge of model strengths and limitations; and model comparisons;
- Ability to communicate.

There are two units for Tropical Cyclone Forecast Services. The first is applicable to forecasters working in a TC warning office (Regional Specialized Meteorological Centre (RSMC) or Tropical Cyclone Warning Centre (TCWC)) at a senior or independent, unsupervised level, providing a range of TC forecast services.

The second applies to forecasters at an office where the support forecaster receives direction from the "parent" RSMC or TCWC.

The RSMC/TCWC senior forecaster has to work at an independent level to devise the official analysis and forecast, whereas the general TC forecaster has the benefit of receiving this analysis and forecast, and the requirement is to understand and interpret this information for the local context. The requirements to determine local weather and marine hazards, issue relevant products and communicate to users are the same.

A. TROPICAL CYCLONE SENIOR FORECASTER AT AN RSMC/TCWC

Unit descriptor

This competency unit is relevant to senior forecasters working in a TC warning office (RSMC/TCWC). The TC forecaster must be able to independently follow the whole forecast process from analysis and forecast through to forecast production without external support or internal supervision. This includes the determination of potential weather and storm tide impacts at a national level. Finally, they must be able to communicate the TC information, both internally and externally, in a manner appropriate to the audience.

Essential prerequisites

The senior TC forecaster must:

- Be a meteorologist (as defined by the WMO classification);
- Have an in-depth knowledge of tropical meteorology;
- Be experienced at synoptic analysis and general weather forecasting;
- Be able to interpret information from numerical weather prediction (models);
- Be able to synthesize information from a range of sources;
- Have good written and oral communication skills.

Regional variations

The context of these competencies will change from office to office.

- Regional climatology and impacts
- Regional geography, especially how it affects hazards including storm tide, rainfall and wind
- Observation networks, including surface, upper-air, weather radar, aircraft and access to satellite information
- Local forecast procedures and thresholds

- Forecast systems, operational websites
- Procedures and technology for warning transmission and for briefings
- Variations in products issued and briefing requirements
- Variations in user groups and their concerns
- Boundaries of forecast areas
- Communication language(s)
- Procedures for handling external enquiries
- Risk assessment and estimation of forecast uncertainties
- Types and use of forecast guidance

COMPETENCIES

1. **Analyse broad-scale environment and determine TC position, intensity and structure.**

Description

A range of observational information is analysed to interpret the broad-scale environment, position, intensity and structure of the tropical circulation.

Performance criteria

1.1 Analyses the broad-scale environment to assess the likely influence on the circulation in a range of situations;

1.2 Determines the location of the centre and current movement in accordance with standard procedures in a range of situations;

1.3 Determines intensity in accordance with standard procedures in a range of situations;

1.4 Determines structure in accordance with standard procedures in a range of situations.

Background knowledge and skills

Skills in:

- Using data viewing software and other applications in the forecast process;
- Analysing and interpreting observational data: surface and upper-level observations, satellite imagery (visible, infrared, water vapour and microwave), scatterometry data, radar imagery and satellite-derived information such as cloud drift winds, wind shear, upper divergence, etc.;
- Assessing the environment for motion, intensity and structure changes;
- Interpreting NWP guidance material;
- Applying the Dvorak technique for cyclone centre location and intensity estimation;
- Synthesizing available information to estimate the position and intensity;
- Estimating the parameters defining the structure (wind radii by quadrants, radius of maximum winds, pressure and radius of the outer closed isobar).

Knowledge of:

- Local cyclone policy and operating procedures;
- Observation networks;
- Capabilities and limitations of different observational data types;
- TC structure dynamics and conceptual models;

- Synoptic factors that affect intensity, including shear, ocean temperatures, upper-level flow, stability, landfall, vorticity and low to mid-level moisture;
- Strengths and limitations of the Dvorak technique, ADT, AMSU intensity estimation, SATCON and other intensity analysis guidance.

2. **Forecast TC track, intensity and structure.**

Description

A range of information, including NWP and objective aids, in addition to an understanding of conceptual synoptic forecast approaches, is used to forecast the track, intensity and structure in warning products that are issued in accordance with documented procedures.

Performance criteria

2.1 Interprets NWP-predicted broad-scale environment to assess the likely influence on the circulation in a range of situations;

2.2 Determines forecast track in accordance with standard procedures in a range of situations;

2.3 Determines forecast intensity in accordance with standard procedures in a range of situations;

2.4 Determines forecast structure in accordance with procedures and timelines in a range of situations.

Background knowledge and skills

Skills in:

- Evaluating model predictions against observed conditions to assess the most likely forecast environment for motion and intensity changes;
- Interpreting NWP guidance material including ensemble output to determine forecast uncertainty;
- Using software systems to visualize and determine forecast parameters;
- Combining conceptual understanding and objective guidance to forecast track, intensity and structure.

Knowledge of:

- Local cyclone policy and forecast process;
- Relative strengths and limitations of NWP with regard to the track, intensity and structure forecast;
- Conceptual frameworks for changes in motion, intensity and structure;
- Consensus track forecasting techniques.

3. **Determine potential weather impacts.**

Description

The impacts of high winds, rainfall, waves and storm tide are determined for key locations according to appropriate thresholds and including estimates of uncertainty.

Performance criteria

3.1 Forecasts extent of cyclonic winds (e.g. gales, storm force) and onset times for key locations using available guidance in a range of situations;

3.2 Forecasts rainfall using available guidance in a range of situations and liaises with the relevant hydrology/flood programme to determine potential flooding;

3.3 Forecasts storm tide potential considering various track and intensity scenarios and confidence levels (worst case, most likely, alternate track/intensity);

3.4 Forecasts marine hazards – waves and swell using standard techniques.

Background knowledge and skills

Skills in:

- Using software to determine range of impacts;
- Interpreting NWP guidance material including limitations;
- Assessing rainfall potential including ensemble tropical rainfall potential (eTRaP), consensus model guidance and probabilistic rainfall guidance;
- Determining onset, extent and associated uncertainties of weather phenomena;
- Storm tide forecasting.

Knowledge of:

- Local cyclone policy and operating procedures;
- Potential impacts in a range of synoptic situations;
- Local procedures and related warning thresholds for different hazards;
- Local variations in wind, rainfall, storm tide by orography, coastline shape and bathymetry, including vulnerable locations;
- Wave, swell, storm surge and tide theory.

4. **Formulate policy and issue TC products.**

Description

Local forecast production systems are used to produce and disseminate a range of products according to local operating procedures.

Performance criteria

4.1 Liaises effectively with internal staff in the development of tropical cyclone policy and in considering the impact on other services;

4.2 Formulates TC policy in accordance with procedures in a range of situations;

4.3 Determines the appropriate key messages for general and technical audiences in a range of situations;

4.4 Issues the range of TC products in accordance with procedures and timelines in a range of situations.

Background knowledge and skills

Skills in:

- Using appropriate software to produce warning products;
- Communicating with colleagues to arrive at policy decisions;
- Time management to produce the range of products on time;
- Compiling policy, products and key messages for different audiences;
- Converting technical concepts into concise and easy-to-understand language.

Knowledge of:

- Local cyclone policy and operating procedures;
- User needs and significant impact thresholds;
- Product styles and standards.

5. Communicate relevant TC information to internal and external stakeholders.

Description

Forecasters are required to communicate information to internal and external users appropriate to their needs.

Performance criteria

5.1 Logically structures briefings and presentations to contain relevant, accurate and complete information;

5.2 Delivers briefings, presentations and interviews to suit the intended audience, explaining technical information in concise, clear and easy-to-understand language.

Background knowledge and skills

Skills in:

- Compiling policy, products and key messages for different audiences;
- Converting technical concepts into concise and easy-to-understand language;
- Facilitating and engaging in communication exchanges;
- Using equipment for interviews and presentations.

Knowledge of:

- Principles of effective communication, including presentation and interviews;
- Presentation and meeting formats and requirements;
- Legislation, regulations, policies, procedures and guidelines relating to workplace communication in the public sector such as privacy, confidentiality, freedom of information.

B. TROPICAL CYCLONE FORECASTER

Unit descriptor

This competency unit is relevant to forecasters working in a forecasting office that receives guidance from an RSMC or TCWC. It may also be applied to forecasters in the RSMC/TCWC working under the supervision of a senior forecaster, in which case the role is to support the formulation of policy and products and associated communication.

It includes the following requirements:

- Accesses and interprets TC products and services;
- Understands the forecast process and technical components of the forecast inputs such as satellite interpretation including Dvorak, Ascat, etc. but is not expected to perform the technical analysis;
- Uses technical forecasts to determine potential impacts;
- Formulates policy and produces local forecast products based on technical forecasts from the RSMC/TCWC/Joint Typhoon Warning Centre (JTWC);
- Conducts briefings to local user groups – media and emergency services, and provides TC information in response to enquiries;
- Provides support to senior TC forecasters or feedback to the RSMC/TCWC as appropriate.

Essential prerequisites

The TC forecaster must:

- Have a good understanding of tropical meteorology in their region;
- Be able to use the Internet and software to access TC-related information including satellite imagery, NWP and observation systems;
- Be able to interpret weather observations and maintain a weather watch;
- Be able to produce local forecasts and understand concerns of local users;
- Have good written and oral communication skills.

Regional variations

The context of these competencies will change from office to office.

- Regional climatology and impacts
- Regional and local geography, especially how it affects hazards, including storm tide, rainfall and wind
- Observation networks, including surface, upper-air, weather radar, aircraft
- Forecast systems, operational websites
- Local forecast procedures and thresholds
- Local products issued and briefing requirements
- Procedures and technology for warning transmission and for briefings and presentations
- Local forecast procedures and thresholds
- Types and use of forecast guidance
- Variations in user groups and their concerns
- Communication language(s)
- Procedures for handling external enquiries

Competencies

1. **Access and interpret TC products and services.**

Description

Guidance products from the TCWC/RSMC and other agencies are appropriately accessed and interpreted. Technical information, including satellite and other observational information, is interpreted in the context of the guidance products.

Performance criteria

1.1 Accesses the range of appropriate information, including forecasts from the RSMC/TCWC and other agencies;

1.2 Interprets technical forecast guidance to assess impact potential upon forecast region of responsibility;

1.3 Interprets observational and satellite information appropriately.

Background knowledge and skills

Skills in:

- Interpreting official forecast products from RSMC/TCWC agencies;
- Interpreting NWP guidance material;
- Using data viewing software and other applications in the forecast process;
- Interpreting observations, weather radar, satellite and satellite-derived information at a general level;
- Assessing the environment for impact on the TC at a general level.

Knowledge of:

- Local cyclone policy and operating procedures;
- Observation networks;
- Capabilities and limitations of different observational data types;
- TC structure dynamics and conceptual models;
- Synoptic factors that affect the intensity, including shear, ocean temperatures, upper-level flow, stability, landfall, vorticity and low to mid-level moisture;
- Strengths and limitations of the Dvorak technique, ADT, AMSU intensity estimation, SATCON and other intensity analysis guidance.

2. **Determine potential weather impacts.**

Description

The impacts of high winds, rainfall, waves and storm tide are determined for key locations according to appropriate thresholds and including estimates of uncertainty.

Performance criteria

2.1 Forecasts the extent of cyclonic winds (e.g. gales, storm force) and onset times for key locations using available guidance in a range of situations;

2.2 Forecasts rainfall using available guidance in a range of situations and liaises with the relevant organization in charge of hydrology to determine potential flooding;

2.3 Forecasts waves and swell and storm tide potential using standard techniques.

Background knowledge and skills

Skills in:

- Using software to determine range of impacts;
- Interpreting RSMC/TCWC products and NWP guidance material;
- Determining onset, extent and associated uncertainties of weather phenomena;
- Storm tide forecasting.

Knowledge of:

- Local cyclone policy and operating procedures;

- Potential impacts in a range of synoptic situations;
- Local procedures and the related warning thresholds for the different hazards;
- Local variations in wind, rainfall, storm tide by orography, coastline shape and bathymetry, including vulnerable locations.

3. **Formulate policy and issue forecast products.**

Description

Local forecast production systems are used to produce and disseminate a range of products according to local operating procedures.

Performance criteria

3.1 Liaises effectively with internal staff in the development of tropical cyclone policy and in considering the impact on other services;

3.2 Formulates policy in accordance with procedures in a range of situations;

3.3 Determines the appropriate key messages for general and technical audiences in a range of situations;

3.4 Issues the range of TC products in accordance with procedures and timelines in a range of situations.

Background knowledge and skills

Skills in:

- Communicating with colleagues to arrive at policy decisions;
- Using appropriate software to produce warning products;
- Time management to produce the range of products on time;
- Compiling policy, products and key messages for different audiences;
- Converting technical concepts into concise and easy-to-understand language.

Knowledge of:

- Local cyclone policy and operating procedures;
- User needs and significant impact thresholds;
- Product styles and standards.

4. **Communicate relevant TC information to internal and external stakeholders**

Description

Forecasters are required to communicate information to internal and external users appropriate to their needs including responding to enquiries.

Performance criteria

4.1 Logically structures briefings and presentations to contain relevant, accurate and complete information;

4.2 Delivers briefings, presentations and interviews to suit the intended audience, explaining technical information in concise, clear and easy-to-understand language;

4.3 Responds to requests for information appropriately.

Background knowledge and skills

Skills in:

- Compiling key messages for different audiences;
- Converting technical concepts into concise and easy-to-understand language;
- Facilitating and engaging in communication exchanges;
- Using equipment for interviews and presentations.

Knowledge of:

- Principles of effective communication, including presentations and interviews;
- Presentation and meeting formats and requirements;
- Legislation, regulations, policies, procedures and guidelines relating to workplace communication in the public sector such as privacy, confidentiality, freedom of information.

For more information, please contact:

World Meteorological Organization

7 bis, avenue de la Paix – P.O. Box 2300 – CH 1211 Geneva 2 – Switzerland

Strategic Communications Office

Tel.: +41 (0) 22 730 83 14

Email: cpa@wmo.int

wmo.int

JN 25318