

# Manual on the WMO Integrated Processing and Prediction System

Annex IV to the WMO Technical Regulations

2023 edition

Updated in 2024

WEATHER CLIMATE WATER



WORLD  
METEOROLOGICAL  
ORGANIZATION

WMO-No. 485



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#### EDITORIAL NOTE

The following typographical practice has been followed: Standard practices and procedures have been printed in **bold**. Recommended practices and procedures have been printed in regular font. Notes have been printed in smaller type.

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

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#### NOTE

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<i>Date</i>	<i>Part/chapter/section</i>	<i>Purpose of amendment</i>	<i>Proposed by</i>	<i>Approved by</i>
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June 2024	Section 2.2.1.8	Introduce a new general-purpose activity of global climate reanalysis and associated new Appendices 54 and 55	INFCOM	EC-78
June 2024	Section 2.2.1.11	Introduce a new general-purpose activity of global numerical storm surge prediction and associated new Appendices 56 and 57	INFCOM	EC-78
June 2024	Section 2.2.2.5	Introduce a new specialized activity of coordination of assessment of multiple climate reanalysis and associated new Appendix 58	INFCOM	EC-78
June 2024	Section 2.2.2.11	Introduce a new specialized activity of vegetation fire and smoke pollution forecasts and associated new Appendix 59	INFCOM	EC-78
June 2024	Section 2.2.2.14 (previously 2.2.2.12)	Update list of functions carried out by centres conducting marine emergency response and introduce associated new Appendices 60, 61, 62, 63 and 64	INFCOM	EC-78
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<i>Date</i>	<i>Part/chapter/section</i>	<i>Purpose of amendment</i>	<i>Proposed by</i>	<i>Approved by</i>
June 2024	Part III	Add names of new WIPPS Designated Centres	INFCOM	EC-78

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# INTRODUCTION

## General

1. The *Manual on the WMO Integrated Processing and Prediction System* (WMO-No. 485) is the single source of technical regulations for all operational data-processing and forecasting systems of Members designated by WMO as meteorological centres. The Manual is designed to ensure adequate uniformity and standardization of data, information and production practices, procedures and specifications employed among WMO Members in the operation of the WMO Integrated Processing and Prediction System (WIPPS) as it supports the mission of the Organization.
2. The Manual is Annex IV to the WMO Technical Regulations (*Technical Regulations* (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices), in which it is stated that WIPPS is established and shall be operated in accordance with the practices, procedures and specifications described in the present Manual.
3. WIPPS cuts across a number of WMO-related disciplines. It intersects many WMO practices, procedures and specifications that are primarily defined in publications dedicated specifically to them, for example, the *Manual on the WMO Information System* (WMO-No. 1060) and the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).
4. The advances in numerical weather prediction (NWP) in the last few decades have been tremendous: higher accuracy and resolution, longer lead time, and a wider range of relevant applications. Consequently, the emphasis in operational meteorology, hydrology and climatology has been shifting towards the implementation of increasingly sophisticated and diverse numerical models and applications, for an ever-increasing variety of users. WIPPS enables Members to make use of these advances by providing a framework for the sharing of data related to operational meteorology, hydrology and climatology.
5. As part of the WMO Technical Regulations, the *Manual on the WMO Integrated Processing and Prediction System* (WMO-No. 485) sets out standard and recommended practices and procedures. The General Provisions define the meaning of the phrase “standard and recommended practices and procedures”. The General Provisions also contain information on the procedure for amending, updating or issuing a new edition of the Technical Regulations (including Manuals and Guides).
6. This edition has been developed in accordance with quality management principles, which ensures its sustainability as part of the WMO Quality Management Framework.

## How to read this Manual

7. The Manual consists of three Parts, as follows:
  - (a) Part I: Outline of WMO WIPPS – presenting the overall purpose of WIPPS, its organization and the general characteristics of the various activities to be performed;
  - (b) Part II: Specifications of WIPPS activities – providing detailed information on the various activities: mandatory functions including production, verification and documentation; and recommended functions and products. Part II also specifies overall requirements applicable to all types of activities regarding dissemination, verification, training, and the like;
  - (c) Part III: Current WIPPS Designated Centres.

**Table 1. Example of a table specifying responsibilities for modifications to a WIPPS activity, for designation of centres and review of compliance**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/ET-OWFS		
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OWFS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

Acronyms not previously defined: EC – WMO Executive Council; ET-OWFS – Expert Team on Operational Weather Forecasting System; INFCOM – Commission for Observation, Infrastructure and Information Systems; SC-WIPPS – Standing Committee on WMO Integrated Processing and Prediction System

8. The reader seeking general information on WIPPS and its applications should refer to Part I, whereas Parts II and III provide detailed information on the various components of the system, available products and information, status of implementation, as well as compliance criteria.

9. The Manual is designed so that it can be modified as frequently as necessary to keep it up to date. While Part I should be rather stable and seldom require updating, it is expected that the evolution of science, techniques and user requirements will continue to induce developments requiring frequent changes to Parts II and III.

10. In line with quality management requirements, the bodies in charge of managing the information contained in the Manual are explicitly specified for every type of WIPPS activity. This information is contained in Part II, 2.2, Tables 2–33. The following explanations and example (Table 1) are provided:

- (a) The three entries under “Changes to activity specification” indicate the team(s) and body(ies) in charge of preparing specification updates, approving them, and deciding to update the Manual accordingly;
- (b) The two entries under “Centres designation” indicate the bodies responsible for approving the designation of a WIPPS centre for the activity under consideration and for deciding accordingly;
- (c) The two entries under “Compliance” indicate the team(s) and body(ies) in charge of ensuring that the WIPPS Designated Centres remain compliant with the activity specification.

11. The following procedure is applied for the incorporation of new types of WIPPS centres into this Manual:

- (a) The relevant technical commission or programme expert team will develop the criteria and functions for the new type of centre, including the list of mandatory products to be made available in the context of WIPPS;
- (b) The criteria and functions for the new type of centre will be endorsed by the relevant technical commission management group or programme steering committee, and submitted to INFCOM through its president;

- (c) The president of INFCOM will then decide on an expert team of the commission that will be responsible for reviewing the proposal according to the standard procedure for amendments as defined in the General Provisions.

Notes:

1. The General Provisions to the Technical Regulations, formerly reproduced as a part of the present Manual, can be found in the publication *Technical Regulations* (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices.
  2. The former appendix to the General Provisions, entitled "Procedures for amending WMO manuals and guides that are the responsibility of the Commission for Observation, Infrastructure and Information Systems", previously a part of the present Manual, has been updated and can be found in the publication *Rules of Procedure for Technical Commissions* (WMO-No. 1240).
-



# **PART I. OUTLINE OF THE WMO INTEGRATED PROCESSING AND PREDICTION SYSTEM**

## **1.1 PURPOSE AND SUPPORTED ACTIVITIES**

### **1.1.1 General description**

1.1.1.1 WIPPS shall be the worldwide network of operational centres operated by WMO Members. Its purpose shall be to make operationally available among WMO Members and relevant operational organizations defined products and services for applications related to weather, climate, water and environment.

1.1.1.2 WIPPS shall enable scientific and technological advances made in meteorology and related fields to be accessible and exploitable by WMO Members.

1.1.1.3 The activities, organizational structure and operations of WIPPS shall be systematically designed in accordance with Members' needs and their ability to contribute to, and benefit from, the system in an efficient manner and with a minimum of duplication.

1.1.1.4 A key objective of WIPPS should be to facilitate cooperation and the exchange of information, thereby also contributing to capacity development among developing countries.

1.1.1.5 Defined products and services for applications related to weather, climate, water and environment shall include:

- (a) Numerical weather, oceanographic and climate prediction products (analysis and forecast, including probabilistic information);
- (b) Specialized products tailored for specific applications.

1.1.1.6 Additional information necessary for an appropriate use of the identified products and services shall be available. This includes non-real-time information as follows:

- (a) Systems description and characteristics;
- (b) Product metadata;
- (c) Verification and monitoring results.

### **1.1.2 Activities supported by the WMO Integrated Processing and Prediction System**

1.1.2.1 Through WIPPS, Members shall provide and have access to meteorological, hydrological, oceanographic and climatological information supporting a range of operational activities.

1.1.2.2 WIPPS shall be organized as a system with three activity categories as follows:

- (a) General-purpose activities are those that provide real-time analyses and predictions required for a wide range of end uses;
- (b) Specialized activities are those that provide forecasting products tailored for a specific type of application or user community (for example, guidance based on human interpretation);

- (c) **Non-real-time coordination activities are those that, while not providing real-time forecasts, provide consistent presentations of verification and monitoring results, needed for appropriate use of WIPPS products.**

Note: Associated commitments and other appropriate details are specified in Part II.

### 1.1.2.3 WIPPS activities shall be organized as follows:

(a) **General-purpose activities:**

- Global deterministic NWP
- Limited-area deterministic NWP
- Global ensemble NWP
- Limited-area ensemble NWP
- Global numerical sub-seasonal prediction
- Global numerical seasonal prediction
- Annual to decadal climate prediction
- Global climate reanalysis
- Numerical ocean wave prediction
- Global numerical ocean prediction
- Global numerical storm surge prediction
- Nowcasting
- Sub-seasonal to seasonal hydrological prediction
- Snow cover prediction

(b) **Specialized activities:**

- Regional climate prediction and monitoring
- Coordination of multi-model ensembles for sub-seasonal prediction
- Coordination of multi-model ensembles for seasonal prediction
- Coordination of annual to decadal climate prediction
- Coordination of assessment of multiple climate reanalyses
- Regional severe weather forecasting
- Tropical cyclone forecasting, including marine-related hazards
- Nuclear environmental emergency response
- Non-nuclear environmental emergency response
- Atmospheric sand and dust storm forecasts
- Vegetation fire and smoke pollution forecasts
- Volcano watch services for international air navigation
- Marine meteorological services
- Marine emergency response
- Flash flood forecasting

(c) **Non-real-time coordination activities:**

- Coordination of deterministic NWP verification (DNV)
- Coordination of Ensemble Prediction System (EPS) verification
- Coordination of wave forecast verification (WFV)
- Coordination of tropical cyclone forecast verification (TCFV)
- Coordination of observation monitoring

Notes:

1. It is hoped that other activities, including those related to agriculture, polar regions and space weather, will be developed in future.
2. The WIPPS centres responsible for WIPPS activities such as global numerical sub-seasonal prediction, global numerical seasonal prediction, annual to decadal climate prediction, coordination of multi-model ensembles for sub-seasonal prediction, coordination of multi-model ensembles for seasonal prediction, coordination of annual to decadal climate prediction, global climate reanalysis and regional climate prediction and monitoring enable the Climate Services Information System (CSIS) through a cascading process from global to regional to national levels.

The WMO CSIS is the principal mechanism through which information about climate – past, present and future – is routinely produced, archived, analysed, modelled, exchanged and processed, cascading through global, regional and national levels.

## 1.2 **WMO INTEGRATED PROCESSING AND PREDICTION SYSTEM CENTRES**

### 1.2.1 **Definitions**

1.2.1.1 The meteorological forecasting ranges shall be those defined in Appendix 1.1.

1.2.1.2 WIPPS shall be organized as a three-level system of World Meteorological Centres (WMCs), WIPPS Designated Centres (WIPPS-DCs) and National Meteorological Centres (NMCs), which carry out WIPPS functions at the global, regional and national levels, respectively. These centres are referred to as WIPPS centres.

### 1.2.2 **National Meteorological Centres**

1.2.2.1 An NMC shall carry out functions to meet the national and international requirements of the Member concerned.

Note: To fulfil their national and international obligations, NMCs need to be adequately staffed and equipped to enable them to participate effectively in the World Weather Watch system.

1.2.2.2 The functions of an NMC shall include the preparation of forecasts and warnings at all forecasting ranges necessary to meet the requirements of the Member.

1.2.2.3 Depending on the context, other activities of an NMC should include the production of:

- (a) Special-application products, including climate and environmental quality monitoring and prediction products;
- (b) Non-real-time climate-related products.

### 1.2.3 **WMO Integrated Processing and Prediction System Designated Centres**

1.2.3.1 A Member, having accepted the responsibility for providing a WIPPS-DC, shall arrange for this centre to carry out operationally at least one of the activities listed in 1.1.2.3, for which specified standards are described in Part II.

1.2.3.2 A WIPPS-DC conducting general-purpose activities should provide products that a WIPPS-DC carrying out at least one of the specialized activities considers necessary and makes a request to produce.

1.2.3.3 Defined products of a WIPPS-DC shall be categorized as mandatory products or recommended products, defined as follows:

- (a) **Mandatory products shall be the products that the WIPPS-DC is required to produce and provide in order to fulfil its obligation as a WIPPS-DC. The list of mandatory products shall be defined in the present Manual.**
- (b) **Recommended products shall be the products that, while not mandatory, the WIPPS-DC is strongly encouraged to provide to support other WIPPS-DCs and Members. The list of recommended products shall be defined in the present Manual.**

**1.2.3.4 Products that are necessary for the provision of services in support of the protection of life and property and for the well-being of all nations, and which are classified as “core data”, shall be explicitly labelled as “core data” in the present Manual.**

Notes:

1. A WIPPS-DC can also be referred to as a Regional Specialized Meteorological Centre (RSMC), as appropriate.
2. Designation as a WIPPS-DC does not preclude the use of other names as defined in other contexts, for example, Global Producing Centre for Seasonal Prediction (GPC-SP).
2. A WIPPS-DC that leads a coordination activity is also referred to as a Lead Centre.
4. The definition of core data is described in the WMO Unified Data Policy, [Resolution 1 \(Cg-Ext\(2021\)\)](#).

## **1.2.4 World Meteorological Centres**

**A Member, having accepted the responsibility for providing a WMC, shall arrange for this centre to carry out operationally at least the following activities, for which specified standards are described in Part II:**

- (a) Global deterministic NWP;
- (b) Global ensemble NWP;
- (c) Global numerical seasonal prediction.

## **1.2.5 WMO Integrated Processing and Prediction System Centre Networks**

**1.2.5.1 A WIPPS Centre Network (an association of WIPPS-DCs participating in an identified activity of WIPPS) shall follow the same specifications and adhere to the same criteria and commitments as individual WIPPS-DCs carrying out the same activity.**

**1.2.5.2 Appropriate documentation shall be produced and made available by Members having accepted the responsibility to contribute to the WIPPS Centre Network to distribute the tasks and responsibilities among the participating WIPPS-DCs. A unique focal point shall be designated to answer requests from users of the WIPPS Centre Network products.**

Note: Use of the name “WIPPS Centre Network” does not preclude the use of other names as defined in other contexts, for example, for centres conducting regional climate prediction and monitoring, known as “RCC Networks”.

## **1.2.6 Designation process**

**1.2.6.1 Each Member shall designate an NMC.**

**1.2.6.2 The WMCs, WIPPS-DCs and WIPPS Centre Networks shall be designated by a decision of the World Meteorological Congress or the WMO Executive Council. The designation of such centres shall include the specification of the activity and function (or activities and functions) to be carried out.**

**1.2.6.3 Requests for designation as a WMC or WIPPS-DC shall be put forward by the Permanent Representative of the Member of the candidate centre, or, in the case of international organizations, by either the Permanent Representative of the country where the candidate centre is located or the president of the relevant regional association(s) (RA(s)).**

Note: The Permanent Representative of the Member consults with the Hydrological Adviser with respect to requests for designation as a centre relevant to operational hydrology and its application to water management, as per Regulation 5 of General Regulations, ([Basic Documents No. 1](#) (WMO-No. 15)).

**1.2.6.4 Requests for designation as a WIPPS Centre Network shall be put forward by the president of the relevant RA, or, in the case of networks established across two or more RAs, jointly by their presidents.**

Note: Centres constituting a network will organize themselves as appropriate, depending on their own context and specificities, so as to ensure that the documentation requested as per paragraph 1.2.5.2 is available.

**1.2.6.5 Requests for designation shall be addressed to the WMO Secretariat, which will forward them to the relevant constituent bodies as indicated in Tables 2–33 in Part II of the present Manual. Supporting information demonstrating compliance with designation criteria shall be included with the request.**

1.2.6.6 Depending on the type of activity, endorsement by the RA(s) and technical commission(s) should be required before designation by the World Meteorological Congress or WMO Executive Council.

### **1.3 COORDINATION WITH OTHER SYSTEMS OR PROGRAMMES**

**WIPPS shall support all WMO Programmes and related programmes of other international organizations in accordance with decisions of the Organization.**

Notes:

1. In many cases the activities undertaken by WIPPS centres constitute the operational component of a system developed under another structure or programme, either by WMO on its own or jointly with other international organizations. In such cases the regulations pertaining to these activities cover both:
    - (a) The specific requirements defined by the relevant structure;
    - (b) The general WIPPS criteria regarding operational quality and reliability, verification, documentation and compliance (described in Part II of the present Manual).
  2. Coordination mechanisms appropriate for the context and characteristics of the various categories of activity are specified in Part II.
-

## APPENDIX 1.1. DEFINITIONS OF METEOROLOGICAL FORECASTING RANGES

1.	Nowcasting	A description of current weather parameters and of forecasted weather parameters 0 to 2 hours ahead
2.	Very short-range weather forecasting	A description of weather parameters up to 12 hours ahead
3.	Short-range weather forecasting	A description of weather parameters from 12 to 72 hours ahead
4.	Medium-range weather forecasting	A description of weather parameters from 72 to 240 hours ahead
5.	Extended-range weather forecasting	A description of weather parameters from 10 to 30 days ahead, usually averaged and expressed as a departure from climate values for that period
6.	Long-range forecasting	From 30 days up to two years
6.1	Monthly outlook	Description of averaged weather parameters expressed as a departure (deviation, variation, anomaly) from climate values for that month (not necessarily the coming month)
6.2	Three-month or 90-day outlook	Description of averaged weather parameters expressed as a departure from climate values for that 90-day period (not necessarily the coming 90-day period)
6.3	Seasonal outlook	Description of averaged weather parameters expressed as a departure from climate values for that season
Notes:		
1. In some countries, seasonal predictions (SPs) are considered to be climate products.		
2. "Season" has been loosely defined as December/January/February = Winter; March/April/May = Spring; etc., in the northern hemisphere. In tropical areas, seasons may have different durations. Outlooks spanning several months, such as multi-seasonal or tropical rainy season outlooks, may be provided.		
7.	Climate forecasting	Beyond two years
7.1	Annual to decadal climate prediction	Description of the expected climate parameters associated with the variation of interannual, decadal and multi-decadal climate anomalies
7.2	Climate prediction	Description of expected future climate including the effects of both natural and human influences

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## **PART II. SPECIFICATIONS OF WMO INTEGRATED PROCESSING AND PREDICTION SYSTEM ACTIVITIES**

### **2.1 OVERALL REQUIREMENTS AND STANDARDS**

#### **2.1.1 Quality control of incoming observations**

**2.1.1.1 World Meteorological Centres and RSMCs shall identify the observational requirements to conduct all functions of their own activities and express them through the corresponding application areas of the Rolling Review of Requirements.**

Note: Details of the WMO Rolling Review of Requirements are described in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), Appendix 2.3.

**2.1.1.2 World Meteorological Centres and RSMCs shall apply quality control to the incoming observations they use for WIPPS purposes. The objectives of the WIPPS quality control shall be:**

- (a) To ensure the best possible quality of the observations that are used in the real-time operations of WIPPS;**
- (b) In non-real time, to protect and improve the quality and integrity of observations destined for storage and retrieval within WIPPS;**
- (c) To provide the basis for feedback of information on errors and questionable observations to the source of the data.**

Note: The minimum standards for quality control of observations include quality control at various stages of processing. They apply to both real-time and non-real-time processing and lead to various records of quality control actions and relevant metadata.

**2.1.1.3 Quality control processes implemented in WIPPS should adhere to the WMO Integrated Global Observing System (WIGOS) quality assurance and quality control standards.**

Note: Details of the WIGOS quality assurance and quality control standards are described in the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), 2.4.3.

**2.1.1.4 The WIPPS centres with global, hemispheric or near-hemispheric models should monitor the quality of one or more of the main types of observations using techniques such as those listed in Appendix 2.1.1. Statistics should be compiled separately for each land station by station index number, for each ship or aircraft by call sign, for each buoy by identifier, for each satellite by identifier, and also for various geographic areas and levels in the atmosphere.**

**2.1.1.5 The WIPPS centres should analyse the results and produce, in an agreed format, lists of observations believed to be consistently of low quality, together with information on which element of the observation (pressure, temperature, and the like) is thought to be of low quality and the evidence for considering it as such. These lists should be based on data received over one month and should be exchanged monthly between participating centres. Standard procedures and formats for the exchange of monitoring results are given in Appendix 2.1.2.**

Note: Lead Centres, described in 2.2.3, play an essential role in resolving and minimizing recurrence of deficiencies reported by WIPPS centres.

## 2.1.2 **Data collection and product dissemination**

2.1.2.1 **WIPPS centres shall be connected to the WMO Information System (WIS) to ensure suitable exchange of information with other centres.**

2.1.2.2 **World Meteorological Centres and RSMCs shall describe their required products and services according to WMO metadata standards and make them available to other WIPPS centres through WIS in a timely manner for operational use.**

Note: Details on metadata standards are described in the *Manual on the WMO Information System* (WMO-No. 1060).

## 2.1.3 **Long-term storage of data and products**

Note: The non-real-time functions of WIPPS include long-term (that is, around 10 years) storage of observations, products and verification results for operational and research use.

2.1.3.1 **World Meteorological Centres and RSMCs shall operate an archiving and retrieval system to serve the needs of their continual improvement process; this process shall include the non-real-time assessment of their products and the ability to perform re-runs of their operational production.**

2.1.3.2 Members should ensure that their NMCs archive and retrieve appropriate data originating from their national observing networks and facilities.

## 2.1.4 **Product verification and the performance of WMO Integrated Processing and Prediction centres**

2.1.4.1 **The accuracy of forecast products provided by WMCs and RSMCs shall be monitored by objective verification procedures.**

Notes:

1. The goal of the objective verification procedures is to provide consistent standardized verification of the forecast products of WMCs and RSMCs so that users can make best use of these products and so that opportunities for improvement are identified.
2. Detailed procedures for the production and display of a standard set of verification scores are provided in Appendix 2.2.33. A mandatory set will be provided by participating centres. Centres should also provide, if possible, additional statistics as recommended in Appendix 2.2.33.

2.1.4.2 **The Lead Centre(s) for verification shall play an essential role in the coordination of verification and have responsibility for maintaining websites containing verification results and relevant guidance (see 2.2.3), ensuring that users benefit from a consistent presentation of the results.**

2.1.4.3 WIPPS centres receiving RSMC products via WIS should carry out verification over appropriate areas using the standardized measures listed in Appendices 2.2.33 to 2.2.37 and make these results available to the producing RSMCs.

## 2.1.5 **Documentation on system and products**

2.1.5.1 **World Meteorological Centres and RSMCs shall make available, on a publicly accessible website, documentation on the technical characteristics of their operational systems and on the products they deliver. RSMCs shall ensure that the information provided is kept current by updating it as required after every significant change to their operational systems. The mandatory (minimum) information to be provided shall be specified for every activity separately in section 2.2.**

**2.1.5.2 Documentation shall use the International System of Units (SI units). If other units are used, conversion equations shall be included.**

Note: Addresses of WMC and RSMC websites containing such system documentation are given in Part III of the present Manual [in development].

**2.1.6 Training**

**2.1.6.1 World Meteorological Centres and RSMCs shall provide guidance, including training materials, on the interpretation, performance characteristics, strengths and limitations of their products. They shall ensure that this information is kept current by updating it after every significant change to their operational system.**

2.1.6.2 It is possible that WMCs and RSMCs are requested to contribute to specific training activities in support of capacity development and related activities. Products used in such training activities should subsequently be available to users in their own operational working environments.

**2.1.7 Reporting on compliance**

**2.1.7.1 World Meteorological Centres and RSMCs shall provide information about the current implementation of their system.**

Note: This information should be available on the same website as that used for providing system and product documentation and described in section 2.1.5.

**2.1.7.2 World Meteorological Centres and RSMCs shall report non-compliance between the mandatory minimum specifications and their actual implementation to the WMO Secretariat and make corresponding information available on a website. When this non-compliance is reported to Congress or the Executive Council, it shall reconsider the designation.**

**2.1.8 Graphical representation of observations, analyses and forecasts**

**2.1.8.1 World Meteorological Centres and RSMCs that have a mandate of chart-based analysis shall maintain standardized weather forecasting processes, including graphical representation of observations, analyses and forecasts.**

**2.1.8.2 *Standard sets of graphical representation***

2.1.8.2.1 The standard set of symbols and styles should be used in graphical representations of observations and analyses. This may also be used for presentation of forecasts.

Note: The set of symbols and styles is given in the *Manual on Codes* (WMO-No. 306), Volume I.1, Attachment IV.

2.1.8.2.2 All colour scales for colour maps should be properly defined to avoid misinterpretation by any category of users, and they should be standardized whenever possible.

**2.1.8.3 *Analysis and forecasting practices***

**2.1.8.3.1 Reference surfaces for upper-air analysis**

2.1.8.3.1.1 The principal type of reference surface for representing and analysing the conditions in the free atmosphere over large areas shall be isobaric.

2.1.8.3.1.2 **The standard isobaric surfaces for representing and analysing the conditions in the lower atmosphere shall be the 1 000, 850, 700, 500, 400, 300, 250, 200, 150 and 100 hPa surfaces.**

2.1.8.3.1.3 The standard isobaric surfaces for representing and analysing the conditions in the atmosphere above 100 hPa should be the 70, 50, 30, 20 and 10 hPa surfaces.

#### 2.1.8.3.2 **Preparation of upper-air charts**

WIPPS centres should either prepare or have available upper-air charts for at least four of the six following standard isobaric surfaces: 850, 700, 500, 300, 250 and 200 hPa.

#### 2.1.8.3.3 **Weather forecasting**

Note: The weather forecasting process includes analysis, prognoses and interpretation of state and forecasts of weather parameters at the surface and/or in the free atmosphere for short, medium, extended and long ranges for purposes according to the obligations of WIPPS centres and their networks and as agreed by RAs.

#### 2.1.8.4 ***Practices for pictorial representation of information on meteorological charts and diagrams***

##### 2.1.8.4.1 **Scales and projections of meteorological charts**

2.1.8.4.1.1 The following projections, as appropriate, should be used for weather charts:

- (a) The stereographic projection on a plane cutting the sphere at the standard parallel of latitude 60°;
- (b) Lambert's conformal conic projection, the cone cutting the sphere at the standard parallels of latitude 10° and 40° or 30° and 60°;
- (c) Mercator's projection with true-scale standard parallel of latitude 22.5°.

2.1.8.4.1.2 The scales along the standard parallels should be as follows for weather charts:

(a) Covering the world:	1 : 40 000 000	Alternative:	1 : 60 000 000
(b) Covering a hemisphere:	1 : 40 000 000	Alternatives:	1 : 30 000 000 1 : 60 000 000
(c) Covering a large part of a hemisphere or hemispheres:	1 : 20 000 000	Alternatives:	1 : 25 000 000 1 : 30 000 000 1 : 40 000 000
(d) Covering a portion of a continent or an ocean, or both:	1 : 10 000 000	Alternatives:	1 : 25 000 000 1 : 20 000 000 1 : 15 000 000 1 : 7 500 000

2.1.8.4.1.3 The name of the projection, the scale at the standard parallels and the scales for other latitudes should be indicated on every weather chart.

##### 2.1.8.4.2 **Symbols used on meteorological charts**

2.1.8.4.2.1 A standard set of symbols and models should be used for plotting data on meteorological charts.

2.1.8.4.2.2 A standard set of symbols should be used for representing analyses and forecasts on meteorological charts.

Note: The symbols used for the pictorial representation of observational data, analyses and forecasts on meteorological charts are those given in the *Manual on Codes* (WMO-No. 306), Volume I.1, Attachment IV.

#### 2.1.8.4.3 Construction of aerological diagrams

2.1.8.4.3.1 Diagrams used for representation and analysis of upper-air observations of pressure, temperature and humidity should:

- (a) Be constructed on the basis of:
  - (i) The values of the physical constants and parameters given in *Technical Regulations* (WMO-No. 49), Volume I, Part III;
  - (ii) The assumption of ideal gas properties, except for the values of both saturation vapour pressure and heats of transformation of phases of water, at specific temperatures;
- (b) Bear a legend stating the principles used in their construction.

2.1.8.4.3.2 Diagrams used for the accurate computation of geopotential from upper-air observations of pressure, temperature and humidity should possess the following features:

- (a) Equal-area transformation of pressure–volume diagrams;
- (b) Straight and parallel isobars;
- (c) A scale such that the errors involved in computation are significantly smaller than those arising from instrumental errors.

#### 2.1.8.4.4 Preparation of charts and diagrams for facsimile transmission

##### 2.1.8.4.4.1 Preparation of charts

When preparing charts for facsimile transmission, the following basic considerations in the preparation of the original copy should be followed:

- (a) The minimum line thickness should be sufficiently large to ensure clear reproduction;
- (b) Lines that are required to be reproduced uniformly should be of uniform width and intensity;
- (c) The minimum separations of detail in letters, figures, symbols, and the like, should be sufficient to avoid the filling in of spaces in the reproduction;
- (d) Letters, figures, symbols, and the like, should be drawn as simply as possible;
- (e) Models employed in plotting should be as simple as possible.

##### 2.1.8.4.4.2 Standardization of maps for facsimile transmission

The standard projections and scales in 2.1.8.4.1.1 and 2.1.8.4.1.2 should also apply to documents prepared for facsimile transmission.

#### 2.1.8.4.4.3 *Colours and features*

2.1.8.4.4.3.1 Since the reproduced chart or diagram may show little, if any, colour differentiation between the different elements plotted on the original copy, the original should be prepared either using a monochromatic system or, if a polychromatic system is employed, in such a way that the reproduction conforms to a monochromatic system. For example, on the original copy fronts should be entered in their appropriate colours, providing the symbols used to draw the fronts conform to the frontal symbols of the monochromatic system given in the *Manual on Codes* (WMO-No. 306), Volume I.1, Attachment IV.

2.1.8.4.4.3.2 Synoptic weather maps and charts prepared for transmission by facsimile should include the following features:

- (a) Geographical outlines of minimum detail necessary for orientation purposes with coastlines interrupted where station data are to be plotted;
- (b) Selected meridians and parallels printed in double thickness (bold face) for orientation purposes;
- (c) Map references required only for convenience in the entering of data; for example, index numbers, 1° intersections of latitude and longitude, and station circles, to be printed in non-photo blue;
- (d) Letters and figures of a size compatible with resolution characteristics of the transmission system(s) over which the charts are to be transmitted.

#### 2.1.8.4.4.4 *Legend*

All charts and diagrams transmitted by facsimile should bear a bold legend including:

- (a) The type of chart or diagram;
- (b) The date and time to which the data refer or, in the case of forecast charts, the time to which the forecast applies;
- (c) An explanation of the plotted symbols or isopleths if these are not obvious from the style of the chart.

Note: Minimum requirements for identification of charts transmitted in pictorial form are also given in the [Manual on the Global Telecommunication System](#) (WMO-No. 386), Part II, 3.1.

#### 2.1.8.4.4.5 *Plotted data*

Entries on the original copy should conform to the basic principles outlined in the *Manual on Codes* (WMO-No. 306), Volume I.1, Attachment IV.

#### 2.1.8.4.4.6 *Analysed data*

Isopleths, frontal symbols, areas of precipitation, and the like, should be entered, as appropriate, in the manner laid down in the *Manual on Codes* (WMO-No. 306), Volume I.1, Attachment IV. Care should be taken not to obliterate one set of plotted data by another.

## 2.2 SPECIFICATION OF ACTIVITIES AND PROCEDURES FOR INTRODUCING MODIFICATIONS

### 2.2.1 General-purpose activities

#### 2.2.1.1 *Global deterministic numerical weather prediction*

Centres conducting global deterministic NWP shall:

- (a) Produce global analyses of the three-dimensional structure of the atmosphere;
- (b) Produce global forecast fields of basic and derived atmospheric parameters;
- (c) Make available on WIS a range of these products; the list of mandatory products (considered as core data) and recommended products to be made available is given in Appendix 2.2.1;
- (d) Produce verification statistics according to the standard defined in Appendix 2.2.33, and make them available to the Lead Centre(s) for DNV;
- (e) Make available on a website up-to-date information on the characteristics of their global NWP systems. The minimum information to be provided is given in Appendix 2.2.2.

Note: The bodies in charge of managing the information contained in the present Manual related to global deterministic NWP are specified in Table 2.

**Table 2. WMO bodies responsible for managing information related to global deterministic NWP**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OWFS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	INFCOM	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OWFS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.1.2 *Limited-area deterministic numerical weather prediction*

Centres conducting limited-area deterministic NWP shall:

- (a) Produce limited-area analyses of the three-dimensional structure of the atmosphere;
- (b) Produce limited-area forecast fields of basic and derived atmospheric parameters;
- (c) Make available on WIS a range of these products; the list of mandatory products (considered as core data) and recommended limited-area deterministic NWP products to be made available, including metadata, is given in Appendix 2.2.3;

- (d) Produce verification statistics according to the standard defined in Appendix 2.2.33, adapted for the region covered by the model, at an appropriate resolution, and make available consistent up-to-date graphical displays of the verification results on a website;
- (e) Make available on a website up-to-date information on the characteristics of their limited-area NWP systems; the minimum information to be provided is given in Appendix 2.2.4.

Note: The bodies in charge of managing the information contained in the present Manual related to limited-area deterministic NWP are specified in Table 3.

**Table 3. WMO bodies responsible for managing information related to limited-area deterministic NWP**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OWFS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	INFCOM	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OWFS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.1.3 **Global ensemble numerical weather prediction**

Centres conducting global ensemble NWP shall:

- (a) Produce global ensemble forecast fields of basic and derived atmospheric parameters;
- (b) Make available on WIS a range of these products; the list of mandatory products (considered as core data) and recommended products to be made available is given in Appendix 2.2.5;
- (c) Make verification statistics available to the Lead Centre(s) for EPS verification according to the standard defined in Appendix 2.2.34;
- (d) Make available on a website up-to-date information on the characteristics of their global EPS; the minimum information to be provided is given in Appendix 2.2.6.

Note: The bodies in charge of managing the information contained in the present Manual related to global ensemble NWP are specified in Table 4.

**Table 4. WMO bodies responsible for managing information related to global ensemble NWP**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OWFS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			

To be recommended by:	RA	INFCOM	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OWFS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.1.4 **Limited-area ensemble numerical weather prediction**

Centres conducting limited-area ensemble NWP shall:

- (a) Produce limited-area ensemble forecast fields of basic and derived atmospheric parameters;
- (b) Make available on WIS a range of these products; the list of mandatory products (considered as core data) and recommended limited-area ensemble NWP products to be made available is given in Appendix 2.2.7;
- (c) Produce verification statistics according to the standard defined in Appendix 2.2.34, adapted for the region covered by the model, and make available consistent up-to-date graphical displays of the verification results on a website;
- (d) Make available on a website up-to-date information on the characteristics of their limited-area EPS; the minimum information to be provided is given in Appendix 2.2.8.

Note: The bodies in charge of managing the information contained in the present Manual related to limited-area ensemble NWP are specified in Table 5.

**Table 5. WMO bodies responsible for managing information related to limited-area ensemble NWP**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OWFS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	INFCOM	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OWFS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.1.5 **Global numerical sub-seasonal prediction**

2.2.1.5.1 Centres conducting global numerical sub-seasonal prediction (GPCs for sub-seasonal prediction (GPCs-SSP)) shall:

Note: Functions are defined for the sub-seasonal (10 days–4 weeks) prediction activity.

- (a) With at least weekly frequency, generate SSP products with global coverage;
- (b) Make available on WIS the graphical mandatory products (considered as core data) listed in Appendix 2.2.40;

- (c) Provide digital mandatory products (as defined in Appendix 2.2.42, section 1) to the Lead Centre(s) for sub-seasonal prediction multi-model ensembles (SSPMME) no more than two days behind real time;
- (d) Make available on a website up-to-date information on the characteristics of their global numerical SSP systems; the minimum information to be provided is given in Appendix 2.2.41.

2.2.1.5.2 In addition to the mandatory functions above, GPCs-SSP should:

- (a) Make available on WIS the recommended products listed in Appendix 2.2.40;
- (b) Provide digital recommended products to the Lead Centre(s) for SSPMME, as detailed in Appendix 2.2.42, section 1.

Note: The bodies in charge of managing the information contained in the present Manual related to global numerical SSP are specified in Table 6.

**Table 6. WMO bodies responsible for managing information related to global numerical SSP**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OCPS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	INFCOM	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OCPS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

Acronym not previously defined: ET-OCPS – Expert Team on Operational Climate Prediction System

### 2.2.1.6 **Global numerical seasonal prediction**

#### 2.2.1.6.1 Centres conducting global numerical seasonal prediction (GPCs for seasonal prediction (GPCs-SP)) shall:

Note: Functions are defined for the seasonal (1 to 6-month) prediction activity.

- (a) With at least monthly frequency, generate SP products with global coverage;
- (b) Make available on WIS the graphical mandatory products (considered as core data) listed in Appendix 2.2.9;
- (c) Make available on a website up-to-date information on the characteristics of their global seasonal numerical prediction systems; the minimum information to be provided is given in Appendix 2.2.10.
- (d) Provide digital mandatory products to the Lead Centre(s) for SP multi-model ensembles (Lead Centre(s) for SPMME), as detailed in Appendix 2.2.17, section 1.

2.2.1.6.2 In addition to the mandatory activities above, GPCs-SP should:

- (a) Make available on WIS the recommended products listed in Appendix 2.2.9;

- (b) Provide recommended digital products to the Lead Centre(s) for SPMME, as detailed in Appendix 2.2.17, section 1.

Notes:

1. A candidate considered for designation as a GPC-SP is required to produce hindcast verification statistics according to the standard defined in Appendix 2.2.35 and make them available on the candidate's website.
2. It is recommended that the hindcast should cover the years 1993–2016 at the minimum.
3. The bodies in charge of managing the information contained in the present Manual related to global numerical seasonal prediction are specified in Table 7.

**Table 7. WMO bodies responsible for managing information related to global numerical seasonal prediction**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OCPS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	INFCOM	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OCPS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.1.7 **Annual to decadal climate prediction**

Centres conducting annual to decadal climate prediction (GPCs for annual to decadal climate prediction (GPCs-ADCP)) shall:

- (a) Prepare, with at least annual frequency, global forecast fields of variables relevant to ADCP;
- (b) Prepare verification statistics as defined in Appendix 2.2.20;
- (c) Provide an agreed set of forecast and hindcast variables (as defined in Appendix 2.2.19) to the Lead Centre(s) for ADCP;
- (d) Make available on a website up-to-date information on the characteristics of their global decadal prediction systems.

Notes:

1. Non-designated centres with capacity to provide the minimum requirement may also contribute ADCP to the Lead Centre(s) for ADCP;
2. Centres who wish to make available their products worldwide may use WIS as a dissemination platform;
3. The bodies in charge of managing the information contained in the present Manual related to coordination of ADCP are specified in Table 8.

**Table 8. WMO bodies responsible for managing information related to ADCP**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OCPS	
To be recommended by:	INFCOM		

<i>Responsibility</i>			
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OCPS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

### 2.2.1.8 **Global climate reanalysis**

#### 2.2.1.8.1 Centres conducting global climate reanalysis (GCR) shall:

- (a) Produce global climate reanalyses for the surface, near surface and throughout the atmosphere;
- (b) Update all reanalysis products listed in Appendix 2.2.54 to include the previous month within 60 days of the end of the current month;
- (c) Ensure that all products cover at least the most recent WMO climatological reference period;
- (d) Make available on their website the digital mandatory products (considered as core data) listed in Appendix 2.2.54;
- (e) Make available on their website up-to-date information on the characteristics of their global climate reanalysis systems. The minimum information to be provided is given in Appendix 2.2.55.

#### 2.2.1.8.2 In addition to the mandatory functions above, Centres conducting GCR should:

- (a) Make available on their websites the graphic and digital recommended products listed in Appendix 2.2.54;
- (b) Produce their digital mandatory and recommended products in one of the following formats: GRIB1, GRIB2, NetCDF or HDF.

#### Notes:

1. The requirement for users to be registered and/or to accept terms and conditions before retrieving the data does not affect the open and free status of the data.
2. For the purpose of the present Manual, climate reanalysis is defined as the output of a prediction model which makes use of observational data to reconstruct past weather and climate in a way that strives to maximize temporal consistency.
3. The bodies in charge of managing the information contained in the present Manual related to global climate reanalysis are specified in Table 9.

**Table 9. WMO bodies responsible for managing information related to global climate reanalysis**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OCPS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			

<i>Responsibility</i>			
To be recommended by:	INFCOM	RA	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OCPS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.1.9 **Numerical ocean wave prediction**

Centres conducting numerical ocean wave prediction shall:

- (a) Prepare global analyses of ocean wave parameters;
- (b) Prepare global forecast fields of basic and derived ocean wave parameters;
- (c) Make available on WIS a range of these products; the list of mandatory and recommended products to be made available is given in Appendix 2.2.11;
- (d) Prepare verification data and make them available to the Lead Centre(s) for WFV;
- (e) Make available on a website up-to-date information on the characteristics of their global numerical ocean wave prediction systems; the minimum information to be provided is given in Appendix 2.2.12.

Note: The bodies in charge of managing the information contained in the present Manual related to numerical ocean wave prediction are specified in Table 10.

**Table 10. WMO bodies responsible for managing information related to numerical ocean wave prediction**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	SERCOM/SC-MMO	
To be recommended by:	INFCOM	SERCOM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	INFCOM	SERCOM
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SERCOM/SC-MMO		
To be reported to:	INFCOM	SERCOM	

Acronym not previously defined: SC-MMO – Standing Committee on Marine Meteorological and Oceanographic Services

#### 2.2.1.10 **Global numerical ocean prediction**

Centres conducting global numerical ocean prediction shall:

- (a) Prepare global analyses of oceanographic variables;
- (b) Prepare global forecast fields of basic and derived oceanographic variables;
- (c) Make available on WIS a range of these products; the list of mandatory and recommended products to be made available is given in Appendix 2.2.13;

- (d) Prepare verification statistics and make them available on a website;
- (e) Make available on a website up-to-date information on the characteristics of their global numerical ocean prediction systems; the minimum information to be provided is given in Appendix 2.2.14.

Note: The bodies in charge of managing the information contained in the present Manual related to global numerical ocean prediction are specified in Table 11.

**Table 11. WMO bodies responsible for managing information related to global numerical ocean prediction**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	SERCOM/SC-MMO	
To be recommended by:	INFCOM	SERCOM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	INFCOM	SERCOM
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SERCOM/SC-MMO		
To be reported to:	INFCOM	SERCOM	

#### 2.2.1.11 **Global numerical storm surge prediction**

Centres conducting global numerical storm surge prediction shall:

- (a) Prepare, as available, global analyses or pseudo analyses of the initial condition of variables contributing to ocean total water level;
- (b) Prepare global forecast fields of basic and derived variables contributing to ocean total water level;
- (c) Make available on WIS a range of these products; the list of mandatory and recommended products to be made available is given in Appendix 2.2.56;
- (d) Prepare verification statistics and make them available on a website;
- (e) Make available on a website up-to-date information on the characteristics of their global numerical storm surge prediction systems; the minimum information to be provided is given in Appendix 2.2.57.

Note: The bodies in charge of managing the information contained in the present Manual related to global numerical storm surge prediction are specified in Table 12.

**Table 12. WMO bodies responsible for managing information related to global numerical storm surge prediction**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	SERCOM/SC-MMO	
To be recommended by:	INFCOM	SERCOM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			

To be recommended by:	RA	INFCOM	SERCOM
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SERCOM/SC-MMO		
To be reported to:	INFCOM	SERCOM	

#### 2.2.1.12 **Nowcasting**

Centres conducting nowcasting shall:

- (a) Operate a system, including a web-based or generic graphical service, describing in real time or near-real time the current state of the weather in detail and the prediction of its changes for several hours ahead over their area of interest or parts of that area;
- (b) Provide access to this service to National Meteorological and Hydrological Services (NMHSs) whose operational warning services may benefit from it;
- (c) Prepare verification statistics and evaluations of the system;
- (d) Make available on a website up-to-date information on the characteristics of their systems; the minimum information to be provided is given in Appendix 2.2.15.

Note: The bodies in charge of managing the information contained in the present Manual related to nowcasting are specified in Table 13.

**Table 13. WMO bodies responsible for managing information related to nowcasting**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OWFS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	INFCOM	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OWFS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.1.13 **Sub-seasonal to seasonal hydrological prediction**

Centres conducting sub-seasonal to seasonal (S2S) hydrological prediction (Regional Specialized Hydrological Centres (RSHC) conducting S2S hydrological prediction) shall:

- (a) Produce ensemble forecast fields of basic and/or derived hydrological variables;
- (b) Provide forecast data and products to NMHSs at spatial and temporal resolutions that are scientifically and technically appropriate given S2S predictability considerations;
- (c) Produce, where applicable, related forecast information products including categorical probability forecasts (such as tercile forecasts comprising probabilities of above normal, normal and below normal conditions) relative to a reference climatology, in the form of maps, charts and tables;

- (d) Make available on WIS, in a manner agreed on with Members, a range of these products; the list of mandatory and recommended S2S ensemble hydrological products to be made available is given in Appendix 2.2.45;
- (e) To the extent possible, make verification statistics available according to the standards defined in Appendix 2.2.46;
- (f) Make available online up-to-date supporting information on the characteristics of their global S2S ensemble hydrological prediction system, including key datasets and model versions, a summary description of important ancillary methods (such as data assimilation and post-processing), and key references and contacts; the minimum information to be provided is given in Appendix 2.2.47.

Note: The bodies in charge of managing the information contained in the present Manual related to S2S hydrological prediction are specified in Table 14.

**Table 14. WMO bodies responsible for managing information related to S2S hydrological prediction**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	SERCOM/SC-HYD	
To be recommended by:	INFCOM	SERCOM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	SERCOM	INFCOM
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SERCOM/SC-HYD		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	SERCOM

Acronym not previously defined: SC-HYD – Standing Committee on Hydrological Services

#### 2.2.1.14 ***Snow cover prediction***

Centres conducting snow cover prediction (Regional Specialized Hydrological Centres (RSHCs) conducting snow cover prediction) shall:

- (a) Prepare analyses of snow cover parameters over land surfaces at the regional scale;
- (b) Make available on WIS the mandatory products listed in Appendix 2.2.48;
- (c) Produce verification statistics according to the standard defined in Appendix 2.2.49, and make them available on their website;
- (d) Make available on a website up-to-date information on the characteristics of their snow cover prediction systems; the minimum information to be provided is given in Appendix 2.2.50.

In addition to the mandatory activities above, the Centres should:

- (a) Prepare forecasts of snow cover parameters over land surfaces;
- (b) Make available on WIS a range of recommended products listed in Appendix 2.2.48;
- (c) Produce verification statistics according to the standard defined in Appendix 2.2.49, and make them available on their website.

Note: The bodies in charge of managing the information contained in the present Manual related to snow cover prediction are specified in Table 15.

**Table 15. WMO bodies responsible for managing information related to snow cover prediction**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	SERCOM/SC-HYD	
To be recommended by:	INFCOM	SERCOM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	SERCOM	INFCOM
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SERCOM/SC-HYD		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	SERCOM

## 2.2.2 Specialized activities

### 2.2.2.1 Regional climate prediction and monitoring

Centres conducting regional climate prediction and monitoring (RCCs) shall:

- (a) Conduct operational activities for seasonal prediction, both dynamical and statistical, within the range of a one-month to two-year timescale, based on regional needs:
  - Interpret and assess relevant SP products from GPCs-SP; make use of the products from the Lead Centre(s) for SPMME (refer to 2.2.2.3); distribute relevant information to users and provide feedback to GPCs-SP (refer to guidelines given in Attachment 2.2.2);
  - Generate regional and subregional tailored products relevant to user needs, including seasonal outlooks;
  - Generate “consensus” statements on forecasts;
  - Generate and display forecast verification;
  - Provide online access to products and services;
  - Assess use of products and services through feedback from users;
- (b) Conduct operational activities for climate monitoring:
  - Perform climate diagnostics including analyses of climate variability and extremes, at the regional and subregional scales;
  - Establish a historical reference climatology for the region and/or subregions;
  - Implement a regional climate watch;
- (c) Provide operational data services, to support operational seasonal prediction and climate monitoring:
  - Develop quality-controlled regional climate datasets, gridded where applicable;
  - Provide climate database and archiving services;
- (d) Provide training in the use of operational RCC products and services:
  - Provide information on methodologies and product specifications for mandatory RCC products, and provide guidance on their use;
  - Coordinate training for RCC users in interpretation and use of mandatory RCC products.

## Notes:

1. Recipients of RCC products and services will be NMHSs, other RCCs and international institutes recognized by the RA, and will be referred to as RCC users.
2. Details on RCC functions are provided in Appendix 2.2.16. Additional requirements for RCC functions may vary in detail from region to region. A list of recommended, but not mandatory, RCC functions is given in Attachment 2.2.1.
3. The bodies in charge of managing the information contained in the present Manual related to regional climate prediction and monitoring are specified in Table 16.

**Table 16. WMO bodies responsible for managing information related to regional climate prediction and monitoring**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	SERCOM/ET-CIDS	
To be recommended by:	INFCOM	SERCOM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	INFCOM	SERCOM
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SERCOM/ET-CIDS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

Acronym not previously defined: ET-CIDS – Expert Team on Climate Services Information System and Climate Information for Decision Support

#### 2.2.2.2 **Coordination of multi-model ensembles for sub-seasonal prediction**

Centre(s) coordinating SSP multi-model ensembles (Lead Centre(s) for SSPMME) shall:

- (a) Select a group of modelling centres (referred to as “contributing centres”, which also includes the designated GPC-SSP) that meet the GPC-SSP designation criteria and have been approved by ET-OCPS, to contribute to the Lead Centre(s) for SSPMME; and manage changes in the membership of the group, as and when they occur, to maintain sufficient contributions;
- (b) Maintain a list of the active contributing centres and the specifications of their prediction systems;
- (c) Collect an agreed set of digital products listed in Appendix 2.2.42, section 1, from contributing centres;
- (d) Make available on a website of the Lead Centre(s) for SSPMME the graphical products listed in Appendix 2.2.42;
- (e) Redistribute contributing centre digital products listed in Appendix 2.2.42 for those contributing centres that allow it, as described in Appendix 2.2.43;
- (f) Maintain an archive of real-time and hindcast digital products from the contributing centres, which is used to construct the LC graphical products listed in Appendix 2.2.42;
- (g) Maintain a repository of documentation for the system configuration of all contributing centre systems;
- (h) Verify the products using the Standardized Verification System for SSP (SVSSSP) approach in Appendix 2.2.44;

- (i) **Based on a comparison of different models, provide feedback to contributing centres about model performance and make the verification results available on the LC-SSPMME website;**
- (j) **Promote research and expertise in multi-model ensemble techniques and provide guidance and support on multi-model ensemble techniques to contributing centres, RCCs and NMHSs.**

Notes:

1. The website is provided exclusively for the outputs of the specified Lead Centre functions in support of climate services and is to be clearly distinguishable from other types of services.
2. LC-SSPMME will consult contributing centres on which forecast initial conditions to use in the development of real-time products. This will ensure consistency between contributing centres and LC-SSPMME methodologies.
3. The bodies in charge of managing the information contained in the present Manual related to coordination of multi-model ensembles for SSP are specified in Table 17.

**Table 17. WMO bodies responsible for managing information related to multi-model ensembles for SSP**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OCPS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OCPS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.2.3 **Coordination of multi-model ensembles for seasonal prediction**

Centre(s) coordinating SP multi-model ensembles (Lead Centre(s) for SPMME) shall:

- (a) **Collect an agreed set of digital products listed in Appendix 2.2.17, section 1, from GPCs-SP under activity 2.2.1.6;**
- (b) **Make available on a website of the Lead Centre(s) for SPMME the graphical products listed in Appendix 2.2.17;**
- (c) **Redistribute the GPCs-SP digital products listed in Appendix 2.2.17 ;**
- (d) **Maintain an archive of the GPCs-SP digital products and multi-model ensemble products used for graphical products listed in Appendix 2.2.17;**
- (e) **Maintain a repository of documentation for the system configuration of all GPCs-SP systems;**
- (f) **Verify the products using the Standardized Verification System for SP (SVSSP) (Appendix 2.2.35);**
- (g) **Based on comparison among different models, provide feedback to GPCs-SP about model performance and make the verification results available on the LC-SPMME's website;**

- (h) **Promote research and experience in multi-model ensemble techniques and provide guidance and support on multi-model ensemble techniques to GPCs-SP, RCCs and NMHSs;**
- (i) **Prepare and make available monthly updates of the Global Seasonal Climate Update (GSCU) and maintain its archive on the LC-SPMME's website.**

Notes:

1. The requirement for users to be registered and/or accept terms and conditions before retrieving the data does not affect the open and free status of the data.
2. The GSCU, issued quarterly, summarizes the current status (monitoring) and the expected future behaviour (prediction) of the global seasonal climate. It focuses on the major general circulation features and large-scale oceanic anomalies around the globe (such as the El Niño/Southern Oscillation, North Atlantic Oscillation, Indian Ocean Dipole and so forth) and their potential impacts on worldwide surface temperature and precipitation patterns.
3. The bodies in charge of managing the information contained in the present Manual related to coordination of multi-model ensembles for SP are specified in Table 18.

**Table 18. WMO bodies responsible for managing information related to multi-model ensembles for SP**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OCPS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OCPS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.2.4 **Coordination of annual to decadal climate prediction**

2.2.2.4.1 The centre(s) conducting coordination of ADCP (Lead Centre(s) for ADCP) shall:

- (a) **Select a group of modelling centres to contribute to the Lead Centre(s) for ADCP (the "contributing centres") that meet the GPC-ADCP designation criteria and have been approved by ET-OCPS; and manage changes in the membership of the group, as and when they occur, to maintain sufficient contributions;**
- (b) **Maintain a list of the active contributing centres and the specifications of their prediction systems;**
- (c) **Collect an agreed set of hindcast, forecast and verification data (Appendices 2.2.19 and 2.2.20) from the contributing centres;**
- (d) **Make available the agreed forecast products in standard format, including multi-model ensemble products (Appendix 2.2.19);**
- (e) **Make available on the website the agreed hindcast verification products in standard format, including verification of the multi-model ensemble products (Appendix 2.2.20);**
- (f) **Redistribute digital hindcast and forecast data for those contributing centres that allow it;**

- (g) **Maintain an archive of the real-time forecasts from individual contributing centres and from the multi-model ensemble system;**
- (h) **Promote research and experience in ADCP techniques and provide guidance and support on ADCP to RCCs and NMHSs;**
- (i) **Based on comparison among different models, provide feedback to the contributing centres on model performance;**
- (j) **Make available on a website the Global Annual to Decadal Climate Update (GADCU) and maintain its archive;**
- (k) **Coordinate, in liaison with relevant World Climate Research Programme activities, an annual consensus prediction product providing global prospects for the next 1–5 years.**

2.2.2.4.2 Access to data and visualization products held by a Lead Centre for ADCP should follow the rules as detailed in Appendix 2.2.18.

Notes:

1. The GADCU, issued annually in May, summarizes the predicted future of the global climate over the next year and the next five years. The focus is on climate indices such as global mean near-surface temperature, Atlantic multidecadal variability and the El Niño/Southern Oscillation, as well as regional indices and annual and multi-year seasonal means of near-surface temperature, mean sea-level pressure and precipitation. Maps of prediction skill are available to help with interpretation. A short summary of the observed global climate over the past five years is also included, to provide the current climate context.
2. The bodies in charge of managing the information contained in the present Manual related to coordination of ADCP are specified in Table 19.

**Table 19. WMO bodies responsible for managing information related to coordination of ADCP**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OCPS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OCPS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.2.5 **Coordination of assessment of multiple climate reanalyses**

2.2.2.5.1 Centre(s) conducting the assessment of multiple climate reanalyses (Lead Centre(s) for global climate reanalysis) shall:

- (a) **Select a group of global climate reanalysis centres (referred to as “contributing centres”, which also includes the designated GCR centres) that meet the GCR designation criteria and have been approved by ET-OCPS, to contribute to the Lead Centre(s) for global climate reanalysis; and manage changes in the membership of the group, as and when they occur;**
- (b) **Maintain a list of the contributing centres and the specifications of their climate reanalysis systems;**

- (c) Collect an agreed set of digital mandatory products listed in Appendix 2.2.58 from contributing centres;
- (d) Interpolate the collected products onto a common horizontal grid, generate climatologies and make them available for each reanalysis;
- (e) Provide a set of graphical mandatory products listed in Appendix 2.2.58;
- (f) Make available a set of tools to visualize the products as time series and/or maps on the Lead Centre(s') website;
- (g) Update all reanalysis products listed in Appendix 2.2.58 to include the previous month within 90 days of the end of current month;
- (h) Ensure all products cover at least the most recent WMO climatological reference period.

2.2.2.5.2 In addition to the mandatory functions above, Lead Centre(s) for global climate reanalysis should:

- (a) Make available on the Lead Centre(s') website(s) the digital recommended products listed in Appendix 2.2.58;
- (b) Define and provide common evaluation metrics to compare climate reanalysis outputs, jointly with other contributing centres conducting global climate reanalysis;
- (c) Produce their mandatory and recommended digital products in one of the following formats: GRIB1, GRIB2, NetCDF or HDF.

Notes:

1. The requirement for users to be registered and/or to accept terms and conditions before retrieving the data does not affect the open and free status of the data.
2. The digital products will be available through the Lead Centre(s) if the contributing centres agree.
3. The bodies in charge of managing the information contained in the present Manual related to coordination of assessment of multiple climate reanalyses are specified in Table 20.

**Table 20. WMO bodies responsible for managing information related to coordination of assessment of multiple climate reanalyses**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OCPS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OCPS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.2.6 **Regional severe weather forecasting**

Note: This activity includes a network of RSMCs and associated NMCs.

2.2.2.6.1 **Regional Specialized Meteorological Centres conducting regional severe weather forecasting shall:**

- (a) Agree on the targeted severe events, phenomena, criteria for guidance and extent of regional domain with associated NMCs;
- (b) Prepare, at least once per day, severe weather forecasting guidance products for associated NMCs containing an interpretation of deterministic NWP, EPS and remote sensing-based guidance products;
- (c) Make available on a dedicated website (with password protection as appropriate), relevant deterministic NWP, EPS and remote sensing-based guidance products;
- (d) Where severe weather is associated with tropical cyclones, centres will take guidance from the appropriate RSMC conducting tropical cyclone forecasting and interpret it in terms of severe weather guidance.

#### 2.2.2.6.2 National Meteorological Centres associated in this activity shall:

- (a) Provide criteria for severe weather warnings to the relevant RSMCs participating in this activity;
- (b) Evaluate products, including the daily severe weather forecasting guidance, and provide feedback to the RSMCs;
- (c) Ensure that appropriate warnings of severe weather are issued.

Note: The bodies in charge of managing the information contained in the present Manual related to regional severe weather forecasting are specified in Table 21.

**Table 21. WMO bodies responsible for managing information related to regional severe weather forecasting**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OWFS	SERCOM/SC-DRR
To be recommended by:	INFCOM	SERCOM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	INFCOM	SERCOM
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SERCOM/SC-DRR		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	SERCOM

Acronym not previously defined: SC-DRR – Standing Committee on Disaster Risk Reduction and Public Services

#### 2.2.2.7 **Tropical cyclone forecasting, including marine-related hazards**

Note: This activity is coordinated by the Tropical Cyclone Programme regional bodies.

##### 2.2.2.7.1 Regional Specialized Meteorological Centres conducting tropical cyclone forecasting shall:

- (a) Monitor continuously meteorological phenomena such as convective activities to predict or detect tropical cyclone formation;
- (b) Analyse and forecast tropical cyclones based on all available observational data and forecasting guidance, including NWP, EPS and satellite-based products;
- (c) Issue tropical cyclone advisories to associated NMCs;

- (d) As appropriate, add information in tropical cyclone advisories on hazardous phenomena associated with tropical cyclones such as heavy rains, strong winds and storm surges;
- (e) Name tropical cyclones when they have been analysed with maximum wind speeds of 34 knots or more;
- (f) Conduct post-event analysis of tropical cyclones based on quality-assured observational data and issue best-track data within an appropriate period of time (preferably on an annual basis); issue such data to the tropical cyclone community, including the International Best Track Archive for Climate Stewardship;
- (g) Promote research and development, and training in tropical cyclone analysis, forecasting and warning techniques.

2.2.2.7.2 National Meteorological Centres associated with this activity shall:

- (a) Issue forecasts and warnings of tropical cyclones to threatened communities;
- (b) Coordinate with national agencies responsible for disaster risk reduction;
- (c) Provide relevant regional centres with observational data of tropical cyclones on a real-time basis.

2.2.2.7.3 All six RSMCs for tropical cyclone forecasting together with Tropical Cyclone Warning Centre Darwin, which are designated as Tropical Cyclone Advisory Centres (TCAC) by regional air navigation agreement within the framework of the tropical cyclone watch of the International Civil Aviation Organization (ICAO), shall issue tropical cyclone advisories for aviation in accordance with the provisions made in *Meteorological Service for International Air Navigation*, Annex 3 to the Convention on International Civil Aviation, ICAO; and *Technical Regulations* (WMO-No. 49), Volume II, Parts I and II. SIGMET information concerning tropical cyclones shall be issued by the meteorological watch offices for the flight information region concerned and should be based on the tropical cyclone advisory issued by TCACs in accordance with ICAO Annex 3 and *Technical Regulations* (WMO-No. 49), Volume II, 3.4 and 7.

2.2.2.7.4 Members holding METAREA responsibility within the Global Maritime Distress and Safety System (GMDSS) protocols – established by the International Maritime Organization in Chapter IV of the International Convention of Safety Of Life At Sea – shall include information on tropical cyclones as needed in their GMDSS maritime weather information for shipping.

Note: The bodies in charge of managing the information contained in the present Manual related to tropical cyclone forecasting are specified in Table 22.

**Table 22. WMO bodies responsible for managing information related to tropical cyclone forecasting**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	SERCOM/SC-DRR	
To be recommended by:	INFCOM	Regional Tropical Cyclone committee	SERCOM
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM	Regional Tropical Cyclone committee	SERCOM
To be decided by:	EC/Congress		
<i>Compliance</i>			

<i>Responsibility</i>			
To be monitored by:	SERCOM/SC-DRR		
To be reported to:	INFCOM	SERCOM	

### 2.2.2.8 **Nuclear environmental emergency response**

Centres conducting nuclear environmental emergency response shall:

- (a) **Contribute to support for WMO Members and the International Atomic Energy Agency (IAEA):**
- (i) Prepare, on request from a delegated authority<sup>1</sup> and/or IAEA, basic information relating to events in which nuclear contaminants have been released into the atmosphere; the activation of the support for nuclear emergency response is described in Appendix 2.2.21;
  - (ii) As soon as possible, but no longer than three hours after reception of a request, make a range of products available to the NMHS operational contact point<sup>2</sup> and/or IAEA.<sup>3</sup> The minimum list, including parameters, forecast range, time steps and frequency, is given in Appendix 2.2.22;
  - (iii) Use agreed standard emission source parameters for atmospheric transport and dispersion modelling (ATDM) when source information is not available; default source parameters are given in Appendix 2.2.23;
  - (iv) Make available up-to-date information on the characteristics of their ATDM systems (minimum information to be provided is given in Appendix 2.2.24) and a user interpretation guide for ATDM products.

Note: The forms to request WMO support by a delegated authority and by IAEA are given in Appendix 2.2.25.

- (b) **Contribute to support for the Comprehensive Nuclear-test-ban Treaty Organization (CTBTO):**
- (i) Prepare, on request from CTBTO, relevant atmospheric backward transport and dispersion products;
  - (ii) Make the requested products available to CTBTO.

Notes:

1. Arrangements for activation and product specifications are given in Appendix 2.2.26.
2. The bodies in charge of managing the information contained in the present Manual related to nuclear environmental emergency response are specified in Table 23.

**Table 23. WMO bodies responsible for managing information related to nuclear environmental emergency response**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-ERA	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			

<sup>1</sup> The person authorized by the Permanent Representative of the WMO Member to request support.

<sup>2</sup> Designated by the Permanent Representative.

<sup>3</sup> Via a password-protected dedicated website.

<i>Responsibility</i>			
To be recommended by:	INFCOM	RA	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-ERA		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

Acronym not previously defined: ET-ERA – Expert Team on Emergency Response Activities

### 2.2.2.9 **Non-nuclear environmental emergency response**

Note: This activity includes a network of regional centres and NMCs within a geographical region.

**Centres conducting non-nuclear environmental emergency response shall:**

- (a) Prepare, on request from an authorized person,<sup>4</sup> ATDM forecast or hindcast products relating to events in which hazardous non-nuclear contaminants have been released into the atmosphere; the criteria for activation of the regional support procedures and the request form are given in Appendices 2.2.27 and 2.2.31, respectively;
- (b) As soon as possible, but usually within two hours of a request from an authorized person, make available a range of products to the NMHS operational contact point<sup>5</sup> by email or retrieval from the RSMC designated website; the list of mandatory and recommended products to be made available, including parameters, forecast range, time steps and frequency, is given in Appendix 2.2.28;
- (c) Use agreed default emission source parameters for essential parameters when actual source information is not available; default source parameters for a range of release scenarios are given in Appendix 2.2.29;
- (d) Make available on a website up-to-date information on the characteristics of their ATDM systems (minimum information to be provided is given in Appendix 2.2.30) and a user interpretation guide for ATDM products.

Note: The bodies in charge of managing the information contained in the present Manual related to non-nuclear environmental emergency response are specified in Table 24.

**Table 24. WMO bodies responsible for managing information related to non-nuclear environmental emergency response**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-ERA	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM	RA	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-ERA		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

<sup>4</sup> The person authorized by the Permanent Representative of the WMO Member to request RSMC support; normally the NMHS operational contact point.

<sup>5</sup> Designated by the Permanent Representative.

### 2.2.2.10 **Atmospheric sand and dust storm forecasts**

Centres conducting atmospheric sand and dust storm forecasts shall:

- (a) Operate an NWP model incorporating parameterizations of all the major phases of the atmospheric dust cycle;
- (b) Prepare limited-area analyses of variables relevant to atmospheric sand and dust storms;
- (c) Prepare limited-area forecast fields of variables relevant to atmospheric sand and dust storms;
- (d) Make available on WIS and on a web portal a range of these products; the list of mandatory products to be made available is given in Appendix 2.2.32.

Note: The bodies in charge of managing the information contained in the present Manual related to atmospheric sand and dust storm forecasts are specified in Table 25.

**Table 25. WMO bodies responsible for managing information related to atmospheric sand and dust storm forecasts**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS		RB/SDS-WAS Steering Committee
To be recommended by:	RB/EPAC SSC	INFCOM	
To be decided by:	EC/Congress		
<i>Centres designation*</i>			
To be recommended by:	RB/EPAC SSC	INFCOM	RA
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/SC-WIPPS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

Acronyms not previously defined: RB – Research Board; SDS-WAS – Sand and Dust Storm Warning Advisory and Assessment System; EPAC SSC – Environmental Pollution and Atmospheric Chemistry Scientific Steering Committee

\* The detailed designation procedure of RSMCs with activity specialization on atmospheric sandstorm and dust storm forecasts (RSMC-ASDF) is referred to in *Sand and Dust Storm Warning Advisory and Assessment System (SDS-WAS) Science and Implementation Plan 2015–2020*, WWRP 2015-5, Geneva, WMO, 7 – Transition to operational activities: Proposed designation as regional specialized meteorological centre with specialization on atmospheric sand and dust forecasting (RSMC-ASDF).

### 2.2.2.11 **Vegetation fire and smoke pollution forecasts**

Centres conducting vegetation fire and smoke pollution forecasts shall:

- (a) Operate at least an atmospheric chemistry model incorporating parameterizations of all major processes (emission, transport and deposition) related to fire propagation and fire smoke dispersion in the atmosphere;
- (b) Prepare limited-area forecast fields of variables relevant to fire information and atmospheric pollution;
- (c) Prepare limited-area products on fire activity and fire risk;

- (d) **Make available on a website a range of mandatory and recommended products listed in Appendix 2.2.59;**
- (e) **Make available on a website up-to-date information on the characteristics of its atmospheric chemistry forecast system.**

Note: The bodies in charge of managing the information contained in the present Manual related to vegetation fire and smoke pollution forecasts are specified in Table 26.

**Table 26. WMO bodies responsible for managing information related to vegetation fire and smoke pollution forecasts**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	VFSP-WAS Steering Committee	
To be recommended by:	RB/EPAC SSC	INFCOM	
To be decided by:	EC/Congress		
<i>Centres designation*</i>			
To be recommended by:	RB/EPAC SSC	INFCOM	RA
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/SC-WIPPS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

Acronym not previously defined: VFSP-WAS – Vegetation Fire and Smoke Pollution Warning Advisory and Assessment System

#### 2.2.2.12 **Volcano watch services for international air navigation**

The nine Volcanic Ash Advisory Centres (VAACs), designated by the International Civil Aviation Organization (ICAO), shall issue volcanic ash advisories for aviation in accordance with the provisions set out in *Meteorological Service for International Air Navigation, Annex 3 to the Convention on International Civil Aviation*, and in *Technical Regulations (WMO-No. 49), Volume II, 3.5*. Eight of the nine VAACs are co-located with RSMCs. SIGMET information concerning volcanic ash shall be issued by meteorological watch offices for the flight information region concerned and should be based on the volcanic ash advisory issued by the VAACs, in accordance with ICAO Annex 3 and *Technical Regulations (WMO-No. 49), Volume II, 3.4 and 7*. Service provision arrangements for volcano observatories in support of aviation are described in ICAO Annex 3 and in *Technical Regulations (WMO-No. 49), Volume II, 3.6*.

#### 2.2.2.13 **Marine meteorological services**

Notes:

- Operations, including practices, procedures and specifications are described in the [Manual on Marine Meteorological Services \(WMO-No. 558\)](#), Volume I;
- This activity includes a network of National Meteorological Centres.

##### 2.2.2.13.1 **National Meteorological Centres conducting marine meteorological services (including preparation services) shall:**

- Issue forecasts of marine environmental conditions for coastal and offshore areas, as defined in Appendix 2.2.38;**
- Issue warnings of marine meteorological hazards for coastal and offshore areas, as defined in Appendix 2.2.38;**

- (c) Coordinate with national agencies responsible for marine matters, including disaster risk reduction and search and rescue.

2.2.2.13.2 In compliance with the *Joint IMO/IHO/WMO Manual on Maritime Safety Information*, Members holding METAREA responsibility under the WMO/IMO Worldwide Met-ocean Information and Warning Service (WMMIWS), shall:

- (a) Issue forecasts of marine environmental conditions for the high seas, as defined in Appendix 2.2.38;
- (b) Issue warnings of marine meteorological hazards for the high seas, as defined in Appendix 2.2.38;
- (c) Organize the broadcast of marine forecasts and warnings on broadcast systems compliant with the GMDSS;
- (d) Undertake METAREA Coordinator duties, including verification activities as defined in Appendix 2.2.39.

Note: The WMO bodies in charge of managing the information contained in manuals related to marine meteorological services are specified in Table 27.

**Table 27. WMO bodies responsible for managing information related to marine meteorological services**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	SERCOM/SC-MMO	
To be recommended by:	SERCOM	INFCOM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be approved by:	SERCOM	INFCOM	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SERCOM/SC-MMO		
To be reported to:	INFCOM	SERCOM	

#### 2.2.2.14 **Marine emergency response**

Centres conducting marine emergency response (MER) shall:

- (a) Prepare, on request from an authorized person, MER analysis and forecast products relating to non-nuclear marine pollution (MER-non-nuclear pollution) and/or search and rescue (MER-SAR) incidents for global or multiple/single ocean basins (Atlantic, Pacific, Indian, Arctic or Southern Ocean, depending on their designation: see Note 5), or part of an ocean basin; the procedures for activation of the regional support and the request form are given in Appendices 2.2.60 and 2.2.61;
- (b) As soon as possible after a request is received from an authorized person, but usually within one hour for a SAR event and four hours for a non-nuclear marine pollution event, make available a range of products to the requester, only by way of a pre-agreed secure method (for example, by email, retrieval from the RSMC password-protected designated website and/or FTP server); the list of mandatory and recommended products to be made available, including parameters, forecast range, time steps and frequency, is given in Appendix 2.2.62;

- (c) Use default source parameters for marine drifting modelling (MDM) when actual source information is not available; default source parameters for a range of scenarios are given in Appendix 2.2.63;
- (d) Make available on a website up-to-date information on the characteristics of their MDM systems (the minimum information to be provided is given in Appendix 2.2.64), including:
- the type of incidents covered;
  - the geographic coverage;
  - a user interpretation guide for MER products (which includes a list of oil and/or other hazardous and noxious substances, as well as the classification of objects that could be used in the drift models);
- (e) Participate in MER testing exercises at the request of WMO or the International Maritime Organization (IMO), and their Members/Member States, including national authorities; all products provided in this context shall be labelled as "EXERCISE – EXERCISE – EXERCISE" on all pages and in large font.

## Notes:

1. A hazardous and noxious substance in the present Manual is defined as any substance, including oil, which, if introduced into the marine environment, is likely to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with other legitimate uses of the sea.
2. An authorized person is a 24/7 operational contact point from an NMHS, a Rescue Coordination Centre and/or a Regional Marine Pollution Emergency Response Centre. Authorized persons are nominated by the General-Director(s) of the NMHS, the Rescue Coordination Centre and the Regional Marine Pollution Emergency Response Centre, and are authorized by the Permanent Representative of the WMO Member hosting the centre. The WMO Secretariat maintains a list of operational contact points and authorized persons on its website, and regularly communicates it to WMO Members through a circular letter.
3. Centres can be designated to conduct MER-SAR or MER for non-nuclear pollution or both.
4. Centres can be designated to conduct MER for non-nuclear pollution for oil and/or other non-nuclear hazardous and noxious substance(s), depending on their capabilities.
5. Designated centres can have global coverage, coverage of one or more ocean basins (Atlantic, Pacific, Indian, Arctic or Southern Ocean), or coverage of part of an ocean basin (such as the North or South Atlantic or Pacific or Indian Ocean). Note that the basin of the Southern Ocean is defined in accordance with the International Hydrographic Organization (IHO) Resolution 02/2023 – *Recognition of the Southern Ocean and consequences on the limits of some global sea areas*.
6. A designated RSMC-MER may wish to develop a web interface for registered users to submit the request form in case of an incident.
7. The bodies in charge of managing the information contained in the present Manual related to marine emergency response are specified in Table 28.

**Table 28. WMO bodies responsible for managing information related to marine emergency response**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	SERCOM/SC-MMO	
To be recommended by:	SERCOM	INFCOM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be approved by:	SERCOM	INFCOM	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SERCOM/SC-MMO		
To be reported to:	INFCOM	SERCOM	

### 2.2.2.15 **Flash flood forecasting**

Centres conducting flash flood forecasting (Regional Specialized Hydrological Centres (RSHCs) conducting flash flood forecasting) shall:

- (a) Produce flash flood products and provide specific products to National Hydrological and Meteorological Services (NMHSs), which are agreed upon in advance with participating Members. The list of mandatory and recommended products is specified in Appendix 2.2.51;
- (b) Support NMHSs in the generation of flash flood forecasting information;
- (c) Make a range of these products available on the WIS and/or another web-based platform;
- (d) Prepare verification statistics and make them available on a website (some recommendations regarding verification are given in Appendix 2.2.52);
- (e) Make available on a website up-to-date information on the characteristics of the flash flood forecasting system. The minimum information to be provided is specified in Appendix 2.2.53.

Note: The bodies in charge of managing the information contained in the present Manual related to flash flood forecasting are specified in Table 29.

**Table 29. WMO bodies responsible for managing information related to flash flood forecasting**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	SERCOM/SC-HYD	
To be recommended by:	SERCOM	INFCOM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	SERCOM	INFCOM
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SERCOM/SC-HYD		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	SERCOM

### 2.2.3 **Non-real-time coordination activities**

#### 2.2.3.1 **Coordination of deterministic numerical weather prediction verification**

2.2.3.1.1 The centre(s) coordinating DNV (Lead Centre(s) for DNV) shall:

- (a) Provide the facility for WIPPS centres producing global NWP to automatically deposit their standardized verification statistics as defined in Appendix 2.2.33, and provide access to these verification statistics;
- (b) Maintain an archive of the verification statistics to allow the generation and display of trends in performance;
- (c) Monitor the received verification statistics and consult with the relevant participating centres if data are missing or suspect;

- (d) Collect annually from the participating centres information on their implementation of the standardized verification system, confirm any changes to their implementation (including the annual change of station list and changes in additional statistics) and changes in their NWP models;
- (e) Provide access to standard datasets needed to perform the standard verification, including climatology and lists of observations, and keep this up to date according to INFCOM recommendations;
- (f) Provide on their website(s):
- Consistent up-to-date graphical displays of the verification results from participating centres through processing of the received statistics;
  - Relevant documentation, including access to the standard procedures required to perform the verification, and links to the websites of WIPPS-participating centres;
  - Contact details to encourage feedback from NMHSs and other WIPPS centres on the usefulness of the verification information.

2.2.3.1.2 Lead Centre(s) for DNV should also provide access to standardized software for calculating scoring information.

Note: The bodies in charge of managing the information contained in the present Manual related to coordination of DNV are specified in Table 30.

**Table 30. WMO bodies responsible for managing information related to coordination of DNV**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OWFS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OWFS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

### 2.2.3.2 **Coordination of Ensemble Prediction System verification**

2.2.3.2.1 The centre(s) conducting coordination of EPS verification (Lead Centre(s) for EPS verification) shall:

- (a) Provide the facility for the WIPPS centres producing global EPS data to automatically deposit their standardized verification statistics as defined in Appendix 2.2.34, and provide access to these verification statistics;
- (b) Maintain an archive of the verification statistics to allow the generation and display of trends in performance;
- (c) Monitor the received verification statistics and consult with the relevant participating centres if data are missing or suspect;

- (d) Provide access to standard datasets needed to perform the standard verification, including climatology and lists of specified observation sites, and keep this up to date according to INFCOM recommendations;
- (e) Provide on its website(s) (for example, <http://epsv.kishou.go.jp/EPsv/>):
- Consistent up-to-date graphical displays of the verification results from participating centres through processing of the received statistics;
  - Relevant documentation, including access to the standard procedures required to perform the verification, and links to the websites of WIPPS-participating centres;
  - Contact details to encourage feedback from NMHSs and other WIPPS centres on the usefulness of the verification information.

2.2.3.2.2 Lead Centre(s) for EPS verification should also provide access to standardized software for calculating scoring information.

Note: The bodies in charge of managing the information contained in the present Manual related to coordination of EPS verification are specified in Table 31.

**Table 31. WMO bodies responsible for managing information related to coordination of EPS verification**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OWFS	
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OWFS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

### 2.2.3.3 **Coordination of wave forecast verification**

2.2.3.3.1 The centre(s) coordinating WFV (Lead Centre(s) for WFV) shall:

- (a) Provide the facility for WMO designated centres endorsed by SERCOM/SC-MMO that produce global or ocean-basin scale wave forecasts to automatically deposit their gridded forecast fields as defined in Appendix 2.2.36, and provide access to the verification statistics computed for these fields;
- (b) Maintain an archive of the verification statistics to allow the generation and display of trends in performance;
- (c) Monitor the received forecast fields and consult with the relevant WMO designated centres endorsed by SERCOM/SC-MMO if data are missing or suspect;
- (d) Collect annually from the participating centres information on any changes to their wave forecast systems;
- (e) Provide access to the datasets used to perform the standard verification, including lists of observations, and keep this up to date according to SERCOM/SC-MMO recommendations;

## (f) Provide on their websites:

- Consistent up-to-date graphical displays of the verification results from WMO designated centres endorsed by SERCOM/SC-MMO based on verification of the received forecast fields;
- Relevant documentation including access to the standard procedures required to perform the verification, and links to the websites of WMO designated centres endorsed by SERCOM/SC-MMO;
- Contact details to encourage feedback from WMO designated centres endorsed by SERCOM/SC-MMO on the usefulness of the verification information.

2.2.3.3.2 The Lead Centre(s) for WFV should also provide access to standardized software for calculating scoring information.

Note: The bodies in charge of managing the information contained in the present Manual related to WFV are specified in Table 32.

**Table 32. WMO bodies responsible for managing information related to coordination of WFV**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OWFS	SERCOM/SC-MMO
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OWFS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

#### 2.2.3.4 **Coordination of tropical cyclone forecast verification**

2.2.3.4.1 The centre(s) coordinating TCFV (Lead Centre(s) for TCFV) shall:

- (a) Provide the facility for WIPPS centres, including RSMCs participating in global deterministic NWP defined in 2.2.1.1, that produce tropical cyclone forecasts to deposit their gridded forecast fields as defined in Appendix 2.2.37, and have access to the verification statistics computed for these fields;
- (b) Maintain an archive of the verification statistics to allow the generation and display of trends in performance;
- (c) Monitor the received forecast fields and consult with the relevant WIPPS-participating centres if data are missing or suspect;
- (d) Provide access to the datasets used to perform the standard verification, including best-track data produced by RSMCs participating in tropical cyclone forecasting defined in 2.2.2.7;
- (e) Provide on their websites:
  - Consistent up-to-date graphical displays of the verification results from participating centres through processing of the statistics received;

- **Relevant documentation, including access to the standard procedures required to perform the verification, and links to the websites of WIPPS-participating centres;**
- **Contact details to encourage feedback from NMHSs and other WIPPS centres on the usefulness of the verification information.**

2.2.3.4.2 The Lead Centre(s) for TCFV should also provide access to standardized software for calculating scoring information.

Note: The bodies in charge of managing the information contained in the present Manual related to TCFV are specified in Table 33.

**Table 33. WMO bodies responsible for managing information related to coordination of TCFV**

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	INFCOM/SC-WIPPS	INFCOM/ET-OWFS	RB/JWGFVR, RB/WGNE
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	INFCOM		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	INFCOM/ET-OWFS		
To be reported to:	INFCOM/SC-WIPPS	INFCOM	

Acronyms not previously defined: JWGFVR – Joint Working Group on Forecast Verification Research; WGNE – Working Group on Numerical Experimentation

### 2.2.3.5 **Coordination of observation monitoring**

2.2.3.5.1 **For each type of observation, a Lead Centre for coordination of observation monitoring shall be nominated from time to time by the president of INFCOM.**

2.2.3.5.2 The Lead Centre(s) should liaise with the participating centres to coordinate all the monitoring results of that observation type and to define common methods and criteria to be used for compiling the monthly statistics.

2.2.3.5.3 The Lead Centre(s) should draw the attention of appropriate focal points where they have been identified and of the WMO Secretariat to obvious problems as they are detected.

2.2.3.5.4 The Lead Centre(s) should also produce every six months a consolidated list of observations of the relevant observation type believed to be of consistently low quality. Information on problems with observing systems, as well as individual observations, should also be included. When compiling the consolidated lists of suspect stations, the Lead Centre(s) should be rigorous so as to identify only those stations that the Lead Centre(s) are confident are producing observations of consistently low quality. It should state which elements of the observations are considered to be of low quality and provide as much information as possible concerning the problem. The list should be passed on to the participating centres and to WMO Secretariat.

2.2.3.5.5 Where focal points have not been identified, the Secretariat should notify Members of agencies responsible for observations that appear to be of low quality, and request them to make an investigation with a view to identifying and correcting any possible cause of error. Members should be asked to reply within a fixed period of time, reporting on any remedial action and stating if any assistance is required.

2.2.3.5.6 Monitoring results, including follow-up actions, should be made available to INFCOM, the Executive Council and Congress. In the case of enquiries made by WMO, feedback to the Lead Centres is requested.

Notes:

1. Lead Centre(s) for data quality monitoring are given in the [Guide to the Global Observing System](#) (WMO-No. 488), Part VII, 7.2.2.1.
  2. The WIGOS Quality Management System is being developed to incorporate the observational quality monitoring process described above. The coordination will be defined in this section in due course.
-

## **APPENDIX 2.1.1. TECHNIQUES FOR MONITORING THE QUALITY OF OBSERVATIONS**

- (a) Compilation of statistics on the difference between observed values and the analysis and first-guess field;
  - (b) Compilation of statistics on observations which fail the routine quality control checks;
  - (c) Examination of time series of observations from a particular station (particularly useful in data-sparse areas);
  - (d) Compilation of statistics on the differences between reported values of geopotential height and geopotential height recalculated from significant level data for radiosonde stations, using common formulae for all stations;
  - (e) For surface stations that report both mean sea-level pressure (MSLP) and station-level pressure, compilation of statistics on differences between reported MSLP and MSLP recomputed from reported station-level pressure and temperature and published values of station elevation;
  - (f) Compilation of co-location statistics.
-

## APPENDIX 2.1.2. PROCEDURES AND FORMATS FOR THE EXCHANGE OF MONITORING RESULTS

### 1. GENERAL REMARKS

1.1 Centres participating in the exchange of monitoring results will implement standard procedures and use agreed formats for communicating the information both to other centres and to the data providers. The lists that follow are incomplete and require further development in the light of practical experience. Guidance will be given through the initiative of the Lead Centres in their corresponding fields of responsibility.

1.2 Lead Centres that are informed of remedial actions being taken should provide this information to all participating centres. The WMO Secretariat will forward, every six months, the information it receives to the relevant Lead Centres. All Lead Centres will produce for the WMO Secretariat a yearly summary of information made available to them and/or of those actions taken within their area of responsibility.

### 2. UPPER-AIR OBSERVATIONS

2.1 Monthly exchange for upper-air observations should include lists of stations/ships with the following information.

#### 2.1.1 List 1: Geopotential height

- Month/year;
- Monitoring centre;
- Standard of comparison (first-guess/background field);
- Selection criteria: For 0000 and 1200 UTC separately, at least three levels with 10 observations during the month and 100-metre weighted RMS departure from the field used for comparison between 1 000 and 30 hPa.

The gross error limits to be used for the observed minus reference field are as follows:

<i>Level (hPa)</i>	<i>Geopotential height (m)</i>	<i>Level (hPa)</i>	<i>Geopotential height (m)</i>
1 000	100	250	225
925	100	200	250
850	100	150	275
700	100	100	300
500	150	70	375
400	175	50	400
300	200	30	450

Weights to be used at each level are as follows:

<i>Level (hPa)</i>	<i>Weight</i>	<i>Level</i>	<i>Weight</i>
1 000	3.70	250	1.50

<i>Level (hPa)</i>	<i>Weight</i>	<i>Level</i>	<i>Weight</i>
925	3.55	200	1.37
850	3.40	150	1.19
700	2.90	100	1.00
500	2.20	70	0.87
400	1.90	50	0.80
300	1.60	30	0.64

Data to be listed for each station/ship should include:

- WMO identifier;
- Observation time;
- Latitude/longitude (for land stations);
- Pressure of the level with largest weighted root mean square (RMS) departure;
- Number of observations received (including gross errors);
- Number of gross errors;
- Percentage of observations rejected by the data assimilation;
- Mean departure from reference field;
- RMS departure from reference field (unweighted).

Gross errors should be excluded from the calculation of the mean and RMS departures. They should not be taken into account in the percentage of rejected data (neither the numerator nor denominator).

### 2.1.2 **List 2: Temperature**

Besides the geopotential height, temperature monitoring should be included at standard levels. As an initial criterion, the gross error thresholds to be considered should be:

- 15 (K) for pressure > 700 hPa;
- 10 (K) for 700 to > 50 hPa;
- 15 (K) for pressure ≤ 50 hPa.

### 2.1.3 **List 3: Wind**

- Month/year;
- Monitoring centre;
- Standard of comparison (first-guess/background field);
- Selection criteria: For 0000 and 1200 UTC separately, at least one level with 10 observations during the month and 15 m s<sup>-1</sup> RMS vector departure from the field used for comparison, between 1 000 and 100 hPa.

The gross error limits to be used are as follows:

<i>Level (hPa)</i>	<i>Wind (m s<sup>-1</sup>)</i>	<i>Level (hPa)</i>	<i>Wind (m s<sup>-1</sup>)</i>
1 000	35	300	60
925	35	250	60
850	35	200	50
700	40	150	50
500	45	100	45
400	50		

Data to be listed for each selected station/ship should include:

- WMO identifier;
- Observation time;
- Latitude/longitude (for land stations);
- Pressure of the level with largest RMS departure;
- Number of observations received (including gross errors);
- Number of gross errors;
- Percentage of observations rejected by the data assimilation;
- Mean departure from reference field for the u component;
- Mean departure from reference field for the v component;
- RMS vector departure from reference field.

Gross errors should be treated in the same way as that described for List 1.

#### 2.1.4 **List 4: Wind direction**

The method used for computing the wind direction bias should be included in the reports (clockwise or anticlockwise):

- Month/year;
- Monitoring centre;
- Standard of comparison (first-guess/background field);
- Selection criteria: For 0000 and 1200 UTC separately, at least five observations at each standard level from 500 hPa to 150 hPa; for the average over that layer, mean departure from reference field at least  $\pm 10$  degrees, standard deviation less than 30 degrees, maximum vertical spread less than 10 degrees.

Gross errors should be treated in the way described for List 1. Data for which the wind speed is less than  $5 \text{ m s}^{-1}$ , either observed or calculated, should also be excluded from the statistics.

Data to be listed for each selected station/ship should include:

- WMO identifier;
- Observation time;
- Latitude/longitude (for land stations);
- Minimum number of observations at each level from 500 hPa to 150 hPa (excluding gross errors and data with low wind speed);
- Mean departure from reference field for wind direction, averaged over the layer;
- Maximum spread of the mean departure at each level around the average;
- Standard deviation of the departure from reference field, averaged over the layer.

(To be completed with information from other Lead Centres)

Notes:

1. The responsibility for updating this appendix rests with the Lead Centres.
2. Urgent changes to this appendix recommended by the Lead Centres will be approved, on behalf of INFCOM, by the president of the Commission.

2.2 The profilers should be monitored (suspect platforms) using the same criteria described for radiosondes.

### 3. **LAND-SURFACE OBSERVATIONS**

3.1 The criteria for the production of a monthly list of suspect stations are described in the following sections.

#### 3.1.1 **List 1: Mean sea-level pressure**

Element: MSLP, surface synoptic observations at 0000, 0600, 1200 or 1800 UTC compared with the first-guess field of a data-assimilation model (usually a six-hour forecast).

Number of observations: At least 20 for at least 1 observation time, without distinguishing between observation times.

One or more of the following:

- Absolute value of the mean bias  $\geq 4$  hPa;
- Standard deviation  $\geq 6$  hPa;
- Percentage gross error  $\geq 25\%$  (gross error limit: 15 hPa).

#### 3.1.2 **List 2: Station-level pressure**

The criteria for station-level pressure monitoring are as described for MSLP, above.

#### 3.1.3 **List 3: Geopotential height**

Element: Geopotential height, from surface synoptic observations or derived from station-level pressure, temperature and published station elevations at 0000, 0600, 1200 or 1800 UTC compared with the first-guess field of a data assimilation model (usually a six-hour forecast).

Number of observations: At least five for at least one observation time, without distinguishing between observation times.

One or more of the following:

- Absolute value of the mean bias  $\geq 30$  m;
- Standard deviation  $\geq 40$  m;
- Percentage gross error  $\geq 25\%$  (gross error limit: 100 m).

#### 3.1.4 **Precipitation**

General guidance reflects the Global Precipitation Climatology Centre procedures for precipitation quality monitoring.

## Notes:

1. All monitoring centres are asked to conform to the above specified criteria. These monthly lists should be prepared for at least the RAs of the Lead Centres and, if possible, for other RAs. Consolidated lists of suspect stations should be produced every six months by the Lead Centres (January–June and July–December) and forwarded to the WMO Secretariat for further action.
2. The stations on these consolidated lists should be those appearing on all six-monthly lists of the Lead Centres. Other stations could be added to the consolidated list if the Lead Centres judge that there is sufficient evidence for their inclusion. Each centre should send its proposed consolidated list to all participating monitoring centres for comment. The final list should then be forwarded to the WMO Secretariat.

#### 4. SURFACE MARINE OBSERVATIONS

4.1 Monthly exchange for surface marine observations should include lists of “suspect” ships, buoys and platforms, with the following additional information:

- Month/year;
- Monitoring centre;
- Standard of comparison: First-guess/background field of a global data assimilation model, often a six-hour forecast, but the background values may be valid at the observation time for non-main-hour data using variational data assimilation or time-interpolation of T+3, T+6, T+9 forecasts; for sea-surface temperature (SST), the first-guess/background field may be from a previous analysis.

All surface marine data may be included, not just observations at the main hours of 0000, 0600, 1200, 1800 UTC.

4.2 The elements to be monitored should include:

- MSLP;
- Wind speed;
- Wind direction;

And, where possible:

- Air temperature;
- Relative humidity;
- SST.

4.3 Data to be listed for each ship, buoy or platform, and each element should include:

- WMO identifier;
- Observation time;
- Number of observations received (including gross errors);
- Number of gross errors;
- Percentage of observations rejected by the data assimilation quality control;
- Mean departure from reference field (bias);
- RMS departure from reference field.

Gross errors should be excluded from the calculation of the mean and RMS departures. They should not be taken into account in the percentage of rejected data (neither the numerator nor denominator).

4.4 The criteria for the production of the monthly list of suspect stations are as follows:

##### 4.4.1 List 1: Mean sea-level pressure

- Number of observations: at least 20;
- One or more of the following:
  - Absolute value of the mean bias  $\geq 4$  hPa;

- Standard deviation  $\geq 6$  hPa;
- Percentage gross error  $\geq 25\%$  (gross error limit: 15 hPa).

#### 4.4.2 **List 2: Wind speed**

- Number of observations: at least 20;
- One or more of the following:
  - Absolute value of the mean bias  $\geq 5$  m s<sup>-1</sup>;
  - Percentage gross error  $\geq 25\%$  (25 m s<sup>-1</sup> vector wind).

#### 4.4.3 **List 3: Wind direction**

Data for which the wind speed is less than 5 m s<sup>-1</sup>, either observed or calculated, should be excluded from the statistics.

- Number of observations: at least 20;
- One or more of the following:
  - Absolute value of the mean bias  $\geq 30^\circ$ ;
  - Standard deviation  $\geq 80^\circ$ ;
  - Percentage gross error  $\geq 25\%$  (gross error limit: 25 m s<sup>-1</sup> vector wind).

#### 4.4.4 **List 4: Air temperature**

- Number of observations: at least 20;
- One or more of the following:
  - Absolute value of the mean bias  $> 4$  °C;
  - Standard deviation  $> 6$  °C;
  - Percentage gross error  $> 25\%$  (gross error limit: 15 °C).

#### 4.4.5 **List 5: Relative humidity**

- Number of observations: at least 20;
- One or more of the following:
  - Absolute value of the mean bias  $> 30\%$ ;
  - Standard deviation  $> 40\%$ ;
  - Percentage gross error  $> 25\%$  (gross error limit: 80%).

#### 4.4.6 **List 6: Sea-surface temperature**

- Number of observations: at least 20;
- One or more of the following:
  - Absolute value of the mean bias  $> 3$  °C;
  - Standard deviation  $> 5$  °C;
  - Percentage gross error  $> 25\%$  (gross error limit: 10 °C).

### 5. **AIRCRAFT DATA**

5.1 The criteria for the production of the monthly list of suspect aircraft temperature and wind observations are described below.

5.1.1 Automated aircraft observations, both the aircraft meteorological data relay observing system and the aircraft communications addressing and reporting system, will separately be listed as suspect for temperatures and winds in three pressure categories if the data statistics exceed the criteria defined in 5.1.2. The three pressure categories are: low surface to

701 hPa; mid to 700 to 301 hPa; and high to 300 hPa and above. To be considered as suspect, the number of observations must meet minimal counts and the data statistics versus the guess must exceed at least one criterion or the gross rejection rate must exceed 2%. Thus, if the magnitude of either the temperature or the speed bias exceeds the criterion, or the RMS differences to the guess exceed the limit for the pressure category, then the aircraft is listed as suspect for that pressure category. Observations differing from the guess by amounts larger than gross check limits will be considered gross and not used in computing bias and RMS differences. If the number of gross observations (NG) for a pressure category exceeds 2% of the total number of checked observations, then the aircraft will be listed as suspect. After data thinning for assimilation, the remaining number of observations is NT. The number of rejected observations excluding thinning (NR) is an optional statistic for information, and for which operational practice should be documented.

**List: Temperature and wind:**

- Month/year;
- Monitoring centre;
- Standard of comparison (first-guess/background field).

Each aircraft that is suspect will be listed as follows in one line:

- Aircraft ID;
- Pressure category;
- Total number of available observations (NA);
- NG;
- NT;
- NR;
- Bias;
- RMS difference to the guess;
- For wind reports, the number of exactly calm winds (NC).

**5.1.2 Suspect automated aircraft temperatures and winds observations criteria**

<i>Variable</i>	<i>Low</i>	<i>Mid</i>	<i>High</i>
Gross temperature (K)	15.0	10.0	10.0
Temperature bias (K)	3.0	2.0	2.0
Temperature RMS (K)	4.0	3.0	3.0
Minimum count	20	50	50
Gross wind (m s <sup>-1</sup> )	30.0	30.0	40.0
Wind speed bias (m s <sup>-1</sup> )	3.0	2.5	2.5
Wind RMS (m s <sup>-1</sup> )	10.0	8.0	10.0
Minimum count	20	50	50

**5.1.3 AIREPS**

Monthly exchange for AIREPS of observations should include lists of airlines with the following information:

- Month/year;
- Monitoring centre;
- Standard of comparison (first-guess/background field);
- Selection criteria:

- Number of observations  $\geq 20$ ;
- Levels monitored:
  - 300 hPa and above;
- Elements monitored:
  - Wind and temperature;
- Data to be listed for each airline:
  - Airline ID;
  - Number of observations;
  - Number of rejected observations;
  - Number of gross errors;
  - Number of calm winds ( $< 5 \text{ m s}^{-1}$ );
  - RMS excluding gross errors;
  - Bias excluding gross errors (wind speed and temperature);
  - Gross error limits are:
    - Wind  $40 \text{ m s}^{-1}$ ;
    - Temperature  $10 \text{ }^\circ\text{C}$ .

## 6. SATELLITE DATA

Satellite data monitoring criteria are as specified in the following table:

<i>Geostationary satellite wind (centres must specify either SATOB or BUFR code, as assimilated, and channels)</i>	<i>Recommended criteria</i>
Monitoring satellites	Current operational satellites
Monitoring layers	Upper (101–400 hPa) Middle (401–700 hPa) Lower (701–1 000 hPa)
Minimum observation count	20 (in $10^\circ$ box), 10 (in $5^\circ$ box)
Gross error limit ( $\text{m s}^{-1}$ )	60
Availability map (averaged observation number in 24 hours)	$10^\circ \times 10^\circ$ OR $5^\circ \times 5^\circ$ for all levels
Map: Wind observed value	$10^\circ \times 10^\circ$ OR $5^\circ \times 5^\circ$ for each layer
Map: O-FG wind vector difference (bias)	$10^\circ \times 10^\circ$ OR $5^\circ \times 5^\circ$ for each layer
Map: O-FG wind speed difference (bias)	$10^\circ \times 10^\circ$ OR $5^\circ \times 5^\circ$ for each layer
Map: O-FG RMS of wind vector difference	$10^\circ \times 10^\circ$ OR $5^\circ \times 5^\circ$ for each layer
	The following statistics for all levels, high, medium and low in all regions, N and S extra tropics and tropics for satellite in use and selected channels:  MVD = Mean vector difference RMSVD = Vector difference RMS BIAS = Speed bias SPD = FG/background wind speed NCMV = Number of disseminated SATOB winds
Orbital satellite SATEM	
Monitoring satellites	Current operational satellites
Monitoring parameters	Thickness layers (hPa) 850–1 000, 100–300, 30–50
Gross error limit (m)	150 (1 000–850 hPa), 400 (300–100 hPa), 500 (50–30 hPa)
Availability map (averaged observation number in 24 h)	$5^\circ \times 5^\circ$ OR $10^\circ \times 10^\circ$ for each layer
Map: O-FG thickness difference (bias)	$5^\circ \times 5^\circ$ OR $10^\circ \times 10^\circ$ for each layer
Map: O-FG RMS of thickness difference	$5^\circ \times 5^\circ$ OR $10^\circ \times 10^\circ$ for each layer
Orbital satellite	

<i>Geostationary satellite wind (centres must specify either SATOB or BUFR code, as assimilated, and channels)</i>	<i>Recommended criteria</i>
Atmospheric soundings	
Monitoring satellites	Current operational satellites
Monitoring parameters	Uncorrected brightness temperatures primarily, plus corrected
Monitoring channels	The Lead Centre(s) will recommend a selection of channels to be monitored
Availability map (averaged observation number in 24 h)	5°×5° OR 10°×10° for each satellite
Map: O-FG difference (bias)	5° × 5° OR 10° × 10° for each satellite
Map: O-FG SD of difference	5° × 5° OR 10° × 10° for each satellite
Sea-surface wind (e.g. scatterometers, SSM/I)	Follow guidelines as above for satellite winds where possible, but applied to surface only
Any other satellite product	The pioneering centre can set the initial standard, based on the above guidelines for similar parameters, or a new standard for a new product. Report back to the Lead Centre(s) for information

Acronyms not previously defined: BUFR – binary universal form for the representation of meteorological data; SATOB – report of satellite observations for wind, surface temperature, cloud, humidity and radiation; SSM/I – special sensor microwave imager

## APPENDIX 2.2.1. MANDATORY AND RECOMMENDED GLOBAL DETERMINISTIC NUMERICAL WEATHER PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

### 1. Numerical weather prediction gridded products

#### Mandatory products

<i>Parameter</i>	<i>Level</i>	<i>Resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Geopotential height	850/500/250/200 hPa				
Temperature	850/500/250/200 hPa				
Wind zonal velocity (u) and meridional velocity (v)	925/850/700/500/250/200 hPa				
Relative humidity	850/700/500/200 hPa				
Mean sea-level pressure (MSLP)	Surface	0.5° × 0.5°	Up to 3 days/ Beyond 3 days up to 6 days	Every 3 hours/ Every 6 hours	Twice a day
2-m temperature					
2-m minimum and maximum temperatures in the last 3-hour/6-hour period					
2-m dewpoint temperature					
10-m u, 10-m v					
10-m wind gust <sup>a</sup>					
Total precipitation					
Total solid precipitation <sup>b</sup>					
CAPE <sup>c</sup>					
Total precipitable water					
Total cloud cover					

<sup>a</sup> Wind gust is the maximum gust in the last 3-hour or 6-hour period.

<sup>b</sup> Water equivalent of total solid precipitation is the combination of snow and graupel (ice pellets) (where available); snow and graupel can be provided as two separate parameters.

<sup>c</sup> CAPE: Convective Available Potential Energy. Provision of the most unstable CAPE (MUCAPE) is recommended. RSMCs are required to provide information, on the model characteristics web page, as to which type of CAPE is provided.

**Recommended products:**

- More fields describing precipitation type;
- Mid-level CAPE;
- 1-hour accumulated total precipitation;
- Snow depth;
- Divergence and vorticity (925/850/700/500/250/200 hPa);
- Downward solar radiation at surface;
- Outgoing long-wave radiation at the top of atmosphere;
- Heatwave index;
- The u and v wind components at the additional heights of 80 m, 100 m, 120 m or 150 m above the ground.

Providing data additionally in the form of map layers, graphics or visualization, as well as providing the option to access high-resolution data (up to full model resolution), are also recommended.

**2. Tropical low/cyclone vortex variables**

Vortices of tropical cyclones that exist at the analysis time or that form in the forecast time range should be tracked and included in the parameter file. In this context, “tropical cyclone” is a generic term for a non-frontal synoptic-scale low-pressure system which has a cyclone wind circulation. The recommended criteria can be found in the [Guide to the WMO Integrated Processing and Prediction System](#) (WMO-No. 305) (hereinafter, “*Guide to the WIPPS*”), Appendix 2.3. **If a track has a fix at the analysis time and can be associated with an analysis position from an RSMC conducting tropical cyclone forecasting, then the track shall have the RSMC identifier and name (if it is named).**

**Mandatory products**

<i>Parameter</i>	<i>Unit</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Location (latitude and longitude) of the vortex centre	[degree]	Up to 6 days <sup>c</sup>	Every 6 hours	Twice a day <sup>d</sup>
Maximum sustained 10-m wind speed	[m/s]			
Location <sup>a</sup> (latitude and longitude) of maximum sustained 10-m wind	[degree]			
Minimum mean sea-level pressure (MSLP)	[hPa]			
Quadrant radii of sustained 10-m winds of 28/34/50 <sup>b</sup> /64 kt	[km]			

<sup>a</sup> The recommended procedures for calculating the location of maximum wind is provided in the *Guide to the WIPPS*, Appendix 2.3.

<sup>b</sup> Centres may provide the quadrant radii for 48-kt winds instead of the quadrant radii for 50-kt winds.

<sup>c</sup> Beyond about 6 days, it is recommended that users use ensemble data, and only use the deterministic data as an additional ensemble member.

<sup>d</sup> Providing all mandatory products four times a day or more frequently and with time steps of every 3 hours is recommended.

**Recommended products**

<i>Parameter</i>	<i>Unit</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Average steering wind zonal (u) and meridional (v) <sup>a</sup> velocities at 850/500/200 hPa	[m/s]	Up to 6 days <sup>b</sup>	Every 6 hours	Twice a day <sup>c</sup>

<sup>a</sup> The recommended procedure for calculating average steering wind is provided in the *Guide to the WIPPS*,

Appendix 2.3.

- <sup>b</sup> Beyond about 6 days, it is recommended that users use ensemble data, and only use the deterministic data as an additional ensemble member.
  - <sup>c</sup> Providing all recommended products four times a day or more frequently is strongly recommended.
-

## **APPENDIX 2.2.2. CHARACTERISTICS OF GLOBAL DETERMINISTIC NUMERICAL WEATHER PREDICTION SYSTEMS**

### **1. System**

- System name (version):
- Date of implementation:

### **2. Configuration**

- Horizontal resolution of the model, with indication of grid spacing in km:
- Number of model levels:
- Top of model:
- Forecast length and forecast step interval:
- Runs per day (times in UTC):
- Is model coupled to ocean, wave, sea-ice models? Specify which models:
- Integration time step:
- Additional comments:

### **3. Initial conditions**

- Data assimilation method:
- Additional comments:

### **4. Surface boundary conditions**

- Sea-surface temperature? If yes, briefly describe method(s):
- Land-surface analysis? If yes, briefly describe method(s):
- Additional comments:

### **5. Other details of model**

- What kind of soil scheme is in use?
- How are radiations parameterized?
- What kind of large-scale dynamics is in use (for example, grid-point semi-Lagrangian)?  
Hydrostatic or non-hydrostatic?
- What kind of boundary layer parameterization is in use?
- What kind of convection parameterization is in use?
- What cloud scheme is in use?
- Other relevant details?

### **6. Products**

- Method of the calculation of mandatory and recommended products, for example, those relating to tropical low/cyclone vortex, if the method is not unique:
- Definition of tropical cyclone in numerical model output:
- Other detailed specifications, if necessary:

### **7. Further information**

- Operational contact point:

- URLs for system documentation:
  - URL for list of products:
-

## APPENDIX 2.2.3. MANDATORY AND RECOMMENDED LIMITED-AREA DETERMINISTIC NUMERICAL WEATHER PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

### Mandatory products

<i>Parameter</i>	<i>Level</i>	<i>Resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Geopotential height	925/850/700/500/250 hPa	0.25° × 0.25°	2 days	Every 3 hours (every 1 hour for total and convective precipitation)	Twice a day
Temperature	925/850/700/500/250 hPa				
u, v	925/850/700/500/250 hPa				
Relative humidity	925/850/700/500 hPa				
Divergence, vorticity	925/850/700/500/250 hPa				
Mean sea-level pressure (MSLP)	Surface				
2-m temperature					
2-m dewpoint temperature					
2-m 3-hourly minimum and maximum temperature					
10-m u, 10-m v					
10-m wind gust <sup>a</sup>					
Total precipitation (1-hour accumulation)					
Convective precipitation (1-hour accumulation, where available)					
CAPE <sup>b</sup>					
Low and medium cloud coverage					
Total cloud coverage					
Precipitation type					

<sup>a</sup> Wind gust is the maximum gust in the period of the last 3 hours.

<sup>b</sup> Provision of the most unstable CAPE (MUCAPE) is recommended. RSMCs are required to provide information on the model characteristics web page as to which type of CAPE is provided.

### Recommended products

- Vertical velocity (925, 850, 700, 500 hPa);

- Tropical storm tracks (latitudinal/longitudinal locations, maximum sustained wind speed, mean sea-level pressure (MSLP));
  - Convective inhibition (CIN);
  - 2-m visibility;
  - Lightning;
  - Downward solar radiation at surface;
  - Surface UV radiation.
-

## **APPENDIX 2.2.4. CHARACTERISTICS OF LIMITED-AREA DETERMINISTIC NUMERICAL WEATHER PREDICTION SYSTEMS**

### **1. System**

- System name:
- Date of implementation:

### **2. Configuration**

- Domain:
- Horizontal resolution of the model, with indication of grid spacing in km:
- Number of model levels:
- Top of model:
- Forecast length and forecast step interval:
- Runs per day (times in UTC):
- Is model coupled to ocean, wave, sea-ice models? Specify which models:
- Integration time step:
- Additional comments:

### **3. Initial conditions**

- Data assimilation method:
- Additional comments:

### **4. Surface boundary conditions**

- Sea-surface temperature? If yes, briefly describe method(s):
- Land-surface analysis? If yes, briefly describe method(s):
- Additional comments:

### **5. Lateral boundary conditions**

- Model providing lateral boundary conditions:
- Lateral boundary conditions update frequency:

### **6. Other details of model**

- What kind of soil scheme is in use?
- How are radiations parameterized?
- What kind of large-scale dynamics is in use (for example, grid-point semi-Lagrangian)?  
Hydrostatic or non-hydrostatic?
- What kind of boundary layer parameterization is in use?
- What kind of convection parameterization is in use?
- What cloud/microphysics scheme is in use?
- Other relevant details?

### **7. Further information**

- Operational contact point:
  - URLs for system documentation:
  - URL for list of products:
-

## APPENDIX 2.2.5. MANDATORY AND RECOMMENDED GLOBAL ENSEMBLE PREDICTION SYSTEM PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

### 1. Numerical weather prediction gridded products

#### Mandatory products

<i>Parameter</i>	<i>Level</i>	<i>Thresholds<sup>a</sup></i>	<i>Resolution (lat/lon grid)</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Probability of total precipitation in the last 6 hours and 24 hours	Surface	1, 5, 10, 25, 50 and 100 mm/24 hours 1, 5, 10, 25 and 50 mm/6 hours	0.5° × 0.5°	14 days (or the maximum range if less)	Every 3 hours to 72 hours, then every 6 hours	Twice a day
Percentiles for total precipitation in the last 6 hours and 24 hours	Surface	25th, 50th, 75th, maximum				
Percentiles for total solid precipitation <sup>b</sup> in the last 6 hours	Surface	25th, 50th, 75th, maximum				
Percentiles for temperature	2 m, 850 hPa	min, 25th, 50th, 75th, maximum				
Probability of wind speed	10 m	10, 15, 20 and 25 m s <sup>-1</sup>				
Percentiles for wind speed	10 m, 850 hPa, 250 hPa	min, 25th, 50th, 75th, maximum				
Probability of 10-m wind gust <sup>c</sup>	10 m	15, 25 and 35 m s <sup>-1</sup>				
Percentiles for 10-m wind gust <sup>c</sup>	10 m	min, 25th, 50th, 75th, maximum				
Percentiles for CAPE <sup>d</sup>	Surface	25th, 50th, 75th, maximum				
Percentiles for magnitude of wind shear	Vector difference between 250 hPa and 850 hPa  Vector difference between 700 hPa and 925 hPa	min, 25th, 50th, 75th, maximum				
Percentiles for total cloud cover	Surface	min, 25th, 50th, 75th, maximum				

Parameter	Level	Thresholds <sup>a</sup>	Resolution (lat/lon grid)	Forecast range	Time steps	Frequency
Ensemble mean and spread (standard deviation) of geopotential height	500 hPa		0.5° × 0.5°	14 days (or the maximum range if less)	Every 3 hours to 72 hours, then every 6 hours	Twice a day
Ensemble mean and spread (standard deviation) of mean sea-level pressure (MSLP)	Surface					

- <sup>a</sup> The maximum and minimum percentiles should be represented by an extreme percentile. The most appropriate percentile depends on the configuration of the NWP model and any post-processing, and is to be chosen by the producing centre.
- <sup>b</sup> Water equivalent of total solid precipitation is the combination of snow and graupel (ice pellets) (where available); snow and graupel can be provided as two separate parameters.
- <sup>c</sup> Wind gust is the maximum gust in the last 3-hour or 6-hour period.
- <sup>d</sup> Provision of the most unstable CAPE (MUCAPE) is recommended. RSMCs are required to provide information on the model characteristics web page as to which type of CAPE is provided.

### Recommended products

- Location-specific time series of temperature, precipitation, wind speed, depicting the most likely solution and an estimation of uncertainty (“EPSgrams”); the definition, method of calculation and the locations should be documented;
- Probability of temperature anomalies, at 850 hPa, for  $\pm 1$ ,  $\pm 1.5$ ,  $\pm 2$  standard deviations with respect to a reanalysis climatology specified by the producing centre;
- Percentiles of the following variables:
  - Mid-level CAPE;
  - 1-hour or 3-hour accumulated total precipitation;
  - Snow depth, snow water equivalent (SWE);
  - Heatwave index;
  - Wind u and v at additional heights of 80 m, 100 m, 120 m or 150 m above the ground.

Providing data additionally in the form of high-resolution map layers, graphics or visualization is also recommended. Options to access high-resolution data (up to full model resolution), additional percentile values and probability thresholds, as well as all ensemble members, are also recommended.

## 2. Tropical low/cyclone vortex variables

Vortices of tropical cyclones that exist at the analysis time or that form in the forecast time range should be tracked and included in the parameter file. In this context, “tropical cyclone” is a generic term for a non-frontal synoptic-scale low-pressure system which has a cyclone wind circulation. The recommended criteria can be found in the *Guide to the WIPPS*, Appendix 2.3. **If a track has a fix at the analysis time and can be associated with an analysis position from an RSMC conducting tropical cyclone forecasting, then the track shall have the RSMC identifier and name (if it is named).**

**The RSMCs shall produce the following listed parameters from all ensemble members of the global ensemble prediction system.**

**Mandatory products**

<i>Parameter</i>	<i>Unit</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Location (latitude and longitude) of the vortex centre	[degree]	14 days (or the maximum range if less)	Every 6 hours	Twice a day <sup>c</sup>
Maximum sustained 10-m wind speed	[m/s]			
Location <sup>a</sup> (latitude and longitude) of maximum sustained 10-m wind	[degree]			
Minimum mean sea-level pressure (MSLP)	[hPa]			
Quadrant radii of sustained 10-m winds of 28/34/50 <sup>b</sup> /64 kt	[km]			

<sup>a</sup> The recommended procedure for calculating the location of maximum wind is provided in the *Guide to the WIPPS*, Appendix 2.3.

<sup>b</sup> Centres may provide the quadrant radii for 48-kt winds instead of the quadrant radii for 50-kt winds.

<sup>c</sup> Providing all mandatory products four times a day or more frequently, and with time steps of every 3 hours is recommended.

**Recommended products**

<i>Parameter</i>	<i>Unit</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Average steering wind zonal (u) and meridional (v) <sup>a</sup> velocities at 850/500/200 hPa	[m/s]	14 days (or the maximum range if less)	Every 6 hours	Twice a day <sup>b</sup>

<sup>a</sup> The recommended procedure for calculating average steering wind is provided in the *Guide to the WIPPS*, Appendix 2.3

<sup>b</sup> Providing all recommended products four times a day or more frequently is strongly recommended.

## **APPENDIX 2.2.6. CHARACTERISTICS OF THE GLOBAL ENSEMBLE PREDICTION SYSTEM**

### **1. Ensemble system**

- Ensemble name (version):
- Date of implementation:

### **2. Configuration of the Ensemble Prediction System**

- Horizontal resolution of the model, with indication of grid spacing in km:
- Number of model levels:
- Top of model:
- Forecast length and forecast step interval:
- Runs per day (times in UTC):
- Is there an unperturbed control forecast included?
- Number of perturbed ensemble members (excluding control):
- Is model coupled to ocean, wave, sea-ice models? Specify which models:
- Integration time step:
- Additional comments:

### **3. Initial conditions and perturbations**

- Initial perturbation strategy:
- Optimization time in forecast (if applicable):
- Horizontal resolution of perturbations (if different from model resolution):
- Initial perturbed area:
- Data assimilation method for control analysis:
- Are perturbations to observations employed? If so, which observation types are perturbed?
- Perturbations added to control analysis or derived directly from ensemble analysis:
- Perturbations in +/- pairs?
- Additional comments:

### **4. Model uncertainty perturbations**

- Is model physics perturbed? If so, briefly describe method(s):
- Do all ensemble members use exactly the same model version, or are, for example, different parameterization schemes used? Please describe any differences:
- Is model dynamics perturbed? If so, briefly describe method(s):
- Are the above model uncertainty perturbations applied to the control forecast?
- Additional comments:

### **5. Surface boundary perturbations**

- Perturbations to SST? If so, briefly describe method(s):
- Perturbations to soil moisture? If so, briefly describe method(s):
- Perturbations to surface wind stress or roughness? If so, briefly describe method(s):
- Any other surface perturbations? If so, briefly describe method(s):
- Are the above surface perturbations applied to the control forecast?
- Additional comments:

**6. Other details of model**

- What kind of soil scheme is in use?
- How are radiations parameterized?
- What kind of large-scale dynamics is in use (for example, grid-point semi-Lagrangian)?  
Hydrostatic or non-hydrostatic?
- What kind of boundary layer parameterization is in use?
- What kind of convection parameterization is in use?
- What cloud scheme is in use?
- Other relevant details?

**7. Products**

- Method of calculation of mandatory and recommended products, for example, those relating to tropical low/cyclone vortex, if the method is not unique:
- Definition of tropical cyclone in numerical model output:
- Other detailed specifications, if necessary:

**8. Further information**

- Operational contact point:
  - URLs for system documentation:
  - URL for list of products:
-

## APPENDIX 2.2.7. MANDATORY AND RECOMMENDED LIMITED-AREA ENSEMBLE PREDICTION SYSTEM PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

### Mandatory products

<i>Parameter</i>	<i>Level</i>	<i>Thresholds</i>	<i>Resolution (lat/lon grid)</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Probability of total precipitation	Surface	1, 5, 10, 25, 50 and 100 mm/24 hours 1, 5, 10, 25 and 50 mm/3 hours	0.25° × 0.25°	2 days (or the maximum range if less)	Every 3 hours	Once a day
Percentiles for total precipitation in the last 3 hours	Surface	25th, 50th, 75th, maximum				
Percentiles for temperature	2 m, 850 hPa	min, 25th, 50th, 75th, maximum				
Percentiles for dewpoint temperature	2 m	min, 25th, 50th, 75th, maximum				
Probability of 10-m sustained wind	10 m	10, 15, 20 and 25 m s <sup>-1</sup>				
Percentiles for wind speed	10 m	min, 25th, 50th, 75th, maximum				
Probability of 10-m wind gust	10 m	15, 25 and 35 m s <sup>-1</sup>				
Percentiles for wind gust (maximum during period)	10 m	25th, 50th, 75th, maximum				
Percentiles for CAPE	Surface	25th, 50th, 75th, maximum				
Percentiles for magnitude of wind shear	Vector difference between 250 hPa and 850 hPa	min, 25th, 50th, 75th, maximum				
Percentiles for total cloud cover	Surface	min, 25th, 50th, 75th, maximum				

### Recommended products:

- Location-specific time series of temperature, precipitation, wind speed, depicting the most likely solution and an estimation of uncertainty (“EPSgrams”); the definition, method of calculation and the locations should be documented;
- Tropical storm tracks (latitudinal/longitudinal locations, maximum sustained wind speed, mean sea-level pressure (MSLP) from EPS members), where applicable;
- Probability of lightning;
- Probability of 2-m visibility;
- Ensemble mean and spread of MSLP and geopotential height at 850, 700 and 500 hPa;
- Percentiles of additional variables, which might include:

- Mid-level CAPE;
- 1-hour accumulated total precipitation;
- Downward solar radiation at surface;
- Outgoing long-wave radiation at the top of the atmosphere;
- Wind u and v at additional heights of 80 m, 100 m, 120 m or 150 m above ground.

Providing data additionally in the form of map layers, graphics or visualization is also recommended. Options to access high-resolution data (up to full model resolution), additional percentile values and probability thresholds, as well as all ensemble members, are also recommended.

---

## **APPENDIX 2.2.8. CHARACTERISTICS OF LIMITED-AREA ENSEMBLE PREDICTION SYSTEM**

### **1. Ensemble system**

- Ensemble name (version):
- Date of implementation:

### **2. Configuration of the Ensemble Prediction System**

- Horizontal resolution of the model, with indication of grid spacing in km:
- Number of model levels:
- Top of model:
- Forecast length and forecast step interval:
- Runs per day (times in UTC):
- Is there an unperturbed control forecast included?
- Number of perturbed ensemble members (excluding control):
- Is model coupled to ocean, wave, sea-ice models? Specify which models:
- Integration time step:
- Additional comments:

### **3. Initial conditions and perturbations**

- Initial perturbation strategy:
- Optimization time in forecast (if applicable):
- Horizontal resolution of perturbations (if different from model resolution):
- Initial perturbed area:
- Data assimilation method for control analysis:
- Are perturbations to observations employed? If so, which observation types are perturbed?
- Perturbations added to control analysis or derived directly from ensemble analysis:
- Perturbations in +/- pairs?
- Additional comments:

### **4. Model uncertainty perturbations**

- Is model physics perturbed? If so, briefly describe method(s):
- Do all ensemble members use exactly the same model version, or are, for example, different parameterization schemes used? Please describe any differences:
- Is model dynamics perturbed? If so, briefly describe method(s):
- Are the above model uncertainty perturbations applied to the control forecast?
- Additional comments:

### **5. Surface boundary perturbations**

- Perturbations to SST? If so, briefly describe method(s):
- Perturbations to soil moisture? If so, briefly describe method(s):
- Perturbations to surface wind stress or roughness? If so, briefly describe method(s):
- Any other surface perturbations? If so, briefly describe method(s):
- Are the above surface perturbations applied to the control forecast?
- Additional comments:

**6. Other details of model**

- What kind of soil scheme is in use?
- How are radiations parameterized?
- What kind of large-scale dynamics is in use (for example, grid-point semi-Lagrangian)?  
Hydrostatic or non-hydrostatic?
- What kind of boundary layer parameterization is in use?
- What kind of convection parameterization is in use?
- What cloud/microphysics scheme is in use?
- Other relevant details:

**7. Regional ensemble specifics**

- Regional domain descriptor (latitude/longitude of boundaries):
- Normal source of lateral boundary conditions:
- Are lateral boundary conditions perturbed?
- Specification of lateral boundary conditions required:
- Are lateral boundary condition requirements compatible with any other global models or standards? If so, please describe:
- Additional comments:

**8. Products**

- Method of the calculation, if the method is not unique:
- Other detailed specifications, if necessary:

**9. Further information**

- Operational contact point:
  - URLs for system documentation:
  - URL for list of products:
-

## APPENDIX 2.2.9. MANDATORY AND RECOMMENDED GLOBAL NUMERICAL SEASONAL PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

### Mandatory products (maps)

<i>Variable</i>	<i>Coverage</i>	<i>Forecast range or lead time</i>	<i>Temporal resolution</i>	<i>Output type</i>	<i>Issuance frequency</i>
2-m temperature	Global	Minimum forecast range of four months	Averages over one month or longer periods (seasons)	(1) Ensemble mean anomaly  (2) Probabilities for tercile forecast categories (where applicable)	Monthly
Sea-surface temperature (SST)	Global oceans				
Monthly accumulated total precipitation	Global				

Notes:

1. SST is a mandatory product only for centres operating one-tier systems.
2. Provision of probabilities for extremes, for the variables specified under mandatory products, are recommended.

### Recommended products (maps)

<i>Variable</i>	<i>Coverage</i>	<i>Forecast range or lead time</i>	<i>Temporal resolution</i>	<i>Output type</i>	<i>Issuance frequency</i>
500-hPa height	Global	Minimum forecast range of four months	Averages over one month or longer periods (seasons)	(1) Ensemble mean anomaly  (2) Probabilities for tercile forecast categories	Monthly
Mean sea-level pressure (MSLP)					
850-hPa temperature					

### Recommended products (SST indices)

<i>Index</i>	<i>Description</i>	<i>Coordinates</i>
Pacific Ocean		
Niño 1+2	Region off coasts of Peru and Chile	90°W–80°W, 10°S–0°
Niño 3	Eastern/central tropical Pacific	150°W–90°W, 5°S–5°N
Niño 3.4	Central tropical Pacific	170°W–120°W, 5°S–5°N
Niño 4	Western/central tropical Pacific	160°E–150°W, 5°S–5°N
Atlantic Ocean		
TNA	Tropical North Atlantic	55°W–15°W, 5°N–25°N
TSA	Tropical South Atlantic	30°W–10°E, 20°S–0°
TAD	Tropical Atlantic Dipole	TNA-TSA
Indian Ocean		
WTIO	Western tropical Indian Ocean	50°E–70°E, 10°S–10°N
SETIO	South-eastern tropical Indian Ocean	90°E–110°E, 10°S–0°
IOD (DMI)	Indian Ocean Dipole (Dipole Mode Index)	WTIO–SETIO

## Notes:

1. Extremes (products are recommended, not mandatory) – the recommended definitions to be used for extremes are below the 20th percentile and above the 80th percentile.
  2. Output types – rendered images (for example, forecast maps and diagrams). Note: GPCs-SP are encouraged to make available the retrospective forecast (hindcast) and forecast fields underlying the products. Gridded binary-2 (GRIB-2) format should be used for fields posted on FTP sites or disseminated through WIS.
  3. Definition of lead time – for example, a three-monthly forecast issued on 31 December has a lead time of zero months for a January to March seasonal mean forecast, and a lead time of one month for a February to April seasonal mean forecast.
  4. For all products, forecasts are to be expressed relative to a climatology using at least 15 years of retrospective forecasts.
  5. Information on how category boundaries are defined should be made available.
  6. Indices are to be displayed using “plumes” of individual ensemble members and/or the “climagram” approach.
  7. Indications of skill will be provided in accordance with Appendix 2.2.35.
  8. SST indices are recommended products only for centres operating one-tier systems.
-

## **APPENDIX 2.2.10. CHARACTERISTICS OF GLOBAL NUMERICAL SEASONAL PREDICTION SYSTEMS**

- Date of implementation of the current seasonal prediction system:
  - Whether the system is a coupled ocean-atmosphere forecast system:
  - Whether the system is a tier-2 forecast system:
  - Atmospheric model resolution:
  - Ocean model and its resolution (if applicable):
  - Source of atmospheric initial conditions:
  - Source of ocean initial conditions:
  - If tier-2, the source of SST predictions:
  - Hindcast period:
  - Ensemble size for the hindcasts:
  - Method of configuring the hindcast ensemble:
  - Ensemble size for the forecast:
  - Method of configuring the forecast ensemble:
  - Length of forecasts:
  - Data format:
  - The latest date that predicted anomalies for the next month/season become available:
  - Method of construction of the forecast anomalies:
  - URL where forecast are displayed:
  - Point of contact:
-

## APPENDIX 2.2.11. MANDATORY AND RECOMMENDED NUMERICAL OCEAN WAVE PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

### Mandatory products

<i>Parameter</i>	<i>Level</i>	<i>Minimum resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Significant wave height	Surface	0.5° × 0.5°	Up to 2 days/ Beyond 3 days up to 7 days	Every 3 hours/ Every 6 hours	Twice a day
Peak wave period and mean zero-upcrossing period	Surface				
Prevailing direction – Mean wave direction and/or – Principle wave direction	Surface				

### Recommended products

- u and v component of 10-metre wind or 10 m wind speed and direction;
  - Full 2-D wave spectra at subset of grid points;
  - Wind sea and swell split at all grid points, including swell partitioned parameters;
  - Derived parameters including wave steepness, directional spreading and rogue wave potential.
-

## **APPENDIX 2.2.12. CHARACTERISTICS OF THE NUMERICAL OCEAN WAVE PREDICTION SYSTEMS**

### **1. System**

- System name (version):
- Date of implementation:

### **2. Configuration**

- Horizontal resolution of the model, with indication of grid spacing in km:
- Number of model frequency bands:
- Number of model directional bands:
- Forecast length and forecast step interval:
- Runs per day (times in UTC):
- Is model coupled to ocean, atmosphere, sea-ice models? Specify which models:
- Integration time step:
- Additional comments:

### **3. Initial conditions**

- Data assimilation method for control analysis:
- Additional comments:

### **4. Surface boundary conditions**

- Surface forcing, briefly describe method(s):
- Lateral boundary conditions (for example, sea-ice cover)? If yes, briefly describe method(s):
- Additional comments:

### **5. Other details of model**

- What kind, if any, of sea-swell splitting scheme is in use?
- Are wave observations, or spectra, assimilated? If so, describe method briefly:
- Does the model contain shallow water physics? What bathymetry database is used for shallow water areas?
- Verification approach?
- Other relevant details?

### **6. Further information**

- Operational contact point:
  - URLs for system documentation:
  - URL for list of products:
-

## APPENDIX 2.2.13. MANDATORY AND RECOMMENDED GLOBAL NUMERICAL OCEAN PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

### Mandatory products

<i>Parameter</i>	<i>Level</i>	<i>Minimum resolution</i>	<i>Forecast range</i>	<i>Minimum time steps</i>	<i>Frequency</i>
Sea-surface elevation	Surface	0.25° × 0.25°	Up to 6 days	Every 24 hours	Once a day
SST	Surface (mixed layer)				
Surface u, v	Surface				
Sea-surface absolute salinity	Surface				
u, v	Depth to be determined				
Conservative temperature	10/50/100/250/500 (m)				
Absolute salinity	10/50/100/250/500 (m)				
Mixed layer depth					

\* Mixed layer depth based on temperature and/or density criteria

### Recommended products

- Tropical Cyclone Heat Potential (TCHP), defined as the integrated vertical temperature from the sea surface to the depth of the 26 °C isotherm;
- Ocean initial conditions for seasonal prediction;
- Sea-ice thickness and sea-ice extent.

---

## **APPENDIX 2.2.14. CHARACTERISTICS OF THE GLOBAL NUMERICAL OCEAN PREDICTION SYSTEMS**

### **1. System**

- System name (version):
- Date of implementation:

### **2. Configuration**

- Horizontal resolution of the model, with indication of grid spacing in km:
- Number of model levels:
- Topography data of model:
- Forecast length and forecast step interval:
- Runs per day (times in UTC):
- Is model coupled to atmosphere, wave, sea-ice models? Specify which models:
  - Atmosphere model characteristics (such as, but not limited to configuration, initial and boundary conditions):
  - Wave model characteristics (such as, but not limited to configuration, initial and boundary conditions):
  - Sea-ice model characteristics (such as, but not limited to resolution, rheology, number of sea-ice category):
- Integration time step:
- Horizontal and vertical coordinate system of the model:
- Additional comments:

### **3. Initial conditions**

- Climatology data of the model:
- Data assimilation method, including brief description:
- Observations being assimilated:
- Assimilated window:
- Additional comments:

### **4. Surface boundary conditions**

- Surface forcing, briefly describe method(s), frequency and origin of atmospheric surface forcing:
- Lateral boundary conditions (for example, river discharge)? If so, briefly describe method(s), frequency and origin of lateral boundary conditions:
- Additional comments:

### **5. Other details of the model**

- What kind of mixing scheme is in use?
- List vertical and horizontal mixing, diffusion schemes and ad hoc parameterization in use:
- Parameterization of surface boundary conditions (heat, fresh water, momentum)?
- What kind of large-scale dynamics is in use (for example, grid-point semi-Lagrangian)? Hydrostatic or non-hydrostatic?
- Quality control scheme?
- Verification approach?
- Other relevant details?

**6. Products delivered**

- Resolution of the products:
- Interpolation method if products are post-processed:
- Frequency of the products:
- Latency of the products (time between production and availability):
- Length of the time series available in the past:
- Definition of the Tropical Cyclone Heat Potential:

**7. Further information**

- Operational contact point:
  - URLs for system documentation:
  - URL for list of products:
  - Graphic and model data output:
-

## **APPENDIX 2.2.15. CHARACTERISTICS OF NOWCASTING SYSTEMS**

### **1. System**

- Application areas:
- Name(s) of system(s) involved:
- Date(s) of implementation:

### **2. Configuration**

- Domain and resolution:
- Parameters:
- Production cycle (frequency of updates, time range, time interval):
- Production methods (extrapolation, blending, NWP (deterministic or ensemble), expert system, human-machine interfaced system, and the like):
- Additional comments:

### **3. Input data**

- (For example, observations, analyses, numerical forecasts, ...):
- Additional comments:

### **4. NWP**

Refer to appendices related to the characteristics of global deterministic and limited-area NWP systems (Appendices 2.2.2 and 2.2.4, respectively), and characteristics of global and limited-area EPS (Appendices 2.2.6 and 2.2.8, respectively) (no need to repeat system description if available under those sections).

### **5. Output data (product)**

### **6. Data visualization system**

### **7. Verification system**

(For example, verified parameters, performance matrix, ...):

### **8. Further information**

- Operational contact point:
  - URLs for system documentation:
  - URL for list of products:
-

## APPENDIX 2.2.16. REGIONAL CLIMATE CENTRE MANDATORY FUNCTIONS

<i>Functions</i>	<i>Activities</i>	<i>Criteria</i>
<b>Operational activities for SP</b> (both dynamical and statistical, within the range of a one-month to two-year timescale, based on regional needs)	Interpret and assess relevant SP products from GPCs-SP, make use of the Lead Centre(s) for SPMME, distribute relevant information to RCC users, and provide feedback to GPCs-SP (see Attachment 2.2.1)	<b>Product:</b> Assessment of the reliability and outcomes of products from GPCs-SP or Lead Centre(s) for SPMME, including the reasoning (make use of verification metrics as defined in <a href="#">Guidance on Verification of Operational Seasonal Climate Forecasts</a> (WMO-No. 1220)), for the region of interest, in the form of texts, tables, figures, etc. <b>Element:</b> 2-m mean temperature, total precipitation <b>Update frequency:</b> Monthly or at least quarterly
	Generate regional and subregional tailored products, relevant to RCC user needs, including seasonal outlooks	<b>Product:</b> Probabilities for tercile (or appropriate quantile) categories for the region or subregion <b>Element:</b> 2-m mean temperature, total precipitation Output type: Rendered images (maps, charts), text, tables, digital data <b>Forecast period:</b> one month up to six months Update frequency: Ten days to one month
	Generate consensus* statement on regional or subregional forecasts  * A collaborative process involves discussion with experts in the region (e.g., through Regional Climate Outlook Forums (RCOFs) and teleconferencing). Consensus is both the agreed process and its joint conclusion, and the consensus can be that there is limited skill in the prediction for a region or subregion	<b>Product:</b> Consensus statement on regional or subregional forecast <b>Element:</b> 2-m mean temperature, total precipitation Output type: Report <b>Forecast period:</b> A climatologically significant period (from one month to one year) <b>Update frequency:</b> At least once per year (to be defined by the region)
	Perform verification of RCC quantitative SP products, including the exchange of basic forecasts and hindcast data	<b>Products:</b> Verification datasets (e.g. SVSSP scores, Brier skill score; relative operating characteristic (ROC); hit rate skill score) <b>Element:</b> 2-m mean temperature, total precipitation
	Provide online access to RCC products and services to RCC users	<b>Product:</b> An online data/information portal
	Assess use of RCC products and services through feedback from RCC users	<b>Product:</b> Analysis of feedback (which is made available using a template) <b>Update frequency:</b> Annually, as part of a regular reporting of RCCs to WMO RAs

<i>Functions</i>	<i>Activities</i>	<i>Criteria</i>
<b>Operational activities for climate monitoring</b>	Perform climate diagnostics, including analysis of climate variability and extremes, at the regional and subregional scales	<b>Products:</b> Climate diagnostics bulletin including tables, maps and related products <b>Element:</b> Mean, maximum and minimum temperatures, total precipitation; other elements (especially Global Climate Observing System (GCOS) essential climate variables) to be determined by region <b>Update frequency:</b> Monthly
	Establish a historical reference climatology for the region and/or subregions	<b>Product:</b> Database of climatological means for various reference periods (e.g., 1931–1960; 1951–1980; 1961–1990; 1971–2000) Spatial resolution: By station <b>Temporal resolution:</b> Monthly at a minimum <b>Elements:</b> Mean, maximum and minimum temperatures; total precipitation; other elements (especially GCOS essential climate variables) to be determined by region <b>Update frequency:</b> At least 30 years, preferably 10 years
	Implement a regional climate watch	<b>Products:</b> Climate advisories and information for RCC users <b>Update:</b> Whenever required, based on the forecast of significant regional climate anomalies
<b>Operational data services, to support operational SP and climate monitoring</b>	Develop quality-controlled regional climate datasets, gridded where applicable	<b>Products:</b> Regional, quality-controlled climate datasets, gridded where applicable, following SERCOM/SC-CLI guidance on procedures for quality control and assurance <b>Elements:</b> Mean, maximum and minimum temperature, and total precipitation, at a minimum <b>Temporal resolution:</b> Daily <b>Update:</b> Monthly
	Provide climate database and archiving services, at the request of NMHSs	<b>Products:</b> National databases with metadata, accessible to the NMHS in question (backup service, development site, etc.) <b>Elements:</b> As determined by NMHS <b>Update:</b> At the request of NMHS
<b>Training in the use of operational RCC products and services</b>	Provide information on methodologies and product specifications for mandatory RCC products, and provide guidance on their use	<b>Products:</b> Manuals, guidance documents and information notes <b>Update frequency:</b> When methods/products are revised, introduced or discontinued
	Coordinate training for RCC users in interpretation and use of mandatory RCC products	<b>Products:</b> Survey and analysis of regional training needs, and proposals for training activities

Note: An RCC is expected to perform certain functions (for example, for homogeneity testing; database management; metadata management; statistical evaluation of climate data) using procedures proposed in the [Guide to Climatological Practices](#) (WMO-No. 100) and in other official SERCOM/SC-CLI guidance documents.

## APPENDIX 2.2.17. MINIMUM INFORMATION TO BE AVAILABLE FROM THE LEAD CENTRE(S) FOR SEASONAL PREDICTION MULTI-MODEL ENSEMBLES

### 1. Digital products

Monthly mean global fields of the following forecast variables from GPCs-SP for individual ensemble members for at least each of the three months following the month of submission, for example, March, April, May if the month of submission is February.

#### Mandatory products

<i>Variable</i>	<i>Level</i>	<i>Resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Surface temperature	2 m	2.5° × 2.5°	Minimum of the three months following the month of submission	Monthly mean	Once a month
Sea-surface temperature (SST)	Surface				
Monthly accumulated total precipitation	Surface				
Mean sea-level pressure (MSLP)	Surface				
Temperature	850 hPa				
Geopotential height	500 hPa				
Velocity (u, v)	850 hPa				

Note: SST is a mandatory product only for centres operating one-tier systems.

#### Recommended products

<i>Variable</i>	<i>Level</i>	<i>Resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Sea-ice concentration	Surface	2.5° × 2.5°	Minimum of the three months following the month of submission	Monthly mean	Once a month
Snow water equivalent (SWE)	Surface				
Velocity (u, v)	10 m				
Velocity (u, v)	200 hPa				

## 2. Graphical mandatory products

### Forecast spatial maps

	<i>Variable</i>	<i>Forecast format type</i>	<i>Map type</i>	<i>Digital</i>
Forecast	Monthly accumulated total precipitation	DMME; PMME; Individual GPCs; Consistency maps	Global and regional maps; Various projections	Yes (only global)
	500-hPa geopotential height			
	Mean sea-level pressure (MSLP)			
	2-m temperature			
	850-hPa temperature			
	Sea-surface temperature (SST)			
	850-hPa zonal wind			
850-hPa meridional wind				

#### Notes:

1. The digital mandatory products required for generating the individual GPC's consistency maps do not need to be provided.
2. DMME: deterministic multi-model ensemble
3. PMME: probabilistic multi-model ensemble

### Forecast indices

	<i>Parameter</i>	<i>Forecast format type</i>	<i>Map type</i>	<i>Digital</i>
Forecast	Niño 1+2	DMME; Individual GPCs	Time series	No
	Niño 3			
	Niño 3.4			
	Niño 4			
	Indian Ocean Dipole Mode Index (DMI)			
	Tropical South Atlantic (TSA) index			
	Tropical North Atlantic (TNA) index			

**Verifications**

	<i>Variable</i>	<i>Verification for</i>	<i>Map type</i>	<i>Digital</i>
Hindcast	Monthly accumulated total precipitation	DMME; PMME; Individual GPCs	Global and regional maps	Yes (only global)
	500-hPa geopotential height			
	Mean sea-level pressure (MSLP)			
	2-m temperature			
	850-hPa temperature			
	Sea-surface temperature (SST)			
	850-hPa zonal wind			
	850-hPa meridional wind			

Note: Verify products using the Standardized Verification System for SP (SVSSP) (Appendix 2.2.35).

### 3. **Mandatory post-processed and original Global Producing Centre digital products**

Monthly mean global fields of forecast variables collected from GPCs-SP for individual ensemble members are listed in the table of mandatory variables in section 1 of the present Appendix.

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## **APPENDIX 2.2.18. ACCESS TO DATA AND VISUALIZATION PRODUCTS HELD BY THE LEAD CENTRE(S) FOR ANNUAL TO DECADAL CLIMATE PREDICTION**

- (a) Requests for contributing centre output should be referred to the relevant contributing centre in cases where the digital hindcast and forecast data from the relevant contributing centre is not archived at the Lead Centre.
  - (b) Institutions, including research centres, except contributing centres, RCCs, NMHSs and institutions coordinating RCOFs, may not use Lead Centre(s) for ADCP products to generate and display/disseminate independent products for operational forecasting. These institutions must agree with these restrictions.
-

## **APPENDIX 2.2.19. HINDCAST AND FORECAST DATA TO BE COLLECTED BY LEAD CENTRES FOR ANNUAL TO DECADAL CLIMATE PREDICTIONS AND PRODUCTS TO BE GENERATED AND DISPLAYED**

Contributing centres shall provide necessary hindcast and forecast data to the Lead Centre(s) for ADCP to allow generation of the following minimum products for each contributing centre and for the multi-model ensemble.

Stage 1:

- (a) Global maps of ensemble mean anomalies with indications of ensemble spread for the following variables averaged over at least year 1 and years 1–5 of the forecast:
  - Near-surface air temperature;
  - Precipitation;
  - Sea-level pressure;
- (b) Ensemble mean annual global mean near-surface temperature and indications of ensemble spread, for every year of the forecast;

Stage 2 (with two years of designation of the Lead Centre(s) for ADCP):

- (c) Global maps of probability for tercile categories (or other events) for the following variables averaged over at least year 1 and years 1–5 of the forecast:
    - Near-surface air temperature;
    - Precipitation;
    - Sea-level pressure.
-

## **APPENDIX 2.2.20. VERIFICATION INFORMATION TO BE COLLECTED BY THE LEAD CENTRES FOR ANNUAL TO DECADAL CLIMATE PREDICTION AND PRODUCTS TO BE DISPLAYED**

Hindcast verification:

**The Lead Centre(s) for ADCP shall collect hindcasts and/or verification results from each contributing centre to allow generation and display of the following for each predicted variable (near-surface air temperature, precipitation and sea-level pressure):**

**Stage 1:** Individual contributing centres:

- Global maps of grid-point temporal correlation of the ensemble mean with observations.

**Stage 2:** Individual contributing centres and the multi-model ensemble:

- Global maps of ROC scores for specified categories;
- Reliability and sharpness diagrams for specified categories for the agreed geographical regions.

Contributing centres must adhere to a specified configuration for hindcasts that will form part of criteria set by the Lead Centre(s) for ADCP. In accord with the Decadal Climate Prediction Project (DCPP) protocol, hindcasts will ideally be initialized each year from 1960 to the present, with initialization every other year (specified as 1960, 1962, etc.) as a minimum requirement. Hindcasts will be of sufficient range to verify performance out to at least five years ahead.

The following real-time verifications will be performed (valid only for stage 1):

- Side-by-side global maps of ensemble mean predicted and observed anomalies for temperature, precipitation and sea-level pressure for at least year 1 and years 1–5; regions where the observations lie outside the 5–95% model predicted range will be highlighted;
  - Spatial pattern correlation coefficients between observations and ensemble mean forecasts for global fields of temperature, precipitation and sea-level pressure;
  - A time series of observed annual mean global temperature, which will be updated each year and a graphic generated to compare the past-predicted and observed time series.
-

## **APPENDIX 2.2.21. ACTIVATION OF THE SUPPORT FOR NUCLEAR EMERGENCY RESPONSE AND STANDARDS IN THE PROVISION OF INTERNATIONAL SERVICES BY REGIONAL SPECIALIZED METEOROLOGICAL CENTRES**

### **Notification of WMO**

Within the framework of the Convention on Early Notification of a Nuclear Accident, IAEA informs the WMO Secretariat and the Data Collection or Production Centre (DCPC) of Regional Telecommunication Hub (RTH) Offenbach (Germany) of the status of the emergency. If needed, IAEA will request support from the WMO RSMCs. Beginning with a site area emergency, the DCPC of RTH Offenbach will disseminate the EMERCON messages on the Global Telecommunication System (GTS) and WIS in the form of an alphanumeric bulletin in plain-text English language under the abbreviated heading WNXX01 IAEA for global distribution to the NMCs and RSMCs (see also the *Manual on the Global Telecommunication System* (WMO-No. 386) and the *Manual on the WMO Information System* (WMO-No. 1060) for details on the dissemination of the EMERCON messages).

When IAEA no longer requires WMO RSMC support, IAEA will send an EMERCON termination message to the RSMCs, the WMO Secretariat and the DCPC of RTH Offenbach. The DCPC of RTH Offenbach will disseminate the EMERCON termination message on the GTS and WIS in the form of an alphanumeric bulletin in plain-text English language under the abbreviated heading WNXX01 IAEA for global distribution to the NMCs and RSMCs.

### **Regional arrangements**

The RSMCs designated by WMO for the provision of ATDM products for nuclear environmental emergency response shall:

- (a) Provide products only when either the delegated authority<sup>1</sup> of any country in the RSMC region of responsibility or IAEA requests RSMC support. Upon receipt of a request from the delegated authority or from IAEA, the RSMC shall provide basic information to the NMHS of that country<sup>2</sup> or to IAEA, respectively. If multiple requests are received, highest priority shall be given to IAEA requests;
- (b) Upon receipt of a first request for products related to a nuclear incident and in the absence of a prior notification by IAEA, inform the WMO Secretariat, all designated RSMCs and IAEA of the request;
- (c) For an IAEA request “all RSMCs generate products and distribute with their region(s)”, (lead RSMCs only) distribute the basic products to IAEA, and (all RSMCs) distribute to all NMHS operational contact points in their region(s) of responsibility<sup>3</sup> and WMO; for a request for support from a delegated authority and without a request by IAEA, basic information provided to the NMHS operational contact point of the requesting country shall not be disclosed to the public in that country nor distributed by RSMCs to other NMHS operational contact points;
- (d) Provide, on request, support and advice to the IAEA and WMO Secretariats in the preparation of public and media statements; the WMO Secretariat informs relevant NMHSs of the public and media statements beforehand, when necessary;

<sup>1</sup> The person authorized by the Permanent Representative of the country to request RSMC support.

<sup>2</sup> The RSMC products will be provided to the NMHS operational contact point designated by the Permanent Representative.

<sup>3</sup> The basic information will normally be provided by the NMHS to the IAEA national contact point and to other agencies as needed based on the specific arrangements defined within the State as discussed in the paragraph on National Arrangements.

- (e) Determine the standard set of basic products and the method of delivery in consultation with users and IAEA;
- (f) Provide product interpretation guidelines to users;
- (g) Provide support and technology transfer to national and regional meteorological centres that want to become designated RSMCs;
- (h) Make arrangements to provide backup services; these shall normally be between the designated centres in a region. Interim arrangements shall be made by centres in regions with a single designated RSMC;
- (i) Provide a joint response, which means that the collaborating RSMCs shall immediately inform one another of any request received; initially all centres within the region shall produce and send the basic set of products (charts) independently and then move rapidly towards providing fully coordinated responses and services for the duration of the response;
- (j) Following the initial response, develop, provide and update as required, a joint statement to describe a synopsis of the current and forecast meteorological conditions over the area of concern, and the results from the transport models, their differences and similarities and how they apply to the event.

### **Global arrangements**

Until such time as new RSMCs have been designated, it is proposed that RA VI-designated RSMCs be responsible for providing services for radiological emergencies to RA I; RA IV-designated RSMCs be responsible for providing services to RA III; and the RA V-designated RSMC, in collaboration with RA IV-designated RSMCs, be responsible for providing services to RA V and the Antarctic.

### **National arrangements**

The regional and global arrangements are designed to respect the authority of a State with regards to information flow within its boundaries. The NMHSs receiving the RSMC products should determine to which agencies or authorities they should be distributed, based on the arrangements within their State. The ATDM products and relevant information provided by the RSMCs are to be made available to NMHSs to help them assist nuclear agencies and authorities within their State with the interpretation of meteorological and ATDM products.

### **Standards in the provision of international services by Regional Specialized Meteorological Centres conducting nuclear emergency response activities**

The delegated authority requests support from RSMCs for ATDM products by using the form entitled "Environmental Emergency Response Alert Request for WMO RSMC Support by Delegated Authority" (Appendix 2.2.25). The delegated authority then sends the completed form to the RSMCs as per the regional and global arrangements and ensures receipt of the form by phone. This will initiate a joint response from the RSMCs in their region of responsibility.

The IAEA requests support from WMO RSMCs for ATDM products by using the form agreed between WMO and IAEA entitled "Environmental Emergency Response Request for WMO RSMC Support by IAEA" (Appendix 2.2.25). The IAEA then sends the completed form by email (preferred) or by fax, to the RSMCs as per the regional and global arrangements and ensures receipt of the form by phone. **The lead RSMCs shall confirm receipt of IAEA request by email (preferred) or by fax to IAEA.** This will initiate a joint response from the RSMCs in their region of responsibility. An information copy of its request form is sent by IAEA by email (preferred) or by fax to the DCPC of RTH Offenbach. **When the lead RSMCs' products become**

available, the lead RSMCs shall send an announcement to IAEA stating that their respective products are available and where they can be found (RSMC dedicated website), by email (preferred) or by fax.

The designated RSMCs shall implement agreed standard procedures and products by:

- (a) The provision of the standard set of basic products (see Appendix 2.2.22) within two to three hours of reception of a request and according to the general rules for displaying results;
- (b) The adoption of the forecast periods (see Appendix 2.2.22) for the numerical calculations;
- (c) The adoption of a joint response approach (paragraphs (i) and (j)) of the regional arrangements, above);
- (d) The adoption of the general rules for displaying results.

The RSMCs will distribute their standard products to the NMHS operational contact points by email and retrieval from RSMC password-protected designated web pages. Standard products in the International Telecommunication Union Telecommunication Standardization Sector (ITU-T) T.4 format suitable for both group 3 facsimile machines and transmission on parts of WIS will be maintained by exception and only if requested by the NMHS operational contact point. The RSMC may also make use of other appropriate technologies.

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## **APPENDIX 2.2.22. MANDATORY PRODUCTS AND GENERAL RULES FOR DISPLAYING PRODUCTS (NUCLEAR)**

### **1. Basic set of products**

Seven maps that shall consist of:

- (a) Three-dimensional trajectories starting at 500, 1 500 and 3 000 m above the ground, with particle locations at six-hour intervals (main synoptic hours up to the end of the dispersion model forecast);
- (b) Time-integrated airborne concentrations within the layer 500 m above the ground, in  $\text{Bq s m}^{-3}$  for each of the three forecast periods;
- (c) Total deposition (wet + dry) in  $\text{Bq m}^{-2}$  from the release time to the end of each of the three forecast periods.

A joint statement that shall be issued as soon as available.

### **2. Forecast periods for numerical calculations**

The initial set of products shall cover the period from T, the start time of the release, through a forecast of 72 hours from t, the start time of the current output from the operational NWP model.

The first 24-hour period for integrated exposures in the dispersion model shall start at the nearest synoptic time (0000 or 1200 UTC) prior to or equal to T. Subsequent 24-hour integrations of the dispersion model shall be made up to, but not exceeding, the synoptic time nearest to  $t+72$ .

If T is earlier than t, the first response shall use hindcasts to cover the period up to t.

### **3. Joint response and joint statements**

A joint response means that the collaborating RSMCs shall immediately inform each other of any request received; initially they shall produce and send the basic set of products (charts) independently and then move rapidly towards providing fully coordinated response and services for the duration of the response. Following the initial response, the RSMCs shall develop and provide, and update as required, a joint statement to describe a synopsis of the current and forecast meteorological conditions over the area of concern, and the results from the ATDM, their differences and similarities and how they apply to the event.

### **4. General rules for displaying results**

To make the interpretation of the maps easier, the producing centres should adopt the following guidelines:

General guidelines for all maps:

- (a) Provide labelled latitude and longitude lines at  $10^\circ$  intervals and sufficient geographic map background (shorelines, country borders, and the like) to be able to locate precisely the trajectories and contours;
- (b) Indicate the source location with a highly visible symbol (●, ▲, x, \*, ■, etc.);

- (c) Indicate the source location in decimal degrees (latitude – N or S specified; longitude – E or W specified; plotting symbol used), date and time of release (UTC); and the meteorological model initialization date and time (UTC);
- (d) Each set of maps should be uniquely identified by at least product issue date and time (UTC) and issuing centre;
- (e) Previously transmitted products from the dispersion model need not be retransmitted;
- (f) Indicate with a legend if this is an exercise, requested services, or an IAEA-notified emergency.

Specific guidelines for trajectory maps:

- (a) Distinguish each trajectory (500, 1 500, 3 000 m) with a symbol (▲, ●, ■, etc.) at synoptic hours (UTC);
- (b) Use solid lines (darker than map background lines) for each trajectory;
- (c) Provide a time–height (m or hPa) diagram, preferably directly below the trajectory map, to indicate vertical movement of trajectory parcels.

Specific guidelines for concentration and deposition maps:

- (a) Adopt a maximum of four concentration/deposition contours corresponding to powers of 10 with minimum values not less than  $10^{-20}$  Bq s  $m^{-3}$  for time-integrated airborne concentrations and not less than  $10^{-20}$  Bq  $m^{-2}$  for total deposition;
- (b) A legend should indicate that contours are identified as powers of 10 (that is,  $-12 = 10^{-12}$ ). If grey shading is used between contours, then the individual contours must be clearly distinguishable after facsimile transmission and a legend provided on the chart;
- (c) Use solid dark lines (darker than map background lines) for each contour;
- (d) Indicate the following input characteristics:
  - (i) Source assumption (height, duration, isotope, amount released);
  - (ii) The units of time integrated concentration (Bq s  $m^{-3}$ ) or deposition (Bq  $m^{-2}$ );
- (e) In addition, charts should specify:
  - (i) “Time-integrated surface to 500-metre layer concentrations”;
  - (ii) “Contour values may change from chart to chart”;
  - (iii) If the default source is used, “Results based on default initial values”;
- (f) Indicate, if possible, the location of the maximum concentration/deposition with a symbol on the map and include a legend indicating the symbol used and the maximum numerical value;
- (g) Indicate the time integration start and end date and time (UTC).

## **APPENDIX 2.2.23. DEFAULT EMISSION SOURCE PARAMETERS (NUCLEAR)**

Default values to be used in response to a request for products for the unspecified source parameters:<sup>1</sup>

- (a) Uniform vertical distribution up to 500 m above the ground;
- (b) Uniform emission rate during six hours;
- (c) Starting date and time: Date and time specified at "START OF RELEASE" on request form or, if not available, then the "date/time of request" specified at the top of the request form;
- (d) Total pollutant release 1 Bq over six hours;
- (e) Type of radionuclide <sup>137</sup>Cs.

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<sup>1</sup> The adoption of default values is based on the understanding that some runs of the transport/dispersion models need to be carried out with default parameters because little or no information (except location) will be available to the RSMC at an early stage. RSMCs are, however, requested to conduct and propose subsequent model runs with more realistic parameters as they become available (products based upon updated parameters will be provided on request only or confirmed from IAEA or a delegated authority). This may, for example, refer to a more precise assumption of the vertical distribution or the need to conduct a model run for the release of noble gases.

## **APPENDIX 2.2.24. CHARACTERISTICS OF ATMOSPHERIC TRANSPORT AND DISPERSION MODELLING SYSTEMS (NUCLEAR)**

The designated centres will document and maintain in [Documentation on RSMC Support for Environmental Emergency Response](#) (WMO/TD-No. 778) on the WMO Emergency Response Activities website up-to-date information on the characteristics of their ATDM system. The information will contain at a minimum:

For ATDM:

- Name of model(s) and type (Lagrangian, Eulerian);
- Horizontal grid spacing and extent;
- Number of vertical levels and type of vertical coordinates;
- Model calculation time step(s) and model output time step(s);
- Information on dry and wet scavenging schemes;
- How the emission (source term) is represented/modelled;
- Isotopes that can be taken into account.

For NWP data used for ATDM:

- Name of system;
  - Horizontal grid spacing and extent;
  - Number of vertical levels and type of vertical coordinates;
  - Forecast length (hours);
  - Update frequency.
-





## **APPENDIX 2.2.26. SPECIFICATIONS FOR SUPPORT TO THE COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION**

### **1. Global arrangements for all Regional Specialized Meteorological Centres to distribute products to the Comprehensive Nuclear-test-ban Treaty Organization**

Within the framework of the cooperation agreement between the Preparatory Commission for the CTBTO and WMO that entered into force on 23 May 2003, the Provisional Technical Secretariat (PTS) notifies both the RSMCs designated for the provision of atmospheric backward transport and dispersion products and also the WMO Secretariat in the case that anomalous radionuclide measurements occur in the International Monitoring System. The notification will be in the form of an email message that will specify the coordinates of the requested stations as well as the start and termination of the measurements. The measurement scenario will not be revealed.

- (a) All notified RSMCs shall acknowledge the receipt of the request and deliver the requested atmospheric backward transport and dispersion products in electronic form and in the predefined format to a server specified by CTBTO PTS as part of the notification.
- (b) The products shall be delivered as fast as technically possible within defined timelines.
- (c) Every participating RSMC that is temporarily unable to honour the request should notify CTBTO PTS and the WMO Secretariat as soon as possible, but in any case, within 24 hours. The contact officer of the PTS is specified in the email message.
- (d) Requests for support from CTBTO PTS are considered confidential and must not be disclosed.

### **2. Products provided by Regional Specialized Meteorological Centres with activity specialization in atmospheric transport and dispersion modelling (backward transport and dispersion for Comprehensive Nuclear-test-ban Treaty verification support)**

The CTBTO PTS requests support from RSMCs for ATDM (backward transport and dispersion) products by using an email message with the subject line "===== PTS REQUEST FOR SUPPORT =====" to all RSMCs. This will initiate a response from all RSMCs.

The designated RSMCs shall:

- (a) Email back the response form to the responsible officer at PTS within three hours;
- (b) Conduct standardized backward transport and dispersion computations according to the specifications listed below for all measurements included in the request email message;
- (c) Upload the results on a secured FTP server, as defined in the request email message, within 24 hours of reception and according to the format as defined below.

The specifications for the backward transport and dispersion are as follows:

- Simulate a release of  $1.3 \times 10^{15}$  Bq of a tracer integrated backward in time (no deposition, no decay) at a constant rate at the point of the station location from surface to 30 m from measurement stop to measurement start.
- Calculate the respective (backward) tracer concentrations in  $\text{Bq m}^{-3}$  at a global  $0.5^\circ \times 0.5^\circ$  grid, with an output frequency of one hour, time average of output one hour, from surface to 30 m.
- Simulate backwards in time to the requested end date/time (up to 30 days from issuance of request).

**The PTS shall:**

- (a) Restrict requests to cases of anomalous radionuclide measurements or system tests;**
- (b) Contact the RSMCs in case no confirmation of a request was received within three hours;**
- (c) Conduct regular announced and/or unannounced system tests;**
- (d) Share the results of tests with the other RSMCs at a website;**
- (e) Send a cancellation message of the request for support to RSMCs when an issued request is cancelled.**

The PTS will not request any graphical products or products other than those specified above. Customized end-user products will be produced by the PTS for submission to the national authorities, along with RSMC model output. Measurements and end-user products will not be shared by PTS with RSMCs or WMO Secretariat for reasons of confidentiality.

**REQUEST MAIL MESSAGE FOR SUPPORT SENT OUT BY THE PTS TO WMO RSMCs**

===== PTS REQUEST FOR SUPPORT =====

Date issued: YYYYMMDD hhmm

Responsible officer: NAME

Point of contact:

NAME

Tel. ....

Fax. ....

name@\*\*\*\*.\*\*\*

Secure website (location/user/password)

Download of information:

\*\*\*\*://\*\*\*\*\*

username

Password

Data upload:

\*\*\*\*://\*\*\*\*\*

Username

Password

For authentication purposes, this mail message is also available on the website:

\*\*\*\*://\*\*\*\*\*.txt

=====

= Source-receptor matrix results are requested for 006 stations

#	LON	LAT	ID	Measurement Start/stop time (YYYYMMDD hh)
001	-70.90	-53.10	CLP18	20050328 15 20050329 15
002	-70.90	-53.10	CLP18	20050329 15 20050330 15
003	-71.25	-41.10	ARP03	20050329 12 20050330 12
004	-58.47	-34.54	ARP01	20050329 18 20050330 18
005	-70.90	-53.10	CLP18	20050330 15 20050331 15
006	-71.25	-41.10	ARX03	20050329 12 20050330 00

=====

Please calculate backward to YYYYMMDD hh

=====

Please upload data within 24 hours

==RESPONSE FORM==

=== WMO Centre response form ===

=== Please send back this form ===

=== to the sender of the request as ===

=== soon as possible ===

- (x) We will send our contributions within the time limit (default)
- ( ) We will send our contributions kkk hours later then the time limit
- ( ) We got your request but are not able to perform computations

===== PTS REQUEST FOR SUPPORT =====

**CANCELLATION MAIL MESSAGE SENT OUT BY THE PTS TO WMO RSMCs**

===== PTS CANCELS REQUEST FOR SUPPORT =====

Date issued: YYYYMMDD hhmm

**FORMAT OF THE MODEL RESULTS AS DELIVERED BY THE RSMCs**

Line 1: Header line (station longitude, latitude, start of measurement interval (YYYYMMDD hh), end of measurement interval (YYYYMMDD hh), release strength (Bq), number of hours backward, output every "k" hours, time average of output, horizontal grid space in x direction, horizontal grid space in y direction, station name)

Line 2-k: data lines (latitude, longitude, time step number, value)

17.57 59.23 20030106 09 20030107 09 0.13E+16 144 3 3 1.0 1.0 "SEP63"

58.00 15.00 1 0.1209120E-01

59.00 15.00 1 0.6446140E-01

60.00 15.00 1 0.3212887E-02

58.00 16.00 1 0.2649441E+01

59.00 16.00 1 0.9029172E+01

60.00 16.00 1 0.7616042E-01

58.00 17.00 1 0.1073919E+02

59.00 17.00 1 0.3082339E+02

60.00 17.00 1 0.1408468E-01

58.00 18.00 1 0.2643455E+00

59.00 18.00 1 0.7357535E+00

58.00 14.00 2 0.7759376E-02

59.00 14.00 2 0.6508716E-01

60.00 14.00 2 0.2403110E-01

61.00 14.00 2 0.6662516E-03

62.00 14.00 2 0.2838572E-04

58.00 15.00 2 0.1015775E+01

59.00 15.00 2 0.5030275E+01

60.00 15.00 2 0.8239139E+00

61.00 15.00 2 0.6797127E-02

62.00 15.00 2 0.6521360E-04

58.00 16.00 2 0.8181147E+01

59.00 16.00 2 0.2503959E+02

60.00 16.00 2 0.5937406E+00

61.00 16.00 2 0.1784474E-02

58.00 17.00 2 0.1403705E+02

59.00 17.00 2 0.3715418E+02

60.00 17.00 2 0.1306086E-01

58.00 18.00 2 0.2718492E+00

59.00 18.00 2 0.7555131E+00

.....

## **APPENDIX 2.2.27. ACTIVATION OF SUPPORT FOR NON-NUCLEAR ENVIRONMENTAL EMERGENCY RESPONSE**

Environmental emergencies can be caused by a broad range of events with various temporal and spatial scales involving the release of hazardous substances into the environment. The scope of non-nuclear emergency response activities includes: smoke from large fires, chemical releases and industrial fire/smoke. Atmospheric sand and dust storm forecasts are covered under activity 2.2.2.10. Ash emitted by volcanic eruptions, in relation to aviation, is covered under activity 2.2.2.12 – Volcano watch services for international air navigation.

National Meteorological and Hydrological Services may request RSMC support for releases that have the potential for long-range impacts (distances greater than 50 km), according to the capability of the RSMC. Products of RSMCs are typically not applicable to shorter-range incidents. Regional Specialized Meteorological Centres may be able to provide services for other types of incident on a case-by-case basis and will advise NMHSs if requests are not within their capabilities.

**National Meteorological and Hydrological Services requesting RSMC support shall:**

- **Request via the authorized person<sup>1</sup> that an RSMC provides, in accordance with its designation, products relating to events in which hazardous non-nuclear contaminants have been released into the atmosphere;**
- **Send, by email (preferred) or fax, the completed form in Appendix 2.2.31 to the appropriate RSMC; if the RSMC has not confirmed reception within 20 minutes, the requester shall contact the RSMC by phone or email;**
- **Provide the RSMCs with the essential information specified on the request form;**
- **Distribute the products within their State or territory based on their national arrangements.**

### **Global arrangements**

Until such time as new RSMCs have been designated, it is proposed that RA VI-designated RSMCs be responsible for providing services for non-radiological emergencies to RA I and RA II, and that RA IV-designated RSMCs be responsible for providing services to RA III, RA V and the Antarctic.

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<sup>1</sup> The person authorized by the Permanent Representative of the WMO Member to request RSMC support; normally the NMHS operational contact point.

## **APPENDIX 2.2.28. MANDATORY PRODUCTS AND GENERAL RULES FOR DISPLAYING PRODUCTS (NON-NUCLEAR)**

### **1. Mandatory non-nuclear products**

The following mandatory non-nuclear products shall be provided:

- Smoke from forest, grass or peat fires (default values in Appendix 2.2.29 shall be used for source parameters not provided):
  - Forecast duration 36 hours;
  - Relative concentrations from the surface to 200 m;<sup>1</sup>
  - Images at intervals of one, three or six hours;<sup>2</sup>
  - Contouring to be determined based on specifics of the event or the request;
- Smoke from industrial fire (default values for parameters not provided):
  - Forecast duration 12 hours;
  - Relative concentrations from the surface to 200 m;<sup>1</sup>
  - Images at intervals of one or three hours;<sup>2</sup>
  - Contouring to be determined based on specifics of the event or the request;
- Chemical releases not involving fire (default values for parameters not provided):
  - Forecast duration 12 hours;
  - Relative concentrations from the surface to 100 m;<sup>1</sup>
  - Images at intervals of one or three hours;<sup>2</sup>
  - Contouring to be determined based on specifics of the event or the request.

The RSMC shall perform a quick assessment of the products before they are issued, and shall provide a short explanatory message if any issues of concern are noted.

### **2. General rules for displaying results**

The designated centres will provide an interpretation guide for users in *Documentation on RSMC Support for Environmental Emergency Response* (WMO/TD-No. 778), which can be found on the WMO Emergency Response Activity website.

To facilitate the interpretation of maps, the producing centres should adopt the following guidelines:

- (a) General guidelines for all maps:
  - (i) Provide labelled latitude and longitude lines at regular intervals and sufficient geographic map background (shorelines, rivers and lakes and, if possible, names of roads and towns for localized events) to be able to locate precisely the trajectories and contours;
  - (ii) Indicate the source location with a highly visible symbol (▲, ●, ■, etc.);

<sup>1</sup> Absolute concentrations may be provided if an estimated or actual value of the total mass released or mass release rate is given.

<sup>2</sup> Additional products (for example, GIS-format files) may be provided to requesting NMHSs if possible.

- (iii) Indicate the source location in decimal degrees (latitude – N or S specified, longitude – E or W specified, plotting symbol used), date and time (UTC) of release, and date and time (UTC) of the meteorological model initialization;
  - (iv) Each set of maps should be uniquely identified by at least product issue date and time (UTC) and issuing centre;
  - (v) Previously transmitted products from the dispersion model need not be retransmitted;
  - (vi) Indicate with a legend whether it is an exercise or a requested service.
- (b) Specific guidelines for concentration maps:
- (i) Adopt a maximum of five concentration contours;
  - (ii) A legend should indicate the contours used on the chart;
  - (iii) Contours may be colour filled but should be clearly distinguishable from map background lines;
  - (iv) Indicate the following input characteristics:
    - a. Source assumption (height, duration, pollutant type, amount released);
    - b. Units of concentration;
  - (v) In addition, charts should specify:
    - a. “Surface to xxx-metre layer concentrations”, where xxx depends on the pollutant type, and whether the default source is used;
    - b. “Results based on default initial values”;
    - c. The location of the maximum concentration with a symbol; a legend indicating the symbol used and the maximum numerical value should be included;
    - d. The start and end date and time (UTC).
-

## APPENDIX 2.2.29. DEFAULT EMISSION SOURCE PARAMETERS (NON-NUCLEAR)

<i>Scenario*</i>	<i>Type of event</i>	<i>Material released</i>	<i>Rate of emission</i>	<i>Vertical distribution</i>
Forest, grass or peat fires	Smoke	Tracer	One unit mass per hour over 36 hours	Constant from the surface to 500 m
Major industrial fire	Smoke	Tracer	One unit mass per hour over 6 hours	Constant from the surface to 500 m
Chemical release not involving fire	Chemical	Tracer	One unit mass per hour over 6 hours	Constant from the surface to 20 m
Other events	RSMC defined	Tracer	RSMC defined	RSMC defined

\* Default date and start time of release are those given in the request form (mandatory information). If not provided, the date and time of reception of the request will be used.

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## **APPENDIX 2.2.30. CHARACTERISTICS OF ATMOSPHERIC TRANSPORT AND DISPERSION MODELLING SYSTEMS (NON-NUCLEAR)**

The designated centres will document and maintain in *Documentation on RSMC Support for Environmental Emergency Response* (WMO/TD-No. 778), on the WMO Emergency Response Activities website, up-to-date information on the characteristics of their ATDM system. The information will contain at a minimum:

For ATDM:

- Name of model(s) and type (Lagrangian, Eulerian);
- Horizontal grid spacing and extent;
- Vertical spacing and type of vertical coordinates used to calculate layer concentrations;
- Model calculation time step(s) and model output time step(s);
- Information on horizontal and vertical diffusion schemes for the tracers;
- Information on dry and wet scavenging schemes;
- Information on how chemicals are treated (if available);
- How the emission (source term) is represented/modelled.

For NWP data used for ATDM:

- Name of system;
  - Horizontal grid spacing and extent;
  - Number of vertical levels and type of vertical coordinates;
  - Forecast length (hours);
  - Update frequency.
-

## APPENDIX 2.2.31. REQUEST FORM TO ACTIVATE REGIONAL SPECIALIZED METEOROLOGICAL CENTRE SUPPORT (NON-NUCLEAR)

### Environmental emergency response request for WMO Regional Specialized Meteorological Centre support by authorized person<sup>1</sup>

- (a) This form should be sent by email to one of the RSMCs' operational contacts in the Regional Association when support is needed for releases that have the potential for long-range impacts (distances greater than 50 km). The RSMC operational contact information is available [here](#).
- (b) If the RSMC does not confirm the reception of the request within 20 minutes, the requester will telephone the RSMC.
- (c) The RSMC will make available its products as soon as possible but usually within two hours. An email will be sent by the RSMC with information on where to access the products. The requester will confirm reception by email.

**Date and time of request:** .....

**(a) Mandatory information:**

- Status (exercise/event):.....

- Name, title, organization/agency, country, phone number and email of the requester:  
.....  
.....  
.....

- Select type of event and provide brief description or details:

- o ..... Forest, grass or peat fire
- o ..... Chemical incident
- o ..... Industrial fire/smoke
- o ..... Other

.....  
.....  
.....  
.....

<sup>1</sup>The person authorized by the Permanent Representative of the WMO Member to request RSMC support; this is normally the NMHS operational contact point

- Date and start time of release (DD/MM/YYYY and UTC): .....

- Location of release (as accurately as possible) in order of preference:

(i) Geographic coordinates (decimal degrees or degrees, minutes and seconds):

Latitude (specify N or S)	.....
Longitude (specify E or W)	.....

(ii) (If appropriate) address, city, country:

.....  
.....

**(b) Other information** – If known, the following would be useful for the modelling and should be provided as well (if not provided, modeller will use default parameters or make a reasonable assumption):

- Name of location (name of chemical plant, factory, etc.):

.....  
.....

- Meteorological conditions at location at the start of the release (wind speed and direction, weather, cloudiness, presence of inversion, etc.):

.....  
.....

- Name or type of pollutant(s) to be modelled if known (smoke, natural gas, sulphur dioxide, etc.) – if unknown, a tracer will be used:

.....  
.....

- Quantity (mass) or release rate (mass per unit time) of pollutant. If unknown, one unit mass or one unit mass per hour will be used:

.....  
.....

- Expected or estimated release duration:

.....  
.....

- Duration of simulation for the dispersion model run:

.....  
.....

- Size of area of interest (for example, within 300 km of source):

.....  
.....

- Base of release (surface or meters above surface), dimension of release area and estimated maximum height in meters reached by the release (for example, top of smoke plume):

.....  
.....

- If quantity (mass) and name of pollutant(s) are provided, what concentrations should be displayed on modelling outputs? Please specify:

.....  
.....

- Any other information that may be useful:

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.....



## **APPENDIX 2.2.32. MANDATORY ATMOSPHERIC SAND AND DUST STORM PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM**

Forecasts, with an appropriate uncertainty information statement, shall include the following set of variables:

- Dust load ( $\text{kg m}^{-2}$ );
- Dust concentration at the surface ( $\mu\text{g m}^{-3}$ );
- Dust optical depth at 550 nm;
- Three-hour accumulated dry and wet deposition ( $\text{kg m}^{-2}$ ).

Forecasts shall cover the period from the starting forecast time (0000 and/or 1200 UTC) up to a forecast time of at least 72 hours, with an output frequency of at least three hours. They shall cover the whole designated area. The horizontal resolution shall be finer than  $0.5^\circ \times 0.5^\circ$ .

Forecasts shall be disseminated through WIS and provided on a web portal in pictorial form not later than 12 hours after the starting forecast time.

An explanatory note should be published on the web portal when operations are stopped due to technical problems.

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## **APPENDIX 2.2.33. STANDARDIZED VERIFICATION OF DETERMINISTIC NUMERICAL WEATHER PREDICTION PRODUCTS**

### **1. Introduction**

This appendix presents detailed procedures for the production and exchange of a standard set of verification scores for deterministic NWP forecasts produced by WIPPS centres. The goal is to provide consistent verification information on the NWP products of WIPPS-participating centres for forecasters in the NMHSs and to help the WIPPS centres compare and improve their forecasts. Scores will be exchanged between the participating producing centres via the Lead Centre(s) for DNV. The Lead Centre functions, as described in 2.2.3.1, include creating and maintaining a website for DNV (<https://wmolcdnv.ecmwf.int/>) information so that potential users will benefit from a consistent presentation of results.

The term “deterministic NWP” refers to single integrations of NWP models providing products defining single future states of the atmosphere (as distinct from EPSs, where multiple integrations provide a range of future states).

The standardized verification should provide key relevant information appropriate to the state of the art in NWP, while being as simple and as easy to implement as possible, and ensuring a consistent implementation across participating centres.

The mathematical formulation of the scores is documented on the Lead Centre(s) for DNV website(s), together with supplementary information on score calculation, the observational and climate datasets to be used for verification, and procedures for submitting scores.

### **2. Verification statistics**

The following sections define two sets of verification statistics. **A mandatory set shall be provided by all participating centres.** The procedures for upper-air fields and for surface fields are different and are presented separately. The detailed procedures are required to ensure it is possible to compare results from the different participating centres in a scientifically valid manner.

A set of additional recommended statistics is also defined that all centres should provide if possible.

### **3. Exchange of scores**

**Each centre shall provide scores monthly to the Lead Centre(s) for DNV.** Details of the procedure and the required format for the data are provided on the website(s) of the Lead Centre(s). **All scores for all forecasts verified within a month shall be provided as soon as possible after the end of that month.**

### **4. Documentation**

Participating centres shall provide to the Lead Centre(s) for DNV information on their implementation of the standardized verification system annually, shall confirm to the Lead Centre(s) any changes to the implementation (including the annual change of station list for upper-air verification, changes in additional statistics), and shall inform the Lead Centre(s) of changes in their NWP model.

## 5. **Standardized verification of upper-air fields**

### 5.1 **Parameters**

Extra-tropics:

- Mandatory:
  - MSLP (verification against analysis only);
  - Geopotential height at 850, 500 and 250 hPa;
  - Temperature at 850, 500 and 250 hPa;
  - Wind at 925, 850, 700, 500 and 250 hPa.
- Additional recommended:
  - Geopotential height, temperature, wind at 100 hPa;
  - Relative humidity at 850 and 700 hPa.

Tropics:

- Mandatory:
  - Geopotential height at 850 and 250 hPa;
  - Temperature at 850 and 250 hPa;
  - Wind at 850 and 250 hPa.
- Additional recommended:
  - Relative humidity at 850 and 700 hPa.

### 5.2 **Forecast times**

**Scores shall be computed daily for forecasts initialized at 0000 UTC and 1200 UTC separately. For those centres not running forecasts from either 0000 UTC or 1200 UTC, scores shall be provided for forecasts initiated at other times and must be labelled as such.**

### 5.3 **Forecast steps**

Mandatory: Forecast steps 24, 48, 72, ... 240 hours or end of forecast;

Additional recommended: 12-hourly throughout forecast (12, 24, 36 h, ...).

### 5.4 **Areas**

Northern hemisphere extra-tropics	90°N–20°N, inclusive, all longitudes
Southern hemisphere extra-tropics	90°S–20°S, inclusive, all longitudes
Tropics	20°N–20°S, inclusive, all longitudes
North America	25°N–60°N 50°W–145°W
Europe/North Africa	25°N–70°N 10°W–28°E
Asia	25°N–65°N 60°E–145°E
Australia/New Zealand	10°S–55°S 90°E–180°E
Northern polar region	90°N–60°N, inclusive, all longitudes
Southern polar region	90°S–60°S, inclusive, all longitudes

Verification against analyses for grid points within each area includes points on the boundary.

## 5.5 **Verification against analyses**

### Grid and interpolation

**All parameters shall be verified against the centre's own analysis on a regular  $1.5^\circ \times 1.5^\circ$  grid.**

In selecting the verification grid, consideration has been given to the variety of resolutions of current global NWP models, the resolved scales of models (several grid lengths), the resolution of the available climatologies, the potential to monitor long-term trends in performance (including earlier, lower-resolution forecasts), and computational efficiency.

**Interpolation of higher-resolution model fields to the verification grid shall be performed to retain features at the scale of the verification grid but not to introduce any additional smoothing. The following procedures shall be used:**

- **Spectral fields: Truncate to equivalent spectral resolution (T120) for the verification grid;**
- **Grid-point fields: Use area weighting to interpolate to the verification grid.**

For scores requiring a climatology, the climatology is made available via the Lead Centre(s) for DNV website(s) on the verification grid and needs no further interpolation.

## 5.6 **Verification against observations**

### 5.6.1 Observations

**All parameters defined in section 5.1, above, except MSLP, shall be verified against a common set of radiosondes.** The list of radiosonde observations for each area is updated annually by the INFCOM Lead Centre(s) for radiosonde monitoring. The data from the chosen stations must be available to all the centres, be of sufficient quality, and be available on a regular basis. Consultation with all centres (usually by email) is desirable before establishing the final list. The current list is available via the website(s) of the Lead Centre(s) for DNV. **The Lead Centre(s) shall contact all participating centres when the new list is available and inform them of the date from which the new list shall be used.**

**The observations used for verification shall be screened to exclude those with large errors.**

In order to do this, it is recommended that centres exclude values rejected by their objective analysis. Moreover, centres which apply a correction to the observations received on the GTS to remove biases (for example, radiation correction) should use the corrected observations to compute verification statistics. Whenever possible, these correction procedures should be documented (for example, by reference to a technical report or journal paper).

### 5.6.2 Interpolation

**Verification shall be made using the nearest native model grid point to the observation location.**

### 5.6.3 Areas

The nine networks used in verification against radiosondes consist of radiosonde stations located in the geographical areas indicated in section 5.4, above.

The list of radiosonde stations to be used for each area is updated annually by the Lead Centre(s) for radiosonde monitoring (see section 5.6.1).

#### 5.6.4 Scores for individual stations

It is recommended that, in addition to the areas listed in section 5.4, scores against observations should be computed for each station individually. The exchange of scores over areas is to be phased out over time.

#### 5.7 Scores

The mathematical formulation of the scores is documented on the Lead Centre(s) for DNV website(s), together with supplementary information on score calculation.

The following scores are to be calculated for all parameters against both analysis and (except mean sea-level pressure) observation.

Wind

- Mandatory:
  - RMS vector wind error;
  - Mean wind speed error.

Other parameters:

- Mandatory:
  - Mean error;
  - RMS error;
  - Correlation coefficient between forecast and analysis anomalies (not required for observations);
  - S1 score (only for MSLP and only against analysis).
- Additional recommended:
  - Mean absolute error;
  - RMS forecast and analysis anomalies (not required for observations);
  - Standard deviation of forecast and analysis fields (not required for observations)

#### 5.8 Climatology

**To ensure consistency between results from different centres, a common climatology shall be used for those scores requiring a climatology. All centres shall use the climatology provided via the Lead Centre(s) for DNV website.**

A daily climatology of upper-air parameters is available for both 0000 and 1200 UTC. This provides an up-to-date estimate of climate characteristics for each day of the year, including climate mean, standard deviation and selected quantiles of the climate distribution. These latter statistics are required for the INFCOM standardized verification of EPS forecasts.

The data are made available in GRIB format. Information on access to the data and further documentation is provided on the Lead Centre(s) for DNV website.

#### 5.9 Monthly and annual averaged scores

**Where average scores are required over a defined period, the averaging shall be made using the following procedures:**

- Linear scores (mean error, mean absolute error) – mean;

- Non-linear scores shall be transformed to appropriate linear measure for averaging;
- Mean of mean square error (MSE);
- Z-transform for correlation.

For a defined period, the average shall be computed over all forecasts verified during the period. Averages shall be computed separately for forecasts initiated at 0000 and 1200 UTC and both sets of average values provided.

Annual averages of the daily scores are for the 24-, 72- and 120-hour forecasts and include the RMS vector wind error at 850 (tropics area only) and 250 hPa (all areas), as well as the RMS error of geopotential heights at 500 hPa (all the areas except for tropics).

## 5.10 **Confidence intervals**

Bootstrapping\*: This will be performed by the Lead Centre(s) for DNV if daily scores are provided.

\*Note: **Introduction**

Any verification score must be regarded as a sample estimate of the “true” value for an infinitely large verification dataset. There is, therefore, some uncertainty associated with the score’s value, especially when the sample size is small or the data are not independent. Some estimate of uncertainty (confidence intervals) must be used to set bounds on the expected value of the verification score. This also helps to assess whether differences between competing forecast systems are statistically significant. Typically, confidence intervals of 5% and 95% are used.

### **Suggested method to calculate the confidence intervals**

Mathematical formulae are available for computing confidence intervals (CIs) for distributions that are binomial or normal. In general, most verification scores cannot be expected to satisfy these assumptions. Moreover, the verification samples are often spatially and temporally correlated, especially at longer forecast ranges. A non-parametric method such as the block bootstrap method handles spatially or temporally correlated data.

As described in Candille et al. (2007), a bootstrap technique for computing CIs involves recomputing scores numerous times after randomly extracting samples from the dataset and then replacing them, again randomly, from the original dataset. The correlation between forecasts on subsequent days is accounted for by extracting and replacing blocks of samples from the dataset, rather than individual samples. Based on a calculation of the autocorrelation between forecasts on subsequent days, it is concluded that blocks of three days may be used to calculate the 5% and 95% confidence intervals.

### **References**

- Candille, G.; Côté, C.; Houtekamer, P. L. et al. Verification of an Ensemble Prediction System against Observations. *Monthly Weather Review* **2007**, 135 (7), 2688–2699. <https://doi.org/10.1175/MWR3414.1>.
- World Meteorological Organization (WMO). *Recommendations for the Verification and Intercomparison of QPFS and PQPFS from Operational NWP Models* (WMO/TD-No. 1485). Revision 2. Geneva, 2009.

## 6. **Standardized verification of surface fields**

### 6.1 **Parameters and units**

Mandatory:

- 2-metre temperature           K
- 10-metre wind speed         m s<sup>-1</sup>
- 10-metre wind direction     deg
- 24-hour precipitation         mm

Additional recommended:

- Total cloud cover                    0–1 (convert to oktas for contingency tables)
- 6-hour precipitation                mm
- 2-metre relative humidity        %
- 2-metre dewpoint                    K

**For two-metre temperature, a simple height correction between model altitude and station elevation shall be applied using a constant lapse rate of  $0.0065 \text{ K m}^{-1}$ . For two-metre dewpoint an analogous height-correction shall be applied using a constant lapse rate of  $0.0012 \text{ K m}^{-1}$ . This approximates the dewpoint lapse rate in an atmosphere with a temperature lapse rate of  $0.0065 \text{ K m}^{-1}$  and constant specific humidity.**

## 6.2 **Forecast times**

Scores shall be computed daily for forecasts initialized at 0000 and 1200 UTC separately. For those centres not running forecasts from either 0000 or 1200 UTC, scores may be provided for forecasts initiated at other times and must be labelled as such.

## 6.3 **Forecast steps**

Mandatory forecast steps shall be:

- Every six hours up to  $T+72$ ; 12-hourly up to  $T+240$  or end of the forecast;
- For 24-hour precipitation: 24-hourly up to  $T+240$  or end of the forecast.

Additional recommended:

- Every three hours up to  $T+72$ ; 6-hourly up to  $T+240$  or end of the forecast (for improved representation of diurnal cycle);
- For six-hour precipitation: six-hourly up to  $T+240$  or end of the forecast.

## 6.4 **Grid and interpolation**

Verification shall be based on the native model grid using the grid point nearest to the observation location.

## 6.5 **Observations**

Verification shall be carried out for synoptic surface observation code (SYNOP) surface stations distributed via the GTS. Each participating centre shall aim to include as many stations as possible to ensure good global coverage. The list of stations used in the verification is allowed to differ between centres. **This is made possible by the fact that scores for individual stations shall be exchanged.**

Centres are encouraged to make use of the quality control procedures available to them to reduce the effect of observation errors on scores. This includes removal of occasional unphysical values as well as data at individual stations that have been systematically rejected over a certain time period. Whenever possible, the quality control procedures should be documented (for example, by reference to a technical report or journal paper).

## 6.6 **Scores**

Scores shall be computed for each station individually. A station for which scores are computed shall have at least 90% data availability during the verification period.

**For 2-metre temperature, 2-metre relative humidity, 2-metre dewpoint, 10-metre wind speed, 10-metre wind direction, and total cloud cover, the following error scores shall be computed:**

- **Mean error;**
- **Mean absolute error;**
- **RMSE.**

Ten-metre wind direction is verified only when the observed wind speed is  $\geq 3 \text{ m s}^{-1}$ . For 10-metre wind direction, the equivalence of  $360^\circ$  and  $0^\circ$  needs to be taken into account (cyclic continuation).

**For 10-metre wind speed, precipitation and total cloud cover, contingency tables for the following thresholds shall be provided:**

- **10-metre wind speed: 5, 10 and 15 m s<sup>-1</sup>;**
- **24-hour precipitation: 1, 10 and 50 mm;**
- **6-hour precipitation: 1, 5 and 25 mm;**
- **Total cloud cover: 2 and 7 oktas.**

For total cloud cover, the model output should be rounded to the nearest okta prior to verification (for the contingency tables only).

**Error scores shall be reported with a precision of at least four significant digits, for example, 3.142 for an error of  $\pi$ . In the contingency tables, absolute number of counts shall be given rather than relative frequencies so that the sample size can be derived.**

**The contingency tables for each parameter shall contain all thresholds given above. The mathematical formulation of the scores is documented on the Lead Centre(s) for DNV website(s), together with supplementary information on score calculation.**

## 6.7 ***Temporal and spatial aggregation***

For any given one-month period, error scores and contingency tables are computed for each station individually. This forms the basis for aggregation by users of the exchanged verification data, both in time and space. **For a defined period, the average shall be computed over all forecasts verified during the period.**

Spatial aggregation is not part of the exchange, and is left to user discretion. Exchanging scores in this way allows forecast users to obtain detailed information on model performance for individual stations. It also ensures a high level of transparency and flexibility for model intercomparison studies. Furthermore, it removes the requirement of coordinating, circulating and updating whitelists of surface stations for verification. For model intercomparison studies the intersection of the different sets of stations used by global modelling centres would be used for comparison (“smallest common denominator”).

If users would like to aggregate the exchanged scores, they can refer to the Lead Centre(s) for DNV website(s), which provides guidelines for the choice of aggregation areas. Compared to upper-air verification, more emphasis needs to be put on aggregating over climatologically relatively homogeneous areas (since absolute thresholds are used for the contingency tables).

## **APPENDIX 2.2.34. STANDARD VERIFICATION MEASURES OF THE GLOBAL ENSEMBLE PREDICTION SYSTEM**

### **1. Introduction**

This appendix presents detailed procedures for the production and exchange of a standard set of verification scores for EPS forecasts produced by WIPPS centres. The goal is to provide consistent verification information on the EPS products of WIPPS-participating centres for forecasters in NMHSs and to help the WIPPS centres compare and improve their forecasts. Scores will be exchanged between the participating producing centres via the Lead Centre(s) for EPS verification. The Lead Centre functions, as described in 2.2.3.2, include creating and maintaining a website for EPS verification information so that potential users will benefit from a consistent presentation of the results.

The Ensemble Prediction System provides a complete estimation of the forecast probability distribution, including a best-estimate deterministic forecast from the ensemble mean, as well as measures of forecast uncertainty and probabilities. Verification of the EPS therefore includes verification of the ensemble mean as a deterministic NWP forecast following the guidance set out in Appendix 2.2.33 as well as specific measures of the probabilistic performance.

The standardized verification should provide key relevant information appropriate to the state of the art in EPS, while being as simple and easy to implement as possible, and ensuring a consistent implementation across participating centres, in particular in the interpolation to the verification grid, and use of a common climatology and set of observations.

### **2. Verification statistics**

Four sets of verification statistics are defined below. **A mandatory set shall be provided by all participating centres.** The detailed procedures are required to ensure it is possible to compare results from the different participating centres in a scientifically valid manner.

A set of additional recommended statistics is also defined that all centres should provide if possible.

The four sets of statistics are summarized as:

- **A mandatory set shall be provided by all participating centres:**
  - **Ensemble mean;**
  - **Spread – standard deviation of the ensemble averaged over the same regions and variables as used for the ensemble mean;**
  - **Continuous ranked probability score (CRPS);**
- Additional recommended:
  - Probability scores – scores for probabilities of specific thresholds are exchanged in the form of reliability tables. Several different scores are computed by the Lead Centres based on the reliability tables provided by participating centres.

Specifications of forecast verification set out in the paragraphs below apply to calculation of the CRPS and other probability scores. Verification of the ensemble mean and spread should follow the specifications set out in Appendix 2.2.33, as stated above.

### 3. Parameters

Root mean square error and correlation coefficient between forecast and analysis anomalies of ensemble mean shall be calculated for the following set of parameters:

- MSLP;
- 500-hPa geopotential height;
- u and v wind components at 850 and 250 hPa;
- 850-hPa temperature.

Spread shall be calculated for the same set of parameters for ensemble mean.

Reliability tables for the calculation of probability scores shall be calculated for the following set of parameters and thresholds:

- MSLP anomalies  $\pm 1$ ,  $\pm 1.5$  and  $\pm 2$  standard deviation with respect to the defined climatology;
- 500-hPa geopotential height anomalies with thresholds  $\pm 1$ ,  $\pm 1.5$  and  $\pm 2$  standard deviation with respect to the defined climatology;
- 850-hPa wind speed with thresholds of 10, 15 and 25  $\text{m s}^{-1}$ ;
- 850-hPa u and v wind components with thresholds of 10th, 25th, 75th and 90th percentile points with respect to the defined climatology;
- 250-hPa u and v wind components with thresholds of 10th, 25th, 75th and 90th percentile points with respect to the defined climatology;
- 850-hPa temperature anomalies with thresholds  $\pm 1$ ,  $\pm 1.5$  and  $\pm 2$  standard deviation with respect to the defined climatology;
- Precipitation with thresholds 1, 5, 10 and 25 mm/24 hours;
- 10-metre wind speed with thresholds 10 and 15  $\text{m s}^{-1}$ ;
- 2-metre temperature anomalies with thresholds  $\pm 1$ ,  $\pm 1.5$  and  $\pm 2$  standard deviation with respect to the defined climatology.

Note: Where thresholds are defined with respect to climatology, the defined climatology is set out in paragraph 11 below.

The CRPS shall be calculated for the same set of parameters for probability score.

### 4. Forecast times

Scores shall be computed daily for forecasts initialized at times to be specified by the centre, but shall include all forecast cycles made available on WIS.

### 5. Forecast steps

Forecast steps shall be every 24 hours to the end of the forecast range.

### 6. Areas

Northern hemisphere extra-tropics	90°N–20°N, inclusive, all longitudes
Southern hemisphere extra-tropics	90°S–20°S, inclusive, all longitudes

Tropics

20°N–20°S, inclusive, all longitudes

Verification against analyses should be performed for grid points within each area, including points on the boundary.

## 7. **Verification against analyses**

### 7.1 **Grid and interpolation**

**All parameters except precipitation shall be verified against the centre's own analysis on a regular 1.5° × 1.5° grid.**

In selecting the verification grid, consideration has been given to the variety of resolutions of current global NWP models, the resolved scales of models (several grid lengths), the resolution of the available climatologies, the potential to monitor long-term trends in performance (including earlier, lower-resolution forecasts) and computational efficiency.

**Interpolation of higher-resolution model fields to the verification grid shall be performed to retain features at the scale of the verification grid but not to introduce any additional smoothing. The following procedures shall be used:**

- **Spectral fields:** Truncate to equivalent spectral resolution (T120) for verification grid;
- **Grid-point fields:** Use area-weighting to interpolate to verification grid.

For scores requiring a climatology the climatology is specified in paragraph 11 below.

Verification of precipitation is recommended to be performed against observations (see paragraph 8), but may alternatively be against a proxy analysis (that is, a short-range forecast from the control, or a high-resolution deterministic forecast, for example, 12–36-hour forecast to avoid spin-up problems).

## 8. **Verification against observations**

### 8.1 **Observations**

**Observations for EPS verification of precipitation shall be based on the GCOS list of surface networks. Producing centres shall have the right to omit certain observation sites if these fail a quality control.**

### 8.2 **Interpolation**

**Verification shall be made using the nearest native model grid point to the observation location.**

### 8.3 **Areas**

The networks used in verification against observations consist of observation stations located in the areas listed in section 6.

## 9. **Scores**

Root mean square error and correlation coefficient between forecast and analysis anomalies are to be calculated for all parameters by the participating centres and provided to the Lead Centre(s) in the form specified on the Lead Centre(s) website(s).

The following scores are to be calculated for all parameters (computed by the Lead Centre(s) based on reliability tables provided by participating centres):

- Brier skill score (with respect to climatology);
- ROC;
- Relative economic value (C/L) diagrams;
- Reliability diagrams with frequency distribution.

The CRPS is to be calculated for all parameters by the participating centres and provided to the Lead Centre(s) in the format specified on the Lead Centre(s) website(s). Centres are encouraged to submit CRPS scores for both EPS and the deterministic (control and high-resolution) forecast – CRPS for deterministic forecast is equal to the mean absolute error.

#### 10. **Exchange of scores**

**Each centre shall provide scores monthly to the Lead Centre(s).** Details of the procedure and the required format for the data are provided on the Lead Centre(s) website(s). **All scores for all forecasts verifying within a month shall be provided as soon as possible after the end of that month.**

#### 11. **Climatology**

**To ensure consistency between results from different centres a common climatology shall be used for those scores requiring a climatology. All centres shall use the climatology provided via the Lead Centre(s) website(s), which is the same climatology specified in Appendix 2.2.33 and available from the Lead Centre(s) for DNV website(s).**

A daily climatology of upper-air parameters are available for both 00 UTC and 12 UTC. This provides an up-to-date estimate of climate characteristics for each day of the year, including climate mean, standard deviation and selected quantiles of the climate distribution. These latter statistics are required for the INFCOM standardized verification of EPS forecasts.

The data are made available in GRIB format. Information on access to the data and further documentation are provided on the Lead Centre(s) for DNV website(s).

#### 12. **Documentation**

**Participating centres shall provide to the Lead Centre(s) information on their implementation of the standardized verification system annually, shall confirm to the Lead Centre(s) any changes to its implementation (including the annual change of station list, changes in additional statistics) and changes in their NWP model.**

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## **APPENDIX 2.2.35. STANDARDIZED VERIFICATION SYSTEM FOR SEASONAL PREDICTION**

### **1. Introduction**

This appendix describes procedures for the production of a standard set of verification scores for SP produced by WIPPS centres. The goal is to provide consistent verification information on the SP products of GPCs that will assist forecasters in RCCs, NMHSs and at RCOFs to prepare regional and national seasonal outlooks, and also to help the GPCs compare and improve their forecast systems. The verification scores described are to be calculated on retrospective forecasts (hindcasts). Skill measures recommended for use by RCCs in verification of regional forecasts include those described here.

This appendix describes the verification scores and the variables, regions, seasons and lead times for which the scores shall be applied. The mathematical formulation of the scores is documented on the Lead Centre(s) for SPMME website(s), together with supplementary information on score calculation, the observational datasets to be used for verification.

### **2. Verification statistics**

The following sections describe the scores that are mandatory for GPCs. Information on additional recommended scores is provided on the Lead Centre(s) for SPMME website(s).

Two types (levels) of verification are required:

- Level 1: Scores aggregated over all grid points within specified regions (which, collectively, include global coverage) and scores for climate indices;
- Level 2: Scores evaluated at individual grid points (with global coverage).

For both levels 1 and 2, verification of both deterministic (ensemble mean) forecasts and probabilistic forecasts (for tercile categories) is required.

### **3. Variables**

The variables and categorical stratifications to be verified for level 1 are:

- (a) Three-month-mean T2m (screen temperature): Ensemble mean and probabilities for three tercile categories;
- (b) Three-month precipitation accumulation: Ensemble mean and probabilities for three tercile categories;
- (c) Monthly Niño3.4 SST indices (for GPCs-SP operating coupled (one-tier) prediction systems): Ensemble mean and probabilities for three tercile categories.

The variables and categorical stratifications to be verified for level 2 are:

- (a) As (a), above;
- (b) As (b), above;
- (c) Three-month-mean SST: Ensemble mean and probabilities for three tercile categories.

Where the terciles of the climatology are defined over the hindcast period used (see section 10) and the three-month-mean periods are as described in section 5.

#### 4. **Forecast times/frequency**

In general, scores shall be computed for hindcasts initialized at monthly intervals. Some level-1 scores are required only at quarterly intervals (see section 5 following).

#### 5. **Forecast target periods and lead times**

##### **Level 1: T2m and precipitation**

- Target periods: The three-month target periods for level 1 are:
  - March-April-May (MAM), June-July-August (JJA), September-October-November (SON) and December-January-February (DJF);
- Lead times: Nominal one-month lead time. For example, forecasts issued on 15 May for the JJA season are considered to have a nominal lead time of one month.

##### **Level 1: Niño 3.4 indices (for GPCs-SP operating coupled systems)**

- Target periods: Each calendar month of the forecast;
- Lead times: One, two, three, four and five months.

##### **Level 2: T2m and precipitation**

- Target periods: Twelve rolling three-month periods (for example, MAM, AMJ, MJJ...).

#### 6. **Areas**

Northern hemisphere extra-tropics:	90°N–20°N, inclusive, all longitudes
Southern hemisphere extra-tropics:	90°S–20°S, inclusive, all longitudes
Tropics:	20°N–20°S, inclusive, all longitudes

Verification to be aggregated over all grid points within each area, including points on the boundary.

For verification of the Niño 3.4 region index, SST averaged over the Niño 3.4 region (5°S–5°N, 170°W–120°W) shall be used.

#### 7. **Verification against analyses**

##### 7.1 **Grid and interpolation**

All variables except indices shall be interpolated to a regular 2.5° × 2.5° grid prior to verification.

The historical SST, T2m and precipitation analyses to be used for verification may be subject to change and are specified on the Lead Centre(s) for SPMME website(s). The Lead Centre(s) for SPMME will inform GPCs when a change is made.

Skill scores require verification of climatology-based forecasts as baseline reference against “true” forecasts. **The same analysis shall be used to verify the reference and the forecast.**

#### 8. **Verification against observations**

Verification against station observations is not mandatory for GPCs. GPCs should use the scores described here and verify against observation sets of their choice that are suitable for purpose.

## 9. Scores

The following scores are to be calculated for all variables:

### Level 1: T2m and precipitation

Probability forecasts:

- Reliability diagrams with frequency histograms;
- ROC diagram with standardized area under the ROC curve.

Deterministic forecasts:

- Mean square skill score (MSSS) with respect to climatology.

### Level 1: Niño 3.4 indices (for GPCs operating coupled systems)

Probability forecasts:

- ROC diagram with standardized area under the ROC curve.

Deterministic forecasts:

- MSSS with respect to climatology and its three-term decomposition.

### Level 2: T2m and precipitation

Probability forecasts:

- ROC diagram with standardized area under the ROC curve.

Deterministic forecasts:

- MSSS with respect to climatology and its three-term decomposition.

Provision of the statistical significance of scores and/or error bars is not currently mandatory but is strongly recommended. GPCs are free to choose the method of calculation (guidance is available on the Lead Centre(s) for SPMME website(s)).

## 10. Hindcast datasets

**Hindcast datasets shall be generated with the same prediction system that is used to generate the real-time forecasts, though it is recognized that the hindcast ensemble may necessarily be smaller than used in real time.** It is also recognized that the source of initial conditions used for hindcasts may, for some centres, be different from that used for real-time forecasts.

The hindcast period used should be as long as possible, but at least 15 years. The recommended period is provided on the Lead Centre(s) for SPMME website(s).

11. **Documentation**

Participating centres shall provide to the Lead Centre(s) for SPMME information on the specification of their prediction system, and promptly update the specification when there are system changes.

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## **APPENDIX 2.2.36. STANDARDIZED VERIFICATION OF WAVE FORECASTS**

### **1. Introduction**

This appendix presents detailed procedures for the generation of a standard set of verification scores for wave forecasts produced by the Lead Centre(s) for WFV, based on gridded wave forecast fields provided by WMO designated centres endorsed by SERCOM/SC-MMO. The goal is to provide consistent verification information on the wave forecast products from different centres for forecasters in the ocean forecast services and to help WMO designated centres endorsed by SERCOM/SC-MMO compare and improve their forecasts. The Lead Centre functions, as described in 2.2.3.3, include creating and maintaining a website for wave verification information, so that potential users will benefit from a consistent presentation of the results.

The standardized verification should provide key relevant information appropriate to the state of the art in wave forecasting, ensuring a consistent verification methodology applied to forecasts from different WMO designated centres endorsed by SERCOM/SC-MMO, and the use of a common set of observations.

### **2. Parameters**

Atmospheric forcing:

- 10-metre wind speed u and v components (10-metre u, 10-metre v).

Wave fields:

- Significant wave height;
- Peak period;
- Mean wave period based on the second moment of the frequency spectrum;
- Mean wave direction.

### **3. Forecast times**

If available, forecasts from 0000, 0600, 1200 and 1800 UTC should be provided.

### **4. Forecast steps**

In as fine temporal granularity as available but at least every six hours to the end of the forecast range.

### **5. Verifying observations**

Forecasts of the above parameters will be evaluated against in situ observations from buoys and platforms available at the Lead Centre(s) for WFV. If additional in situ observations become available over time they will be added following a careful selection and quality control. WMO designated centres endorsed by SERCOM/SC-MMO are encouraged to promote the exchange of in situ wind and wave observations.

### **6. Interpolation**

**Verification shall be made using the nearest native model ocean grid point to the observation location.**

## 7. **Scores**

The following scores shall be calculated for all parameters against observations:

- Mean error;
- RMSE;
- Error standard deviation;
- Scatter index (error standard deviation normalized by observed mean);
- Symmetric slope (variance ratio);
- Quantile-quantile plots.

## 8. **Exchange of forecast fields**

Each WMO designated centre endorsed by SERCOM/SC-MMO shall provide fields to the Lead Centre(s) for WFV on a regular latitude–longitude grid at the resolution that best matches the native resolution of the direct model output. Details of the procedure and the required format for the data are provided on the website(s) of the Lead Centre(s) for WFV.

## 9. **Documentation**

Information shall be provided by WMO designated centres endorsed by SERCOM/SC-MMO to the Lead Centre(s) for WFV on any changes to the production of exchanged forecast fields and changes in their wave forecast systems.

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## **APPENDIX 2.2.37. STANDARDIZED VERIFICATION OF TROPICAL CYCLONE FORECAST PRODUCTS**

### **1. Introduction**

This appendix presents detailed procedures for the production and exchange of a standard set of verification scores for tropical cyclone forecasts produced by the Lead Centre(s) for TCFV based on gridded forecast fields provided by WIPPS-participating centres. The goal is to provide consistent verification information on the tropical cyclone forecast products of WIPPS-participating centres for forecasters in NMHSs, and to help the WIPPS-participating centres compare and improve their forecasts. The Lead Centre functions, as described in 2.2.3.4, include creating and maintaining a website for TCFV information, so that potential users can benefit from a consistent presentation of the results.

The standardized verification should provide key relevant information appropriate to the state of the art in tropical cyclone forecasting, while being as simple and as easy to implement as possible, and ensuring a consistent implementation across WIPPS-participating centres.

### **2. Tropical cyclones to be verified**

Tropical cyclones whose intensity has reached the category of tropical storm with a sustained wind of 34 knots or stronger are set as targets for this verification. The tropical depression stage of the targeted tropical cyclones is also included in this verification. However, the tropical cyclones that never evolve from the tropical depression to tropical storm stage during their life time are excluded.

Tropical cyclones that are not recorded in the best track dataset (see section 7) are also excluded.

### **3. Parameters**

Mandatory:

- MSLP.

Recommended:

- u and v wind components at 850 hPa.

### **4. Forecast times**

Scores shall be computed for forecasts initialized at 1200 UTC. Annual scores shall be computed for a year from 1 January to 31 December in the northern hemisphere and for a year from 1 September to 31 August in the southern hemisphere.

### **5. Forecast steps**

Forecast steps shall be every 6 hours to 192 hours of the forecast range.

## 6. Verification areas

Scores are to be calculated separately for each verification area shown in the table below:

<i>Verification area</i>	<i>Specification of area</i>
Western North Pacific:	0°–90°N, 100°E–180°E
Eastern North Pacific, including central North Pacific	EQ–90°N, 180°W–West Coast of North and South American Continent (Tropical cyclones that are generated in this area are categorized as being of this area throughout their lifetime.)
North Atlantic Ocean	Caribbean Sea, Gulf of Mexico, and EQ–90°N, East Coast of North and South American Continent–35°W (Tropical cyclones that are generated in this area are categorized as being of this area throughout their lifetime.)
North Indian Ocean	EQ–Eurasian Continent, 30°E–100°E
South Indian Ocean	EQ–90°S, 30°E–90°E
South Pacific and around Australia	EQ–90°S, 90°E–120°W

## 7. Verifying datasets

**Verification shall be carried out for best-track datasets available at the Lead Centre(s).**

Best-track datasets are originally provided by RSMCs participating in tropical cyclone forecasting, as defined in 2.2.2.7.

## 8. Grid and interpolation

**Verification shall be made using forecast data on a regular latitude–longitude grid. The Lead Centre(s) shall calculate position and pressure of tropical cyclone centres by linear interpolation using five data of the nearest grid point and its four neighbouring grid points to the north, south, east and west.**

## 9. Scores

Scores are to be calculated for each tropical cyclone individually.

The following scores are to be calculated against the best-track dataset:

- (a) Detection rate;
- (b) Storm track verification:
  - Position error: Distance between predicted and analysed tropical cyclone centres;
  - Along-track/cross-track (ATCT) bias (shown in the pictorial form of scatter diagram) (AT bias: bias in the direction of cyclone movement; CT bias: bias in the rectangular direction of cyclone;
- (c) Bias of central pressure.

The mathematical formulation of the scores is documented on the Lead Centre(s) for TCFV website(s), together with supplementary information on score calculation.

**10. Exchange of forecast fields**

Each WIPPS-participating centre shall provide global fields annually to the Lead Centre(s) for TCFV on a regular latitude–longitude grid at the resolution of 1.5° longitude by 1.5° latitude resolution or finer. Details of the procedure and the required format for the data are provided on the website(s) of the Lead Centre(s).

**11. Exchange of scores**

All calculated scores in the text or binary form shall be made available on the Lead Centre(s) for TCFV website(s).

The Lead Centre(s) for TCFV shall also make available the scores in the pictorial form on its website(s) as follows:

- (a) Detection rate of tropical storm: The score is drawn every 12 hours until 120 hours;
- (b) Storm track verification: Position error and ATCT bias are shown every 24 hours until 192 hours; position error is shown as a map; ATCT bias is shown in scatter-diagram form;
- (c) Bias of central pressure: A scatter diagram of analysed and predicted central pressure is shown every 24 hours until 192 hours.

**12. Documentation**

WIPPS-participating centres shall provide to the Lead Centre(s) on TCFV information on any changes to the production of the exchanged forecast fields.

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## **APPENDIX 2.2.38. MANDATORY AND RECOMMENDED PRODUCTS FOR MARINE METEOROLOGICAL SERVICES TO BE MADE AVAILABLE THROUGH THE WMO INFORMATION SYSTEM**

Marine meteorological services for the high seas, provided through the Worldwide Met-ocean Information and Warning Service, shall include:

- (a) Meteorological warnings;
- (b) Marine forecasts;
- (c) Sea-ice information services.

The standard and recommended practices covering the format and content of each service are described in the [Manual on Marine Meteorological Services](#) (WMO-No. 558), Volume I.

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## **APPENDIX 2.2.39. STANDARDIZED VERIFICATION FOR MARINE METEOROLOGICAL SERVICES**

There are a number of challenges in establishing a verification framework for the Worldwide Met-ocean Information and Warning Service (WWMIWS). These include:

- (a) The large spatial domains of forecast and warning areas;
- (b) The format of the product, which is text based;
- (c) The sparseness of the verifying observations;
- (d) The gaps in required verifying observations.

Customer surveys are used to measure satisfaction with the WWMIWS, and to understand opportunities for improvement.

A periodic self-assessment is conducted by METAREA Coordinators against the mandatory service requirements established by the International Maritime Organization (IMO), and the standard practices established by the WMO Technical Regulations.

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## APPENDIX 2.2.40. MANDATORY AND RECOMMENDED GLOBAL NUMERICAL SUB-SEASONAL PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

### Mandatory products (maps)

Variable	Coverage	Forecast range or lead time	Temporal resolution	Output type	Issuance frequency
2-m temperature	Global	Minimum forecast range of four weeks	Averages over periods (one day to four weeks)	(1) Ensemble mean anomaly (2) Probabilities for tercile forecast categories (where applicable)	Minimum once a week
Sea-surface temperature (SST)	Global oceans				
Daily accumulated total precipitation	Global				

Note: SST is a mandatory product only for centres operating one-tier systems.

### Recommended products (maps)

Variable	Coverage	Forecast range or lead time	Temporal resolution	Output type	Issuance frequency
500 hPa height	Global	Minimum forecast range of four weeks	Averages over periods (one day to four weeks)	(1) Ensemble mean anomaly (2) Probabilities for tercile forecast categories	Minimum once a week
Mean sea-level pressure (MSLP)					
850 hPa temperature					

Notes:

1. Probabilities for extremes, for the variables specified under mandatory products, are recommended.
2. The recommended definition to be used for extremes (for which products are recommended, not mandatory) is: below the 10th percentile and above the 90th percentile.
3. Output is in the form of rendered images (for example, forecast maps and diagrams). GPCs-SSP are encouraged to make available digital data on the retrospective forecast (hindcast) and forecast fields underlying the products. Gridded binary-2 (GRIB-2) format should be used for fields posted on FTP sites or disseminated through WIS.
4. To enable the construction of multi-model products, provision of retrospective forecasts covering the most recent 25 to 30-year period is recommended.
5. Information on how category boundaries are defined should be made available.
6. Indications of skill will be provided in accordance with Appendix 2.2.44.

### Recommended products (diagrams)

Diagrams presenting forecasts of the tropical intraseasonal variability such as the Madden–Julian Oscillation (Wheeler and Hendon, 2004; Gottschalck et al., 2010) are recommended.

### References

- Gottschalck, J.; Wheeler, M.; Weickmann, K. et al. A Framework for Assessing Operational Madden–Julian Oscillation Forecasts: A CLIVAR MJO Working Group Project. *Bulletin of the American Meteorological Society* **2010**, 91 (9), 1247–1258. <https://doi.org/10.1175/2010BAMS2816.1>.
- Wheeler, M. C.; Hendon, H. H. An All-Season Real-Time Multivariate MJO Index: Development of an Index for Monitoring and Prediction. *Monthly Weather Review* **2004**, 132 (8), 1917–1932. [https://doi.org/10.1175/1520-0493\(2004\)132<1917:AARMMI>2.0.CO;2](https://doi.org/10.1175/1520-0493(2004)132<1917:AARMMI>2.0.CO;2).

## **APPENDIX 2.2.41. INFORMATION TO BE PROVIDED ON THE CHARACTERISTICS OF GLOBAL NUMERICAL SUB-SEASONAL PREDICTION SYSTEMS**

- Date of implementation of the current SSP system:
  - Whether the system is a coupled ocean–atmosphere forecast system:
  - Whether the system is a two-tier forecast system:
  - Atmospheric model resolution:
  - Ocean model and its resolution (if applicable):
  - Source of atmospheric initial conditions:
  - Source of ocean initial conditions:
  - If a two-tier system is used, the source of SST predictions:
  - Hindcast period:
  - Ensemble size for the hindcasts:
  - Method of configuring the hindcast ensemble:
  - Ensemble size for the forecast:
  - Method of configuring the forecast ensemble:
  - Length of forecasts:
  - Data format:
  - The latest day of the week that forecast anomalies for the next weeks/months become available:
  - Method of construction of the forecast anomalies:
  - URL where forecast is available:
  - Point of contact:
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## APPENDIX 2.2.42. MINIMUM INFORMATION TO BE AVAILABLE FROM THE LEAD CENTRE(S) FOR SUB-SEASONAL PREDICTION MULTI-MODEL ENSEMBLES

### 1. Digital products

Daily mean global fields of forecast variables from contributing centres for individual ensemble members for at least the four weeks following the forecast initialization date.

#### Mandatory products

<i>Variable</i>	<i>Level</i>	<i>Resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Temperature	2 m	1.5° × 1.5°	Minimum four weeks from the day of submission	Daily mean	Once a week
Sea-surface temperature (SST)	Surface				
Daily accumulated total precipitation	Surface				
Mean sea-level pressure (MSLP)	Surface				
Temperature	850 hPa				
Geopotential height	500 hPa				
Velocity (u, v)	850 hPa and 200 hPa				
Velocity (u)	10 m				
Outgoing long-wave radiation	Top of the atmosphere				

Note: SST is a mandatory product only for centres operating one-tier systems.

#### Recommended products

<i>Variable</i>	<i>Level</i>	<i>Resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Dewpoint temperature	2 m	1.5° × 1.5°	Minimum four weeks from the day of submission	Daily mean	Once a week
Minimum temperature	2 m				
Maximum temperature	2 m				
Geopotential height	850 hPa and 200 hPa				
Specific humidity	850 hPa				
Soil moisture	Top 20 cm and 100 cm				

Note: The minimum and maximum temperatures at 2 m are not daily means; they are selected from a 24-hour window.

## 2. Graphical products

### Mandatory products

#### Forecast spatial maps

	<i>Variable</i>	<i>Forecast format type</i>	<i>Map type</i>	<i>Digital</i>
Forecast	Daily accumulated total precipitation	DMME; PMME; Individual GPCs	Global and regional maps	No
	500-hPa geopotential height			
	Mean sea-level pressure (MSLP)			
	2-m temperature			
	850-hPa temperature			
	Sea-surface temperature (SST)			

Notes:

1. DMME: deterministic multi-model ensemble
2. PMME: probabilistic multi-model ensemble
3. SST is a mandatory product only for centres operating one-tier systems.

### Verification

	<i>Variable</i>	<i>Verification for</i>	<i>Map type</i>	<i>Digital</i>
Hindcast	Daily accumulated total precipitation	DMME; PMME; Individual GPCs	Global and regional maps	No
	500-hPa geopotential height			
	Mean sea-level pressure (MSLP)			
	2-m temperature			
	850-hPa temperature			
	Sea-surface temperature (SST)			

Note: Verify products using the Standardized Verification System for SSP (SVSSSP) (Appendix 2.2.44)

### Recommended products

#### Forecast indices

	<i>Parameter</i>	<i>Forecast format type</i>	<i>Map type</i>	<i>Digital</i>
Forecast	Niño 1+2	DMME; Individual GPCs	Time series	No
	Niño 3			
	Niño 3.4			
	Niño 4			
	Indian Ocean Dipole Mode Index (DMI)			
	Tropical South Atlantic (TSA) index			
	Tropical North Atlantic (TNA) index			

Note: SST indices are recommended products only for centres operating one-tier systems.

**Intraseasonal variability**

Diagrams presenting each contributing centre forecast of the tropical intraseasonal variability such as the Madden–Julian Oscillation are recommended.

**Tropical cyclone**

Graphical maps presenting each contributing centre forecast of the tropical cyclone genesis and activities, including description of the tracking method, are recommended.

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## **APPENDIX 2.2.43. ACCESS TO DATA AND VISUALIZATION PRODUCTS HELD BY THE LEAD CENTRE(S) FOR SUB-SEASONAL PREDICTION MULTI-MODEL ENSEMBLES**

- (a) Access to contributing centre data from the Lead Centre(s) for SSPMME website(s) will be password-protected.
  - (b) Digital data will be redistributed only in cases where the contributing centre data policy allows it. In other cases, requests for contributing centre digital output should be directed to the relevant contributing centre.
  - (c) Formally designated GPCs-SSP, GPCs-SP and RCCs, NMHSs and institutions coordinating RCOFs are eligible for password-protected access to information held and produced by the Lead Centre(s) for SSPMME. Entities that are in demonstration phase to seek designation as GPCs or RCCs are also eligible for password-protected access to information held and produced by the Lead Centre(s) for SSPMME, provided a formal notification has been issued in this regard by the WMO Secretary-General.
  - (d) Institutions other than, but providing contributions to, those identified in (c) may also request access to Lead Centre(s) for SSPMME products. These institutions, referred to as “supporting institutions”, which include research centres, require endorsement letters from: (i) the Permanent Representative of the country where they are hosted, and (ii) the executive manager of the entity they wish to provide contributions to (that is, RCCs, institutions coordinating RCOFs and NMHSs). The use by supporting institutions of products from the Lead Centre(s) for SSPMME is restricted to assistance of the organizations identified in (c) in their production of official forecast outputs. Supporting institutions may not use such products to generate and display or disseminate independent forecast products. Supporting institutions must agree with these restrictions to be eligible for access. Prior to access being granted to an applicant supporting institution, the Lead Centre(s) for SSPMME will refer the application to the INFCOM/ET-OCPS through the WMO Secretariat, for final consultation and review. Decisions to allow access must be unanimous. The Lead Centre(s) will be informed by the WMO Secretariat of such new users accepted for access.
  - (e) A list of users provided with password access will be maintained by the Lead Centre(s) for SSPMME and reviewed periodically by the INFCOM/ET-OCPS, to measure the degree of effective use and also to identify any changes in status of eligible users, and determine further necessary follow-up.
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## **APPENDIX 2.2.44. STANDARDIZED VERIFICATION SYSTEM FOR SUB-SEASONAL PREDICTION**

### **1. Introduction**

This appendix describes procedures for the production of a standard set of verification scores for SSP produced by WIPPS centres. The goal is to provide consistent verification information on the SSP products of GPCs that will assist forecasters in RCCs, NMHSs and at RCOFs to prepare regional and national seasonal outlooks, and also to help the GPCs compare and improve their forecast systems. The verification scores described are to be calculated on retrospective forecasts (hindcasts). GPCs will produce and display the verification scores via their websites. Skill measures recommended for use by RCCs in verification of regional forecasts include those described here.

This appendix describes the verification scores and the variables, regions, relevant time averages and lead times for which the scores shall be applied.

### **2. Verification statistics**

The following sections describe the scores that are mandatory for GPCs.

Two types (levels) of verification are required:

- Level 1: Scores aggregated over all grid points within specified regions (which, collectively, include global coverage) and scores for sub-seasonal indices;
- Level 2: Scores evaluated at individual grid points (with global coverage).

For both levels 1 and 2, verification of both deterministic (ensemble mean) forecasts and probabilistic forecasts (for tercile categories) is required.

### **3. Variables**

**All mandatory variables and categorical stratifications listed in the first table of Appendix 2.2.40 shall be verified for level 1 and 2.** The temporal resolution (averaging period) is the same as for products provided by each GPC-SSP.

Terciles of the climatology are defined over the hindcast period used (see section 8).

### **4. Hindcast times/frequency**

**In general, scores shall be computed for hindcasts initialized at least once a month.**

### **5. Areas**

- Global: 90°N–90°S, inclusive, all longitudes
- Northern hemisphere extra-tropics: 90°N–20°N, inclusive, all longitudes
- Southern hemisphere extra-tropics: 90°S–20°S, inclusive, all longitudes
- Tropics: 20°N–20°S, inclusive, all longitudes

Verification to be aggregated over all grid points within each area, including points on the boundary.

## 6. **Verification against analyses**

### 6.1 **Grid and interpolation**

All variables except indices shall be interpolated to a regular  $1.5^\circ \times 1.5^\circ$  grid prior to verification.

Skill scores require verification of climatology-based forecasts as baseline reference against “true” forecasts. **The same analysis shall be used to verify the reference and the forecast.**

## 7. **Scores**

The following scores are to be calculated for all mandatory variables:

Probability forecasts:

- Reliability diagrams with frequency histograms;
- ROC diagram with standardized area under the ROC curve.

Deterministic forecasts:

- MSSS with respect to climatology and its three-term decomposition.

Provision of the statistical significance of scores and/or error bars is not currently mandatory but is strongly recommended. GPCs are free to choose the method of the calculation.

## 8. **Hindcast datasets**

**Hindcast datasets shall be generated with the same prediction system that is used to generate the real-time forecasts, though it is recognized that the hindcast ensemble may necessarily be smaller than used in real time.** It is also recognized that the source of initial conditions used for hindcasts may, for some centres, be different from that used for real-time forecasts.

**The hindcast period shall be at least 15 years.**

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## **APPENDIX 2.2.45. MANDATORY AND RECOMMENDED SUB-SEASONAL TO SEASONAL HYDROLOGICAL PREDICTION PRODUCTS**

### **1. Introduction**

This appendix presents a list of core mandatory products (in section 2) and recommended global ensemble S2S hydrological products (in section 3) to be supported by qualifying centres. Additional information about the products is included in section 4, and related material describing product verification and system information is included in Appendices 2.2.46 and 2.2.47, respectively.

### **2. Mandatory products**

Centres must operationally produce ensemble or probabilistic forecasts (including a central tendency and spread) for the variables listed below for a global extent, where appropriate. Cryosphere-related products will not be valid over all land areas, though such data products may retain global dimensions. Expanded variable definitions are given in section 4.6.

<i>Variable</i>	<i>Spatial resolution</i>	<i>Temporal resolution (time step)</i>	<i>Forecast lead time</i>	<i>Update frequency</i>	<i>Latency</i>
Runoff (Discharge)	5–25 km grids or mesoscale catchments	Between 1 day and 1 month	From 0 to 12 months with minimum range of 3 months	Between 1 day and 1 month	Between 1 and 10 days

### 3. Recommended products

In addition to the mandatory products, centres are welcome and encouraged to provide probabilistic information products for other variables to give a fuller context to the primary forecast outputs listed above. Expanded variable definitions are given in section 4.6.

<i>Variable</i>	<i>Spatial resolution</i>	<i>Temporal resolution (time step)</i>	<i>Forecast lead time</i>	<i>Update frequency</i>	<i>Latency</i>
River stage	5–100 km reach lengths; Point locations	Between 1 day and 1 month	From 0 to 12 months with minimum range of 3 months	Between 1 day and 1 month	Between 1 and 10 days
Water table depth	5–25 km or equivalent catchments	1 day to 1 month 1 month to 2 years 1 day to 1 month 1 to 10 days (depending on temporal resolution and range)			
Evaporative variables	5–25 km or equivalent catchments				
Groundwater	5–50 km or equivalent catchments				
Surface precipitation and 2-metre air temperature	5–25 km or equivalent catchments				
Hydrologic indices	5–25 km or equivalent catchments				
Water equivalent of snow cover (snow water equivalent)	5–25 km or equivalent catchments				
Soil moisture	5–25 km or equivalent catchments				

### 4. Additional supporting information

#### 4.1 *Spatial resolution*

The spatial resolution of the information products shall be determined by factors including usefulness and usability for stakeholders at the local, regional and global scale, as well as by scientific and technical considerations, to ensure that products can be reliably generated, effectively disseminated and exhibit statistical skill. The mandatory spatial unit of the forecasts is a regular grid; however centres are also encouraged to provide products for other spatial units including watersheds or other delineations (such as administrative units), provided that the formal spatial reference definition is accepted by the community and is publicly available and accessible. It is expected that most qualifying products will adopt an intermediate spatial scale resolution (25–1 000 km<sup>2</sup> or approximately 5–25 km grid spacing). Streamflow or discharge products should be provided for a channel network of commensurate resolution, but also strive to provide outputs for existing and available monitoring gauges, enhancing the products' relevance to stakeholders.

#### 4.2 *Temporal resolution and lead time*

The primary S2S outlook products are temporally coarse, with predictand durations of 1 day to 1 month for lead times of up to one year. Given the skill profile of S2S climate and hydrological phenomena, shorter predictand durations (for example, 1 or 2 weeks) are appropriate for short lead times (up to approximately two months), and longer predictand durations are appropriate for longer lead times. In addition, for some types of forecast outputs, such as ensemble

predictions of streamflow, higher time resolution sequences for each ensemble member are commonly provided for use as inputs to subsequent modelling analyses (for example, reservoir simulation models that may require daily or sub-daily time resolution inputs).

#### 4.3 ***Issuance frequency and latency***

The update frequency is related to the temporal resolution, such that products are updated with sufficiently low latency (the lag between the time for which the forecast is initialized and the release or publication of the final forecast) and high frequency that the first lead time is still valid at the time of issuance. For example, centres producing forecasts with a 1 week temporal resolution should strive for a latency of 3 days or less and an update frequency of 1 week or less, while those producing forecasts with a 1 month temporal resolution should strive for a latency of 10 days or less and an update frequency of 1 month or less.

#### 4.4 ***Uncertainty estimation (ensemble size)***

S2S forecasts should quantitatively and reliably characterize uncertainty, because the ratio of signal to noise at S2S lead times is often relatively low. Ensemble-based systems should use a sufficient number of ensemble members (that is, ensemble size) to estimate forecast central tendency well (with a suggested minimum of 30 members). Statistical forecast systems or methodologies, which are not uncommon for regional applications, should estimate uncertainty from analysis of rigorously cross-validated prediction error rather than from model calibration error.

#### 4.5 ***Output type and formats***

The S2S products will ideally be presented in multiple forms and formats. To facilitate interpretation by stakeholders, a primary form of communication should include the presentation of forecast anomalies (for example, percentile, percent of average, difference from average) calculated with respect to a retrospective climatology (mean annual and/or mean monthly to seasonal). Forecast anomalies may be for a particular percentile (such as the 10th, 50th or 90th) and/or statistic (such as the ensemble mean). Forecasts of the most probable outlook category are also a common derived product, and such categorical forecasts are not limited to the common tercile formulation (that is, normal, below normal and above normal categories). The reference forecast and observational climatology should be based on a record long enough to determine robust statistical thresholds for defining different conditions – preferably two decades or longer.

Forecasts often suffer from systematic mean and variability bias, and the presentation of forecasts in terms of anomalies can aid in circumventing bias as well as standardizing products across multiple sources or centres. The calculation of anomalies should be calibrated to account for variability biases between the observational reference and the forecast system. Additional forms of forecast output are encouraged, including the full value of the raw forecast, forecasts transformed into standardized or normalized index form, as well as supporting information (such as the climatology for each output) as described in Appendix 2.2.47.

**Products shall be made available by the centre on public-facing website(s) in multiple formats, including graphical products (maps) as well as raw or post-processed data files (in standard formats, including ASCII/text or binary files, such as NetCDF or GRIB).** Centres are encouraged to use data archive facilities that provide user-oriented functionality and web services for interactive and automated sub-setting and downloading of forecast data. Lastly, regular forecast product discussions are encouraged, to highlight areas of interest or potential concern for users (such as droughts or flood potential). **The centre shall also provide a clear list of contact points and/or a mechanism for inquiries and feedback from users.**

4.6 **Expanded variable information**

<i>Variable</i>	<i>Description</i>
Runoff (Discharge)	Water input to the river channel network or streamflow. Runoff may be expressed as total runoff and/or one or more of its components, namely surface runoff and subsurface discharge (volume/time unit). Runoff may also be supplied in the form of streamflow (or discharge), which includes the effect of channel routing.
Water equivalent of snow cover (snow water equivalent)	Water depth equivalent of the snow and glacier mass above the land surface (length unit)
Soil moisture	Water depth within the hydrologically active range of the subsurface, typically ranging from 0 m to a maximum depth in the 2–20 m range (length unit)
Groundwater or aquifer storage	Water depth stored in aquifers below the active subsurface soil moisture layers (length unit)
River stage	Elevation of the free water surface of a water body (river) relative to a datum level (length unit)
Water table depth	Depth to the upper surface of the saturated soil moisture zone (length unit)
Evaporation variables	These include actual and potential evapotranspiration (the evaporation that would occur from bare soil or a plant if sufficient water were available and absent any restriction), as well as lake and reservoir evaporation (length/time unit)
Surface precipitation and 2-metre air temperature	These climate forecast variables provide additional context for understanding hydrologic forecast variables. While climate forecasts are available from S2S climate forecasting centres, they may differ in multiple respects from those used directly in producing the hydrological forecasts. Hydrological forecast centres are encouraged to make available at least the primary climate forecast variables (precipitation and 2-metre air temperature) associated with the hydrological forecasts. (length or mass/time unit for precipitation and degrees Celsius or Kelvin units for temperature).
Hydrological and/or drought indices	<p>Some management communities use common indices such as the PDSI to inform decision-making on drought and other extremes. (non-dimensional standardized or normalized units). The <a href="#">Handbook of Drought Indicators and Indices</a> (WMO-No. 1173) provides a list of index definitions, including the following, although this list does not include all indices of interest.</p> <ul style="list-style-type: none"> <li>• Palmer Hydrological Drought Index (PHDI)</li> <li>• Standardized Reservoir Supply Index (SRSI)</li> <li>• Standardized Streamflow Index (SSFI)</li> <li>• Standardized Water-level Index (SWI)</li> <li>• Streamflow Drought Index (SDI)</li> <li>• Surface Water Supply Index (SWSI)</li> <li>• Aggregate Dryness Index (ADI)</li> <li>• Standardized Snowmelt and Rain Index (SMRI)</li> </ul>

## **APPENDIX 2.2.46. STANDARDIZED VERIFICATION OF SUB-SEASONAL TO SEASONAL HYDROLOGICAL PREDICTION PRODUCTS**

### **1. Introduction**

The present appendix describes procedures for producing and exchanging a standard set of verification scores for sub-seasonal to seasonal (S2S) hydrological prediction data and products generated by WMO Integrated Processing and Prediction System (WIPPS) centres for incorporation into the WIPPS. Such centres may generate other hydrological prediction data and products that are not integrated into the WIPPS and that are not subject to the standard set of required verification scores. The goal is to provide consistent verification information on the S2S products of participating forecast centres that will assist users, including forecasters in regional and national centres who use the information to inform regional and national seasonal outlooks. The verification information will provide quantitative benchmarks for documenting and intercomparing the skill of participating centres. The verification scores described in the appendix are to be calculated based on retrospective forecasts (hindcasts). Producing centres will calculate and make the verification scores available via their centre websites. Skill measures recommended for use by participating centres in verification of S2S hydrological forecasts include those described here.

### **2. Verification metrics and skill scores**

The following metrics and skill scores are required for the mandatory prediction variable(s) and derived products:

- Measures of accuracy and skill for ensemble mean and median forecasts, including bias, relative bias, correlation and anomaly correlation, mean absolute error and mean squared error; and associated relative terms, where appropriate: for example, relative bias, relative mean absolute error, both expressed as a percentage;
- Measures of probabilistic skill, including the continuous ranked probability score (CRPS) and the ranked probability score (RPS), and their 3-part decompositions (including, for example, the reliability terms);
- For categorical forecasts, such as tercile predictions, common categorical skill metrics shall be provided, such as hit rates, false alarm ratios, critical success indices or multicategory Brier scores;
- These metrics should also be expressed in the form of a skill score using two separate references: (1) climatology; (2) persistence;
- The observational datasets for the validation of hydrological predictions can be of two types. Official agency observations should be used where available, such as for an appropriate (for example, naturalized or not) streamflow (discharge) value at a river location. Where such observations are not available, such as for subsurface variables or spatially distributed runoff, a high-quality reanalysis may be used. The nature of the validating dataset should be documented along with the presentation of results.

Provision of the statistical significance of skill scores and/or confidence intervals is not currently mandatory but is strongly recommended. Participating centres are free to choose the method of calculating such statistical significance.

### 3. **Application of metrics and skill scores**

The skill scores shall be calculated at the temporal and spatial resolution for which the forecasts are provided (for example, gridded, reach-based, point-based) or as constrained by the available observations and reanalyses, depending on the type of validation being performed.

Forecast skill scores must be stratified by lead time (weekly or monthly) and initialization date or time of year (calendar month or season), recognizing the seasonally varying nature of hydrological prediction skill and its dependence on the influence of initial conditions versus boundary forcings.

Forecast centres are encouraged to provide regional summaries of verification metrics and skill scores, but this is not required. If they are provided, the centre should provide accompanying guidance on the interpretation of such regional summaries, given the heterogeneity of underlying hydrological processes across catchments and sub-basins within the region. Innovative pooling strategies for increasing sample size are also encouraged, if they are well documented.

### 4. **Variables**

All mandatory variables listed in the first table of Appendix 2.2.45 and the derived categorical or anomaly products shall be verified. Verification is also required for recommended variable forecasts and associated products that are to be integrated with the WIPPS. A centre may produce recommended (but not mandatory) outputs without verification, but they will not be integrated into the WIPPS.

### 5. **Hindcast dataset**

The hindcast period for the hindcast dataset used in forecast verification shall be at least 20 years, in order to provide a minimum sample size for assessing forecast performance. Hindcast initialization frequency shall be a minimum of once per month with a minimum ensemble size of 10 members, or an alternate strategy that provides at least 10 members per month shall be used (for example, lagged/pooled members across multiple initialization dates within a month). Hindcast datasets shall be generated with the same prediction system that is used to generate the real-time forecasts, to the extent possible. It is recognized that some aspects of real-time systems may differ (by necessity) from the hindcasting system, such as the data assimilation that is used, and that other details such as ensemble size and update frequency (and even resolution) may differ due to computational constraints. These differences, and their expected or potential impact on the validity of the performance scores calculated from the hindcasts, shall be briefly summarized in documentation available from the centre's website.

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## **APPENDIX 2.2.47. SUPPORTING INFORMATION ON THE SUB-SEASONAL TO SEASONAL HYDROLOGICAL PREDICTION SYSTEM**

The present appendix presents a list of the information required to be made available by centres providing sub-seasonal to seasonal (S2S) hydrological predictions within the WMO Integrated Processing and Prediction System (WIPPS). Such information describes the nature of the system, datasets and methods used to produce the forecasts, and other relevant metadata. The information must be updated in a timely fashion when system upgrades are implemented, and includes the following elements.

- Formal name and date of implementation of the current forecast system producing the S2S predictions;
  - Summary of the configuration of the system, including the details of its major sub-components (for example, ocean, land, sea-ice, atmosphere), their version numbers, horizontal and vertical resolutions and extent (for example, number of levels if appropriate), and the coupling of those components;
  - Summary of the forecast initialization approach, including key observational datasets used in initialization, and the method used for data assimilation (if any);
  - Summary of the ensemble forecast generation approach and ensemble forecast details (including size or number of members, time step of saved outputs, update frequency, latency, lead-time range and list of core output variables);
  - Description of any major external boundary forcings or constraints, if appropriate;
  - Summary of associated hindcasting activities, including hindcast period, ensemble size, frequency, ensemble construction approach, time step of saved outputs, time/space extent of outputs and other relevant details (such as list of core output variables and data format);
  - Summary of verification activities or completed studies addressing the performance of the system for the variables being contributed to the WIPPS;
  - Description of access points to forecasts and hindcasts provided for integration with the WIPPS (typically these are URLs);
  - Point(s) of contact, including either personnel names and office information such as email, website and/or telephone number. This should not be a general agency entry point but rather a programmatic or technical contact;
  - List of key references or documentation on the forecast system and its sub-components and methods, if those are not included in the forecast system documentation.
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## APPENDIX 2.2.48. MANDATORY AND RECOMMENDED SNOW COVER PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

Snow cover analysis products are mandatory, but can be provided either on a grid or at the basin-scale (or both). Snow cover forecasts are recommended, but not mandatory. However, in all cases, the same two parameters are mandatory: snow cover area and water equivalent of snow cover.

### (1) Mandatory products

#### Gridded snow analysis products

<i>Parameter</i>	<i>Spatial resolution</i>	<i>Frequency</i>	<i>Latency</i>
Snow cover area	10 km	Once per day	Less than 12 hours
Water equivalent of snow cover			

Notes:

- Altitude at which parameters are valid must be provided.
- Within a given grid cell, parameters can be provided for multiple combinations of altitude, slope, aspect and vegetation type, but a grid cell average should also be provided.

#### Basin-scale snow analysis products

<i>Parameter</i>	<i>Spatial resolution</i>	<i>Frequency</i>	<i>Latency</i>
Snow cover fraction	Basin average	Twice monthly	Less than 7 days
Water equivalent of snow cover			

### (2) Recommended products

#### Gridded snow analysis products

<i>Parameter</i>	<i>Spatial resolution</i>	<i>Frequency</i>	<i>Latency</i>
Snow depth	10 km	Once per day	Less than 12 hours
Vertical average of snowpack temperature profile			
Liquid water content of snow [% of total mass]			
Snowmelt runoff at the base of the snowpack			

Notes:

- Altitude at which parameters are valid must be provided.
- Within a given grid cell, parameters can be provided for multiple combinations of altitude, slope, aspect and vegetation type, but a grid cell average should also be provided.

**Gridded snow forecast products**

<i>Parameter</i>	<i>Spatial resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>	<i>Latency</i>
Snow cover area*	10 km	Up to 3 days/ Beyond 3 days, up to 32 days	3 hours/ 24 hours	Once per day	Less than 12 hours
Water equivalent of snow cover*					
Snow depth					
Vertical average of snowpack temperature profile					
Liquid water content of snow [% of total mass]					
Snowmelt runoff at the base of the snowpack					

\*Required products for gridded snow cover forecast (if forecasts are provided)

Notes:

1. Altitude at which parameters are valid must be provided.
2. Within a given grid cell, parameters can be provided for multiple combinations of altitude, slope, aspect and vegetation type, but a grid cell average should also be provided.

**Basin-scale snow analysis products**

<i>Parameter</i>	<i>Spatial resolution</i>	<i>Frequency</i>	<i>Latency</i>
Snow depth	Basin average	Twice monthly	Less than 7 days
Vertical average of snowpack temperature profile			
Liquid water content of snow [% of total mass]			
Snowmelt runoff at the base of the snowpack			

**Basin-scale snow forecast products**

<i>Parameter</i>	<i>Spatial resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>	<i>Latency</i>
Snow cover fraction*	Basin average	Up to 32 days	24 hours	Twice monthly	Less than 7 days
Water equivalent of snow cover*					
Snow depth					
Vertical average of snowpack temperature profile					
Liquid water content of snow [% of total mass]					
Snowmelt runoff at the base of the snowpack					

\*Required products for basin-scale snow cover forecast (if forecasts are provided)

## **APPENDIX 2.2.49. STANDARDIZED VERIFICATION OF SNOW COVER PREDICTION PRODUCTS**

### **1. Introduction**

The present appendix presents detailed procedures for the generation of a standard set of verification scores for snow cover predictions. Standard verification methods are presented for the two mandatory parameters (snow cover fraction and water equivalent of snow cover) as well as one recommended parameter (snow depth). Different verification methods are also presented for deterministic and probabilistic snow cover predictions.

### **2. Verification metrics**

For water equivalent of snow cover (SWE) and snow depth (SD), verification statistics shall include mean error (ME) and root mean square error (RMSE). These shall be provided for deterministic forecasts as well as for the mean of the predictive distribution (or ensemble mean) in the case of probabilistic forecasts.

The continuous ranked probability score (CRPS) shall be used to evaluate probabilistic predictions of SWE and SD. The decomposition of CRPS into a potential CRPS and a reliability term shall be provided (see Hersbach, 2000).

For verification of deterministic predictions of snow cover area (SCA), a 2x2 contingency table shall be used in order to identify true positives (TP), true negatives (TN), false positives (FP) and false negatives (FN). Areas where modelled snow depth is lower than the detection threshold of the verifying observations shall be considered snow free.

In addition to the contingency table itself, summary statistics obtained from the contingency table shall be provided, and in particular: accuracy, precision, recall and the F score (see Cooper et al., 2018).

For verification of probabilistic predictions of SCA, the Brier score shall be provided, as well as its decomposition into uncertainty, reliability and resolution components (see Murphy, 1973).

### **3. Verifying observations**

Ideally, predictions shall be verified against independent in situ or remotely sensed observations. Because of the persistence of snowpack in time, model errors are strongly correlated in time. Hence, observations from a given network or platform cannot generally be considered independent of model predictions made at an earlier time if the same observation network or platform was used to initialize the model.

Recognizing the challenge of obtaining independent observations for model verification, it is deemed acceptable to verify predictions through a data denial experiment. If such an approach is used, the details of the data denial experiment shall be provided by the centre together with the verification statistics.

When verification against independent observations or through data denial experiments is not possible, verifications shall be made against the centre's own analysis as well as against at least one other analysis product. Differences between the scores obtained using the centre's own analysis and using other analyses shall be provided.

When verifying gridded snow predictions, the difference between the model topography and the altitude of the verifying observation shall not exceed 400 m.

#### 4. **Temporal and spatial aggregation**

Pooling of prediction/observation pairs in time and space shall be performed in order to obtain a sample size large enough to compute stable verification metrics as well as to provide summary statistics for regions and periods of interest.

Pairs valid during the same month shall be pooled together for reporting purposes. Pooling of prediction/observation pairs in space shall be done by basins and sub-basins and/or ecological zones and/or mountain zones. The details of the strategy used for spatial aggregation shall be provided by the centre.

Basin boundaries shall be obtained from the WMO Basins and Sub-Basins (WMOBB) database. Ecological zones shall be obtained from the Global Ecological Zones dataset distributed by the FAO (<https://data.apps.fao.org/catalog/dataset/2fb209d0-fd34-4e5e-a3d8-a13c241eb61b>). Mountain zones shall be obtained from the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC). Further stratification by altitude, slope and aspect can be considered.

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## **APPENDIX 2.2.50. CHARACTERISTICS OF SNOW COVER PREDICTION SYSTEMS**

### **1. System**

- System name and version:
- Date of implementation:

### **2. Configuration**

- Domain:
- Horizontal resolution of the model, with indication of grid spacing in km:
- Number of snow layers:
- Forecast length and forecast step interval:
- Runs per day (times in UTC):
- Integration time step:
- Additional comments:

### **3. Initial conditions**

- Data assimilation method:
- In situ datasets assimilated:
- Remotely sensed datasets assimilated:
- Additional comments:

### **4. Boundary conditions**

- List of atmospheric driving variables:
- Source of information for atmospheric driving variables:
- Time step and horizontal resolution of atmospheric driving variables:
- Lower boundary conditions (to compute ground thermal flux):
- Additional comments:

### **5. Probabilistic predictions**

- Are probabilistic predictions provided? If so, describe method briefly:
- Additional comments:

### **6. Other details of model**

- List of prognostic variables:
- Is snow microstructure represented? If so, describe method briefly:
- Is blowing snow sublimation represented? If so, describe method briefly:
- Is wind-induced snow transport represented? If so, describe method briefly:
- Is interaction with tall vegetation represented? If so, describe method briefly:
- Are the effects of slope and aspect on incoming radiation represented?
- Additional comments:

### **7. Verification approach**

- Which verification approach is used to evaluate the analyses and forecasts?
- In situ datasets used for verification:
- Remotely-sensed datasets used for verification:
- Additional comments:

### **8. Further information**

- Operational contact point:

- URLs for system documentation:
  - URL for list of products:
-

## APPENDIX 2.2.51. MANDATORY AND RECOMMENDED FLASH FLOOD FORECASTING PRODUCTS TO BE MADE AVAILABLE FOR THE PARTICIPATING MEMBERS

### Mandatory products

<i>Parameter/product/variable</i>	<i>Forecast lead time</i>	<i>Issuance frequency</i>	<i>Temporal resolution</i>	<i>Spatial resolution</i>
Flash flood risk (in categories) (e.g. high, moderate, low)	Up to 36 hours	As necessary for the region of interest and depending on available forcing data, but not more than every 6 hours	Temporal steps ranging from less than 1 hour to 6 hours, depending on modelling uncertainties and the source of available rainfall data	Basin areas / grid-cells size up to 200 km <sup>2</sup> , depending on input sources and modelled domain

### Recommended products

<i>Parameter/product/variable</i>	<i>Forecast lead time</i>	<i>Issuance frequency</i>	<i>Temporal resolution</i>	<i>Spatial resolution</i>
Peak discharge Flash flood threshold	Up to 36 hours	As necessary for the region of interest and depending on available forcing data, but not more than every 6 hours	Temporal steps ranging from less than 1 hour to 6 hours, depending on modelling uncertainties and the source of available rainfall data	Basin areas / grid-cells size up to 200 km <sup>2</sup> , depending on input sources and modelled domain

Products may be generated in a number of formats selected to facilitate their usage by different stakeholders and partners, and their processing by other centres and decision support systems, compliant with approved WMO data exchange files formats.

The standard and recommended practices with respect to format and content are described in the [Technical Regulations](#) (WMO-No. 49), Volume III.

---

## **APPENDIX 2.2.52. RECOMMENDATIONS ON VERIFICATION FOR FLASH FLOOD FORECASTING PRODUCTS**

The present appendix presents procedures for the generation of a standard set of verification scores for mandatory products of the Regional Specialized Hydrological Centre (RSHC) for flash flood forecasting based on available ground truth data and whether flash flood flows or flash flood occurrences were forecasted by NMHSs based on flash flood forecasting products and information. The goal is to provide consistent verification information on the flash flood forecast products from different centres for forecasters in the hydrological forecast services and to help RSHCs conducting flash flood forecasting to compare and improve their forecasts. **The RSHC shall create and maintain a website for flash flood verification information, so that potential users benefit from a consistent presentation of the results.**

The standardized verification should provide key relevant information appropriate to the state of the art in flash flood forecasting, ensuring a consistent verification methodology applied to forecasts from different RSHCs, and the use of a common set of observations.

Appropriate forecast verification procedures and metrics will be used, depending on the available ground truth data and whether flash flood flows or flash flood occurrences are forecast. Contingency tables for the mandatory flash flood products provide the number of forecast products and actual events, linking the matches, false warnings and misses. Such tables will produce statistics on the probability of detection, false alarm ratio and probability of a miss.

Other examples of verification metrics include second moment residual statistics and critical success index. Underlying hydrological models will be verified by using usual metrics. For instance, the Nash-Sutcliffe efficiency criterion (NSE) and the index of volumetric fit (IVF).

**Forecast verifications shall be made on an annual basis, with due consideration of the lack of reliability of the scores when computed on a reduced number of cases.**

**The initial model verification shall be made during the implementation of the system.**

Further verification should be carried out on an annual basis or when there is evidence of poor performance. The model verification should be made in all basin outlets where observed data are available and with sufficient record length.

For systems allowing forecaster adjustments, verification will also be carried out on forecaster-adjusted products and on the resultant warnings.

---

## **APPENDIX 2.2.53. CHARACTERISTICS OF FLASH FLOOD FORECASTING SYSTEMS**

### **1. System**

- System name and version:
- Date of implementation:

### **2. Configuration**

- Geographical coverage of the system:
- Horizontal resolution of the model:
- Forecast length and forecast step interval:
- Runs per day (times in UTC):

### **3. Other details of the system**

- Hydrological modelling:
- Soil moisture modelling:
- Satellite and radar precipitation information:
- Configuration and implementation of weather prediction models:

### **4. Products**

- Description of the products and methods for the calculation:
- Other details, if necessary:

### **5. Further information**

- Operational contact point:
  - URL for system documentation:
  - URL for list of products:
-

## APPENDIX 2.2.54. MANDATORY AND RECOMMENDED GLOBAL CLIMATE REANALYSIS PRODUCTS

### 1. Mandatory products (core data) – digital data

<i>Variable</i>	<i>Level</i>
Total precipitation	Surface
Pressure	Surface
Mean sea-level pressure (MSLP)	Surface
Sea-surface temperature (SST)	Surface
Land mask	Surface (constant)
Topography	Surface (constant)
Sea-ice cover	Surface
Water equivalent of snow cover (snow water equivalent)	Surface
Incoming short-wave radiation	Surface
Outgoing long-wave radiation	Top of the atmosphere (TOA)
Dewpoint temperature/specific humidity/relative humidity	2 m
Temperature	2 m
Zonal and meridional wind velocity (u, v)	10 m
Geopotential height	850, 500, 200, 100, 50, 30 and 5 hPa
Temperature	850, 500, 200, 100, 50, 30 and 5 hPa
Zonal and meridional wind velocity (u, v)	850, 500, 200, 100, 50, 30 and 5 hPa
Specific humidity	850, 500, 200, 100, 50, 30 and 5 hPa

Notes:

- Centres provide one of the following variables: dewpoint temperature, specific humidity or relative humidity at 2 m, based on their products.
- Centres provide the above variables with at least 1.25° x 1.25° spatial resolution.
- Centres provide the above variables at least six-hourly.
- Centres also provide the monthly mean of the above variables.

Centres also provide the following products:

- The monthly climatology of the above variables, calculated based on the most recent WMO climatological reference period;
- Time series of global average monthly mean temperature at 2 m.

Centres provide the documentation that explains which data are provided.

### 2. Recommended products – digital data

Centres provide daily climatology of the variables listed in section 1, keeping the same horizontal resolution, and calculated based on the most recent WMO climatological reference period.

Developing and maintaining documentation that includes the calculation methods for generating daily climatology is recommended.

### 3. **Recommended products – maps**

Centres provide spatial maps of the monthly mean and anomalies of variables listed in section 1.

---

## **APPENDIX 2.2.55. CHARACTERISTICS OF GLOBAL CLIMATE REANALYSIS SYSTEMS**

### **1. System**

- System name (version):
- Date of implementation:

### **2. Configuration**

- Earth system components included in the analysis system (e.g. ocean, sea-ice, land, etc.):
- Horizontal resolution of the model, with indication of grid spacing in km (for the different Earth system components included in the model):
- Number of levels in the different Earth system components:
- Frequency of the outputs:
- Top of the atmospheric model:
- Number of analysis cycles per day:
- Earliest start date:
- Integration time step:
- Length and frequency of the longest forecast:
- Dataset latency:
- Additional comments:

### **3. Analysis system**

- Data assimilation method:
- Length of the analysis window:
- Number of ensemble members and their resolution:
- Additional comments:

### **4. Externally prescribed boundary conditions**

Note: Briefly describe boundary conditions (if used) and their source.

- Sea-surface temperature (SST):
- Sea ice:
- Snow:
- Vegetation:
- Land use (and its evolution in time):
- Aerosols:
- Greenhouse gases:
- Solar forcing:
- Additional comments:

### **5. Details of model**

- Dynamical core (e.g. semi-Lagrangian):
- Grid structure:
- Hydrostatic or non-hydrostatic:
- Radiations parameterization:
- Boundary layer parameterization:
- Convection parameterization:

- Cloud parameterization scheme:
- Land surface parameterization scheme:
- Other relevant details:

6. **Further information**

- Operational contact point:
- URL of the technical note/reference paper:
- URL for list of products:

7. **Observational data used**

- URL with the list of observational data used in the reanalysis:
- DOI of data product if available.

8. **Other sources for data access, if available**

---

**APPENDIX 2.2.56. MANDATORY AND RECOMMENDED GLOBAL NUMERICAL STORM SURGE PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM**

**Mandatory products**

<i>Parameter</i>	<i>Level</i>	<i>Minimum resolution</i>	<i>Forecast range</i>	<i>Minimum time steps</i>	<i>Frequency</i>
Total water level	Surface	0.1° x 0.1°	Up to 3 days	Hourly	Twice a day
Tide	Surface				
Storm surge	Surface				

**Recommended products**

- Forecast range: up to 7 days;
- Ensembles;
- Vertical reference for these data, such as mean sea level and geoid.

---

## **APPENDIX 2.2.57. CHARACTERISTICS OF GLOBAL NUMERICAL STORM SURGE PREDICTION SYSTEMS**

### **1. System**

- System name (version):
- Date of implementation:

### **2. Configuration**

- Horizontal resolution of the model, with indication of grid spacing in km:
- Number of model vertical levels:
- Forecast length and forecast step interval:
- Runs per day (times in UTC):
- Is model barotropic or baroclinic?
- Is model coupled to ocean, wave, atmosphere, sea-ice models? Specify which models:
- Horizontal and vertical coordinate system of the model:
- Integration time step:
- Additional comments:

### **3. Initial conditions**

- Climatology data of the model:
- Data assimilation method:
- Observations being assimilated:
- Assimilated window:
- Additional comments:

### **4. Surface boundary conditions**

- Surface forcing: briefly describe method(s), spatial resolution, frequency and origin of atmospheric surface forcing:
- Lateral or external forcings (such as sea ice):
- Lateral boundary conditions (for example, sea ice, river discharge)? If so, briefly describe method(s), frequency and origin of lateral boundary conditions:
- Additional comments:

### **5. Other details of model**

- How is total water level computed (for example, linear superposition)?
- What is the vertical reference datum (mean sea level, geoid)?
- Wave model characteristics (such as, but not limited to, configuration, initial and boundary conditions):
- Sea-ice model characteristics (such as, but not limited to, resolution, rheology, number of sea-ice category):
- Are tide and surge interaction considered?
- Are ice or density effect considered?
- How is the bathymetry obtained?
- Source, resolution and interpolation method:
- Is the water depth clipped and if so at what depth?
- Is wetting and drying considered?
- Verification approach (for example, following the [Guide to Storm Surge Forecasting](#) (WMO-No. 1076), the Surge Model Intercomparison Project or other):

- Other relevant details?

6. **Products delivered**

- Numerical model data output in netCDF or GRIB2:
- Resolution of the products:
- Interpolation method if products are post-processed:
- Frequency of the products:
- Latency of the products (time between production and availability):

7. **Further information**

- Operational contact point:
  - URLs for system documentation:
  - URL for list of products:
-

## APPENDIX 2.2.58. MANDATORY AND RECOMMENDED LEAD CENTRE CLIMATE REANALYSIS PRODUCTS

### 1. Digital products

#### Mandatory products

<i>Variable</i>	<i>Level</i>
Total precipitation	Surface
Pressure	Surface
Mean sea-level pressure (MSLP)	Surface
Sea-surface temperature (SST)	Surface
Land mask	Surface (constant)
Topography	Surface (constant)
Sea-ice cover	Surface
Water equivalent of snow cover (snow water equivalent)	Surface
Incoming short-wave radiation	Surface
Outgoing long-wave radiation	Top of the atmosphere (TOA)
Dewpoint temperature/specific humidity/relative humidity	2 m
Temperature	2 m
Zonal and meridional wind velocity (u, v)	10 m
Geopotential height	850, 500, 200, 100, 50, 30 and 5 hPa
Temperature	850, 500, 200, 100, 50, 30 and 5 hPa
Zonal and meridional wind velocity (u, v)	850, 500, 200, 100, 50, 30 and 5 hPa
Specific humidity	850, 500, 200, 100, 50, 30 and 5 hPa

Note: The Lead Centre(s) provide the monthly mean of the above variables on a common grid with at least 1.25° x 1.25° spatial resolution.

Lead Centre(s) also provide the monthly climatology of the above variables, calculated based on the most recent WMO climatological reference period.

Lead Centre(s) provide the documentation that explains which data are provided.

#### Recommended products

Lead Centre(s) provide daily climatology for 2 m, daily minimum and maximum temperature, and total precipitation, calculated based on the most recent WMO climatological reference period, keeping the same horizontal resolution as mandatory products.

Developing and maintaining documentation that includes the calculation methods for generating daily climatology is recommended.

2. **Graphical products**

**Mandatory products**

Lead Centre(s) provide time series and/or maps of digital products listed in section 1.

---

## **APPENDIX 2.2.59. MANDATORY AND RECOMMENDED VEGETATION FIRE AND SMOKE POLLUTION PRODUCTS**

An explanatory note should be published on the website if operations are interrupted due to technical or organizational problems.

An explanatory note on the methodology used to produce “daily fire activity” shall be available on the website.

### **1. Mandatory products**

Analysis products for the current fire situation shall be:

- Daily fire activity for last two days: daily release of fire energy (J), burnt area (m<sup>2</sup>) or other gridded variable quantifying the fire intensity for the specific day.

Forecast products shall include the following set of variables:

- Surface concentrations of particulate matter (PM) with a diameter equal to or less than 2.5 μm, also called fine (PM<sub>2.5</sub>), and 10 μm (PM<sub>10</sub>), measured in kg m<sup>-3</sup>

Forecasts shall cover the period from the starting forecast time (0000 and/or 1200 UTC) up to a forecast time of at least 72 hours, with an output frequency of at least 3 hours.

Forecasts shall cover the whole designated area. The horizontal resolution of the model configuration shall be finer than 0.5° × 0.5°.

Forecasts shall be made available on the website of the centre conducting the forecast not later than 12 hours after the starting forecast time.

### **2. Recommended products**

Recommended forecast products should include the following set of variables:

- Concentrations of relevant gaseous compounds near the surface (kg m<sup>-3</sup> or mole m<sup>-3</sup>) for at least the following species: CO, CO<sub>2</sub>, O<sub>3</sub>, SO<sub>2</sub>, NO<sub>x</sub> and volatile organic compounds (VOC);
- Surface concentration by species (kg m<sup>-3</sup>) for PM<sub>2.5</sub> and PM<sub>10</sub> fractions, including at least organic matter (OM) and black carbon (BC);
- Aerosol optical column depth at 550 nm (unitless);
- Aerosol optical column depth at 550 nm (unitless) by species including at least organic matter (OM) and black carbon (BC);
- Hourly emission of fire smoke composition: aerosol PM chemical speciation (including at least OM and BC), and major greenhouse (CO<sub>2</sub>) and reactive gaseous (CO, O<sub>3</sub>, SO<sub>2</sub>, NO<sub>x</sub> and VOC) species (kg m<sup>-2</sup> h<sup>-1</sup> or mole m<sup>-2</sup> h<sup>-1</sup>);
- Fire risk index: categorical map including at least four categories, that is, low, moderate, high and extreme.

Evaluation of the forecasts for surface concentrations and/or total aerosol optical column depth in the range of 340 nm to 1 020 nm.

---

## **APPENDIX 2.2.60. PROCEDURES FOR ACTIVATION OF SUPPORT FOR MARINE EMERGENCY RESPONSE**

Marine emergencies are a range of scenarios and types of events, listed in Appendix 2.2.63. The scope of marine emergency response (MER) activities includes spills of oil and other non-nuclear hazardous and noxious substances, and search and rescue (SAR).

A MER request for WMO RSMC support by an authorized person is activated based on the following procedures:

- (a)** A request form shall be sent by email to one of the operational contacts in the RSMC-MER (either a MER-SAR operational contact or MER-non-nuclear pollution operational contact) covering the related ocean basin (Atlantic, Pacific, Indian, Arctic or Southern Ocean) or part of it or, in the case of no specific regional coverage, to an RSMC-MER with global coverage, when marine meteorological and specialized services (as listed in Appendix 2.2.62) are required in support of MER;
- (b)** Any submission of a request shall be accompanied by a confirmation of receipt of the request by a pre-agreed method (for example, a telephone call);
- (c)** In the event that the requester is a Rescue Coordination Centre or a Regional Marine Pollution Emergency Response Centre, it shall always copy the email with the request form to the NMHS(s) of the country(ies) nearest to the incident, which shall also receive the MER products from the RSMC-MER;
- (d)** The RSMC-MER (either MER-SAR or MER-non-nuclear pollution) shall make available its products as a matter of high priority for response within the agreed time frame, preferably within 1 hour in the case of a SAR incident and 4 hours in the case of a release of non-nuclear hazardous and noxious substances. An email shall be sent by the RSMC-MER with information on where to access the products. The requester shall acknowledge receipt of the products by email. The requester may also inquire with the RSMC-MER about interpretation of the products, if necessary.

Note: Operational contacts in the RSMC-MER are nominated by the Permanent Representative of the WMO Member hosting the designated RSMC-MER.

---

## APPENDIX 2.2.61. REQUEST FORM TO ACTIVATE REGIONAL SPECIALIZED METEOROLOGICAL CENTRE SUPPORT (MARINE EMERGENCY RESPONSE)

EXERCISE – EXERCISE – EXERCISE/REAL INCIDENT [Select as appropriate]

Notes:

1. Please acknowledge receipt of the request form.
2. Delay of response: (a) for SAR incident, MER products shall be provided within 1 hour; (b) for non-nuclear pollution, MER products shall be provided within 4 hours.

From (institution): \_\_\_\_\_ To (institution): \_\_\_\_\_

Name (focal point): \_\_\_\_\_ Tel.(s): \_\_\_\_\_

Tel.(s): \_\_\_\_\_ Fax: \_\_\_\_\_

Fax: \_\_\_\_\_ Email: \_\_\_\_\_

Email: \_\_\_\_\_

Date and time of request (DD/MM/YYYY and UTC):.....

(a) **Mandatory information:**

Select type of incident and provide brief description or details:

- Release of non-nuclear hazardous and noxious substances
- Search and rescue of a floating object (such as a person, container and so forth)

.....

.....

.....

.....

Note: A list of non-nuclear hazardous and noxious substances, as well as the classification of objects that can be used in the drift models, is provided on the RSMC-MER website.

Date and start time of the incident (DD/MM/YYYY and UTC):.....

Note: If appropriate, provide the uncertainty of the time of the incident, for example, a time range.

Location of the release or the deployment of the floating object (as accurately as possible) in order of preference:

i. Geographic coordinates (decimal degrees, or degrees, minutes and seconds):

Latitude (specify N or S)	.....
Longitude (specify E or W)	.....

Note: If appropriate, please provide the uncertainty of the initial location (in km or nautical miles (NM))

ii. If appropriate, provide the nearest land location (for example, city, country):

.....  
.....

Expected or estimated release duration (in case of a release of non-nuclear hazardous and noxious substances) and rate:

.....  
.....

Duration of simulation for the drift model run (for example, 24 h, 36 h, 48 h):

.....  
.....

Name or type of pollutant(s) or floating object to be modelled, if known (oil, container, human being and so forth) – if unknown, a tracer will be used:

.....  
.....

Quantity (mass), type of release (continuous or instantaneous) and release rate (mass per unit time of pollutant if continuous). If unknown, one unit mass or one unit mass per hour will be used:

.....  
.....

(b) **Other information – If known, the following would be useful for the modelling and should be provided (if not provided, the modeller will use default parameters or make a reasonable assumption):**

Name of object (name of vessel, IMO number, news release and so forth):

.....  
.....

Meteorological conditions at location at the start of the release or the deployment of the floating object (wind speed and direction, weather, cloudiness, presence of inversion and so forth):

.....  
.....

Size of area of interest (for example, within 300 km (or NM) of source):

.....  
.....

In case of non-nuclear marine pollution, if quantity (mass) and name of pollutant(s) are provided, what concentrations should be displayed on modelling outputs? Please specify:

.....  
.....

Any other information that may be useful:

.....  
.....  
.....  
.....

\_\_\_\_\_

## **APPENDIX 2.2.62. MANDATORY AND RECOMMENDED MARINE EMERGENCY RESPONSE PRODUCTS**

The following mandatory MER products (in graphical format, at intervals of 1 h, 3 h or 6 h, up to 24 h, 36 h or 48 h, as per the request) shall be provided by the RSMC-MER:

- To support MER-non-nuclear pollution operations (default values in Appendix 2.2.63 shall be used for source parameters, if not provided):
  - Drift forecasts/model outputs;
  - Relative concentrations or density of points.
- To support search and rescue operations:
  - Drift forecasts/model outputs.

The RSMC shall perform a quick assessment of the products before they are issued and shall provide a short explanatory message if any issues of concern are noted.

If deemed requested, the RSMC-MER should also provide analysis and forecasts (at intervals of 1 h, 3 h or 6 h, up to 24 h, 36 h or 48 h as per the request) of:

- Wind speed and direction (graphical format);
- Sea state, including significant wave height and mean direction (graphical format);
- Visibility (text format);
- Cloud coverage (text format);
- Humidity (text format);
- Ocean currents and temperature (graphical format);
- Sea ice (only applicable for polar or seasonal ice regions) (graphical format).

The following recommended MER products could be provided by the RSMC-MER:

- Tide height and time (observations and forecasts) (text format).
-

**APPENDIX 2.2.63. DEFAULT SOURCE PARAMETERS (MARINE EMERGENCY RESPONSE SEARCH AND RESCUE AND NON-NUCLEAR POLLUTION)**

<i>Scenario</i>	<i>Type of event</i>	<i>Material released</i>	<i>Vertical distribution</i>
Oil spill	Oil	Tracer	Surface
Non-nuclear hazardous and noxious substances other than oil	Chemical, algae, etc.	Tracer	Constant from the surface to 200 m
Search and rescue	Human, wrecks, container, etc.	Tracer	Surface
			RSMC defined

Note: Default date and start time of release are those given in the request form (mandatory information) in Appendix 2.2.61. If not provided, the date and time of reception of the request will be used.

---

## **APPENDIX 2.2.64. CHARACTERISTICS OF MARINE DRIFTING MODELLING SYSTEMS**

### **1. System**

- System name (version):
- Type of a drift model:
- Geographical domain:
- Oceanographic model and NWP model used:
- Implementation date:
- References:

### **2. Initial conditions and trajectory algorithm**

- Input (pollutant/object data):
- Input (environmental data):
- Trajectory algorithm – wind:
- Trajectory algorithm – current:
- Trajectory algorithm – waves (generation method, effect on advection):
- Fate algorithm – evaporation, emulsification:
- Any other fate and weathering processes:

### **3. Other details of the model**

- Model validation/verification for at least one event:

### **4. Further information**

- URLs for system documentation:
  - URLs for list of trials and actual marine pollution and SAR emergencies:
-

## **ATTACHMENT 2.2.1. RECOMMENDED REGIONAL CLIMATE CENTRE FUNCTIONS**

### **1. Climate prediction and climate projection:**

- Assist RCC users in the access and use of World Climate Research Programme Coupled Model Intercomparison Project climate model simulations;
- Perform downscaling of climate-change scenarios;
- Provide information to RCC users for use in development of climate adaptation strategies;
- Generate, along with warnings of caution on uncertainty, seasonal prediction for specific parameters where relevant, such as:
  - Onset, intensity and cessation of rainy season;
  - Tropical cyclone frequency and intensity;
- Perform verification on consensus statements for forecasts;
- Perform assessment of other GPC products such as SSTs and winds.

### **2. Non-operational data services:**

- Keep abreast of activities and documentation related to WIS, and work towards WIS compliance and data collection or production-centre designation;
- Assist NMHSs in the rescue of climate data from outmoded storage media;
- Assist NMHSs to develop and maintain historical climate datasets;
- Assist RCC users in the development and maintenance of software modules for standard applications;
- Advise RCC users on data quality management;
- Conduct data homogenization, and advise RCC users on homogeneity assessment, and development and use of homogeneous datasets;
- Develop and manage databases, and generate indices, of climate extremes;
- Perform quality assurance and quality control on national datasets, at the request of an NMHS;
- Provide expertise on interpolation techniques;
- Facilitate data and metadata exchange among NMHSs, including online access, through an agreed regional mechanism;
- Perform quality assurance and quality control on regional datasets.

### **3. Coordination functions:**

- Strengthen collaboration between NMHSs on related observing, communication and computing networks including data collection and exchange;

- Develop systems to facilitate harmonization and assistance in the use of SP products and other climate services;
- Assist NMHSs in user liaison, including the organization of climate and multidisciplinary workshops and other forums on user needs;
- Assist NMHSs in the development of a media and public-awareness strategy on climate services.

4.           **Training and capacity-building:**

- Assist NMHSs in the training of users on the application and implications of SP products;
- Assist in the introduction of appropriate decision models for end users, especially as related to probability forecasts;
- Promote technical capacity-building at the NMHS level (for example, acquisition of hardware and software), as required for implementation of climate services;
- Assist in professional capacity-building (training) of climate experts for generating user-targeted products.

5.           **Research and development:**

- Develop a climate research and development agenda and coordinate it with other relevant RCCs;
  - Promote studies of regional climate variability and change, predictability and impact in the region;
  - Develop consensus practices to handle divergent climate information for the region;
  - Develop and validate regional models, methods of downscaling and interpretation of global output products;
  - Promote the use of proxy climate data in long-term analyses of climate variability and change;
  - Promote application research, and assist in the specification and development of sector-specific products;
  - Promote studies of the economic value of climate information.
-

## **ATTACHMENT 2.2.2. GUIDELINES FOR FEEDBACK FROM REGIONAL CLIMATE CENTRES AND NATIONAL METEOROLOGICAL AND HYDROLOGICAL SERVICES TO GLOBAL PRODUCING CENTRES**

- (a) Products used (from the minimum list defined in Appendix 2.2.9).
  - (b) Additional products used.
  - (c) Qualitative assessment on the following aspects of products:
    - (i) Accessibility and timely availability;
    - (ii) Completeness and quality;
    - (iii) Usefulness for purpose.
  - (d) How the data are processed (for example, details of any post-processing/downscaling carried out).
  - (e) Forecast applications that have been developed using the data.
  - (f) Report on the comparative performance of GPCs for the region for which the RCC or NMHS has responsibility – both for real-time forecasts and, if available, from retrospective forecasts.
  - (g) Research studies that have been conducted using the data.
  - (h) Any other comments.
-

## **PART III. CURRENT WMO INTEGRATED PROCESSING AND PREDICTION SYSTEM DESIGNATED CENTRES**

### **1. The World Meteorological Centres are located in:**

Beijing  
ECMWF  
Exeter  
Melbourne (southern hemisphere only)  
Montreal  
Moscow  
Offenbach  
Tokyo  
Toulouse  
Washington

Acronym not previously defined: ECMWF – European Centre for Medium-range Weather Forecasts

### **2. The Regional Specialized Meteorological Centres with geographical specialization are located in:**

Algiers	Darwin	New Delhi
Brasilia	Jeddah	Tashkent
Buenos Aires	Melbourne	Tunis/Casablanca
Cairo	Miami	

Broadened RSMC functions:

Offenbach – Provision of ultraviolet-index forecasts for Region VI (Europe)

### **3. The Regional Specialized Meteorological Centres for general-purpose activities are:**

Global deterministic numerical weather prediction:

RSMC Beijing  
RSMC ECMWF  
RSMC Exeter  
RSMC Montreal  
RSMC Moscow  
RSMC Offenbach  
RSMC Tokyo  
RSMC Toulouse  
RSMC Washington

Limited-area deterministic numerical weather prediction:

RSMC Khabarovsk  
RSMC Moscow  
RSMC Novosibirsk  
RSMC Offenbach  
RSMC Pretoria  
RSMC Rome

## Global ensemble numerical weather prediction:

RSMC Beijing  
 RSMC ECMWF  
 RSMC Exeter  
 RSMC Montreal  
 RSMC Moscow  
 RSMC Offenbach  
 RSMC Tokyo  
 RSMC Toulouse  
 RSMC Washington

## Limited-area ensemble numerical weather prediction:

RSMC Offenbach  
 RSMC Rome

## Global numerical sub-seasonal prediction:

GPC Beijing  
 GPC CPTEC (Brazil)  
 GPC ECMWF  
 GPC Moscow  
 GPC Tokyo

Acronym not previously defined: CPTEC – Centro de Previsão de Tempo e Estudos Climáticos

## Global climate reanalysis

GCR ECMWF  
 GCR NASA (USA)

Acronym not previously defined: NASA – National Aeronautics and Space Administration

## Global numerical seasonal prediction:

GPC Beijing	GPC Offenbach
GPC CMCC (Italy)	GPC Pretoria
GPC CPTEC (Brazil)	GPC Pune
GPC ECMWF	GPC Seoul
GPC Exeter	GPC Tokyo
GPC Melbourne	GPC Toulouse
GPC Montreal	GPC Washington
GPC Moscow	

Acronym not previously defined: CMCC – Centro Euro-Mediterraneo sui Cambiamenti Climatici

## Annual to decadal climate prediction:

GPC Barcelona  
 GPC CSIRO (Australia)  
 GPC Exeter  
 GPC Montreal  
 GPC Offenbach

Acronym not previously defined: CSIRO – Commonwealth Scientific and Industrial Research Organisation

## Numerical ocean wave prediction:

RSMC Exeter

RSMC INCOIS (India)  
 RSMC Melbourne  
 RSMC Montreal  
 RSMC Tokyo  
 RSMC Toulouse

Acronym not previously defined: INCOIS – Indian National Centre for Ocean Information Services

Global numerical ocean prediction

RSMC INCOIS (India)  
 RSMC Montreal

Nowcasting:

RSMC Hong Kong  
 RSMC Offenbach  
 RSMC Tokyo

4. **The Regional Specialized Meteorological Centres for specialized activities are:**

Regional climate prediction and monitoring:

RCC Africa hosted by the African Centre of Meteorological Applications for Development (RA I)

RCC Beijing (RA II)

RCC Caribbean hosted by the Caribbean Institute for Meteorology and Hydrology (RA IV)

RCC Intergovernmental Authority on Development (IGAD) hosted by the IGAD Climate Prediction and Applications Centre (RA I)

RCC Moscow (RA II)

Arctic RCC Network (RA II, IV and VI): Nordic node with pan-Arctic climate data function; Northern Eurasian node with pan-Arctic climate monitoring function; Northern American node with pan-Arctic seasonal prediction function

RCC Network (RA VI): De Bilt node on climate data services, Offenbach node on climate monitoring, and Toulouse and Moscow node on seasonal prediction

RCC Network Northern Africa (RA I)

RCC Network Southern South America (RA III)

RCC Pune (RA II)

RCC Tokyo (RA II)

RCC Washington (RA IV)

RCC Western South America hosted by the International Research Centre on El Niño (RA III)

Notes:

1. RCC Moscow (RA II) – North Eurasian Climate Centre.
2. The RA VI RCC Network consists of three nodes: (a) climate data services, led by the Koninklijk Nederlands Meteorologisch Instituut (KNMI), Netherlands; (b) climate monitoring, led by Deutscher Wetterdienst (DWD),

Germany; (c) seasonal prediction, jointly led by Météo-France and Roshydromet, Russian Federation. These Lead Centres are fully responsible for discharging the mandatory functions of the RA VI RCC Network, with the support of the following contributing NMHSs:

- RA VI RCC node on climate data services:  
KNMI (lead), Météo-France, [Országos Meteorológiai Szolgálat](#)/Hungary, Norwegian Meteorological Institute/Norway, Republic Hydrometeorological Service (RHMS)/Serbia, Swedish Meteorological and Hydrological Institute/Sweden and the Turkish State Meteorological Service (TSMS)/Türkiye;
  - RA VI RCC node on climate monitoring:  
DWD (lead), Armstatehydromet/Armenia, Météo-France, KNMI, RHMS and TSMS;
  - RA VI RCC node on seasonal prediction:  
Météo-France and Roshydromet (joint leads), met.no, RHMS and TSMS;
  - Overall coordination:  
DWD is responsible for the overall coordination;
3. The Arctic RCC Network (ArcRCC-Network) comprises three nodes, each performing mandatory functions and relevant recommended functions for a well-defined subregional domain. Additionally, each node consolidates a specific cross-node mandatory function for the entire Arctic region. The structure for ArcRCC-Network is as follows:
- North American node, responsible for pan-Arctic seasonal prediction function:  
Environment and Climate Change Canada (Lead); National Oceanic and Atmospheric Administration/USA (consortium member);
  - Nordic node, responsible for pan-Arctic climate data services function:  
Norwegian Meteorological Institute/Norway (Lead); Danish Meteorological Institute/Denmark, Finnish Meteorological Institute/Finland, Icelandic Meteorological Office/Iceland, Swedish Meteorological and Hydrological Institute/Sweden (consortium members);
  - Northern Eurasia node, responsible for pan-Arctic climate monitoring function:  
Roshydromet/Russian Federation (Lead);
  - Training function: a common responsibility for all the nodes;
  - Overall coordination: Norwegian Meteorological Institute/Norway.

Coordination of assessment of multiple climate reanalyses:

ECMWF

Coordination of multi-model ensembles for sub-seasonal prediction:

ECMWF

Coordination of multi-model ensembles for seasonal prediction:

Seoul and Washington (joint centre)

Coordination of annual to decadal climate prediction:

Exeter

Regional severe weather forecasting:

RSMC Dakar  
RSMC Dar-es-Salaam  
RSMC Nairobi  
RSMC Pretoria  
RSMC Wellington

Tropical cyclone forecasting, including marine-related hazards:

RSMC Honolulu – Hurricane centre  
RSMC La Réunion – Tropical cyclone centre  
RSMC Nadi – Tropical cyclone centre  
RSMC New Delhi – Tropical cyclone centre  
RSMC Miami – Hurricane centre  
RSMC Tokyo – Typhoon centre

## Nuclear environmental emergency response:

RSMC Beijing	RSMC Offenbach
RSMC Exeter	RSMC Tokyo
RSMC Melbourne	RSMC Toulouse
RSMC Montreal	RSMC Vienna
RSMC Obninsk	RSMC Washington

## Non-nuclear environmental emergency response:

RSMC Montreal  
RSMC Offenbach  
RSMC Toulouse

## Atmospheric sand and dust storm forecasts:

RSMC-ASDF Barcelona  
RSMC-ASDF Beijing (RA II)

## Volcano watch services for international air navigation:

VAAC Anchorage  
VAAC Buenos Aires (co-located with RSMC Buenos Aires)  
VAAC Darwin (co-located with RSMC Melbourne)  
VAAC London (co-located with RSMC Exeter)  
VAAC Montreal (co-located with RSMC Montreal)  
VAAC Tokyo (co-located with RSMC Tokyo)  
VAAC Toulouse (co-located with RSMC Toulouse)  
VAAC Washington (co-located with RSMC Washington)  
VAAC Wellington (co-located with RSMC Wellington)

## Marine meteorological services:

RSMC Athens	RSMC Ottawa
RSMC Beijing	RSMC Pretoria
RSMC Buenos Aires	RSMC St Petersburg
RSMC Callao	RSMC Tokyo
RSMC Edmonton	RSMC Toulouse
RSMC Exeter	RSMC Tromsø
RSMC Karachi	RSMC Vacoas
RSMC La Réunion	RSMC Valparaiso
RSMC Melbourne	RSMC Vladivostok
RSMC Miami	RSMC Washington DC
RSMC New Delhi	RSMC Wellington
RSMC Niteroi	RSMC Winnipeg

## Vegetation fire and smoke pollution forecasts:

Montreal  
Singapore

5. **The Regional Specialized Meteorological Centres for non-real-time coordination activities are:**

## Coordination of deterministic numerical weather prediction verification:

ECMWF

Coordination of Ensemble Prediction System verification:

Tokyo

Coordination of wave forecast verification:

ECMWF

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For more information, please contact:

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