

Manual on the Global Data-processing and Forecasting System

Annex IV to the WMO Technical Regulations

2017 edition

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 <http://public.wmo.int/en/resources/meteoterm>.

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GENERAL PROVISIONS

1. The *Technical Regulations* (WMO-No. 49) of the World Meteorological Organization are presented in three volumes:

Volume I – General meteorological standards and recommended practices

Volume II – Meteorological service for international air navigation

Volume III – Hydrology

Purpose of the Technical Regulations

2. The Technical Regulations are determined by the World Meteorological Congress in accordance with Article 8 (d) of the Convention.

3. These Regulations are designed:

- (a) To facilitate cooperation in meteorology and hydrology among Members;
- (b) To meet, in the most effective manner, specific needs in the various fields of application of meteorology and operational hydrology in the international sphere;
- (c) To ensure adequate uniformity and standardization in the practices and procedures employed in achieving (a) and (b) above.

Types of Regulations

4. The Technical Regulations comprise *standard* practices and procedures and *recommended* practices and procedures.

5. The definitions of these two types of Regulations are as follows:

The *standard* practices and procedures:

- (a) Shall be the practices and procedures that Members are required to follow or implement;
- (b) Shall have the status of requirements in a technical resolution in respect of which Article 9 (b) of the Convention is applicable;
- (c) Shall invariably be distinguished by the use of the term *shall* in the English text, and by suitable equivalent terms in the Arabic, Chinese, French, Russian and Spanish texts.

The *recommended* practices and procedures:

- (a) Shall be the practices and procedures with which Members are urged to comply;
- (b) Shall have the status of recommendations to Members, to which Article 9 (b) of the Convention shall not be applied;
- (c) Shall be distinguished by the use of the term *should* in the English text (except where otherwise provided by decision of Congress) and by suitable equivalent terms in the Arabic, Chinese, French, Russian and Spanish texts.

6. In accordance with the above definitions, Members shall do their utmost to implement the *standard* practices and procedures. In accordance with Article 9 (b) of the Convention and in conformity with Regulation 128 of the General Regulations, Members shall formally notify the Secretary-General, in writing, of their intention to apply the *standard* practices and procedures of the Technical Regulations, except those for which they have lodged a specific

deviation. Members shall also inform the Secretary-General, at least three months in advance, of any change in the degree of their implementation of a *standard* practice or procedure as previously notified and the effective date of the change.

7. Members are urged to comply with *recommended* practices and procedures, but it is not necessary to notify the Secretary-General of non-observance except with regard to practices and procedures contained in Volume II.

8. In order to clarify the status of the various Regulations, the *standard* practices and procedures are distinguished from the *recommended* practices and procedures by a difference in typographical practice, as indicated in the editorial note.

Status of annexes and appendices

9. The following annexes to the *Technical Regulations* (Volumes I to III), also called Manuals, are published separately and contain regulatory material having the status of *standard* and/or *recommended* practices and procedures:

- I *International Cloud Atlas* (WMO-No. 407) – Manual on the Observation of Clouds and Other Meteors, sections 1, 2.1.1, 2.1.4, 2.1.5, 2.2.2, 1 to 4 in 2.3.1 to 2.3.10 (for example, 2.3.1.1, 2.3.1.2, etc.), 2.8.2, 2.8.3, 2.8.5, 3.1 and the definitions (in grey-shaded boxes) of 3.2;
- II *Manual on Codes* (WMO-No. 306), Volume I;
- III *Manual on the Global Telecommunication System* (WMO-No. 386);
- IV *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485);
- V *Manual on the Global Observing System* (WMO-No. 544);
- VI *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I;
- VII *Manual on the WMO Information System* (WMO-No. 1060);
- VIII *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

These annexes (Manuals) are established by decision of Congress and are intended to facilitate the application of Technical Regulations to specific fields. Annexes may contain both *standard* and *recommended* practices and procedures.

10. Texts called appendices, appearing in the *Technical Regulations* or in an annex to the *Technical Regulations*, have the same status as the Regulations to which they refer.

Status of notes and attachments

11. Certain notes (preceded by the indication “Note”) are included in the *Technical Regulations* for explanatory purposes; they may, for instance, refer to relevant WMO Guides and publications. These notes do not have the status of Technical Regulations.

12. The *Technical Regulations* may also include attachments, which usually contain detailed guidelines related to *standard* and *recommended* practices and procedures. Attachments, however, do not have regulatory status.

Updating of the *Technical Regulations* and their annexes (Manuals)

13. The *Technical Regulations* are updated, as necessary, in the light of developments in meteorology and hydrology and related techniques, and in the application of meteorology and operational hydrology. Certain principles previously agreed upon by Congress and applied in the selection of material for inclusion in the Technical Regulations are reproduced below. These principles provide guidance for constituent bodies, in particular technical commissions, when dealing with matters pertaining to the Technical Regulations:

- (a) Technical commissions should not recommend that a Regulation be a standard practice unless it is supported by a strong majority;

- (b) Technical Regulations should contain appropriate instructions to Members regarding implementation of the provision in question;
- (c) No major changes should be made to the Technical Regulations without consulting the appropriate technical commissions;
- (d) Any amendments to the Technical Regulations submitted by Members or by constituent bodies should be communicated to all Members at least three months before they are submitted to Congress.

14. Amendments to the *Technical Regulations* – as a rule – are approved by Congress.

15. If a recommendation for an amendment is made by a session of the appropriate technical commission and if the new regulation needs to be implemented before the next session of Congress, the Executive Council may, on behalf of the Organization, approve the amendment in accordance with Article 14 (c) of the Convention. Amendments to annexes to the *Technical Regulations* proposed by the appropriate technical commissions are normally approved by the Executive Council.

16. If a recommendation for an amendment is made by the appropriate technical commission and the implementation of the new regulation is urgent, the President of the Organization may, on behalf of the Executive Council, take action as provided by Regulation 9 (5) of the General Regulations.

Note: A simple (fast-track) procedure may be used for amendments to technical specifications in Annexes II (*Manual on Codes* (WMO-No. 306)), III (*Manual on the Global Telecommunication System* (WMO-No. 386)), IV (*Manual on the Global Data-processing and Forecasting System* (WMO-No. 485)), V (*Manual on the Global Observing System* (WMO-No. 544)), VII (*Manual on the WMO Information System* (WMO-No. 1060)) and VIII (*Manual on the WMO Integrated Global Observing System* (WMO-No. 1160)). Application of the simple (fast-track) procedure is defined in the [appendix](#) to these General Provisions.

17. After each session of Congress (every four years), a new edition of the *Technical Regulations*, including the amendments approved by Congress, is issued. With regard to the amendments between sessions of Congress, Volumes I and III of the *Technical Regulations* are updated, as necessary, upon approval of changes thereto by the Executive Council. The *Technical Regulations* updated as a result of an approved amendment by the Executive Council are considered a new update of the current edition. The material in Volume II is prepared by the World Meteorological Organization and the International Civil Aviation Organization working in close cooperation, in accordance with the Working Arrangements agreed by these Organizations. In order to ensure consistency between Volume II and Annex 3 to the Convention on International Civil Aviation – *Meteorological Service for International Air Navigation*, the issuance of amendments to Volume II is synchronized with the respective amendments to Annex 3 by the International Civil Aviation Organization.

Note: Editions are identified by the year of the respective session of Congress whereas updates are identified by the year of approval by the Executive Council, for example “Updated in 2012”.

WMO Guides

18. In addition to the *Technical Regulations*, appropriate Guides are published by the Organization. They describe practices, procedures and specifications which Members are invited to follow or implement in establishing and conducting their arrangements for compliance with the Technical Regulations, and in otherwise developing meteorological and hydrological services in their respective countries. The Guides are updated, as necessary, in the light of scientific and

technological developments in hydrometeorology, climatology and their applications. The technical commissions are responsible for the selection of material to be included in the Guides. These Guides and their subsequent amendments shall be considered by the Executive Council.

APPENDIX. PROCEDURES FOR AMENDING WMO MANUALS AND GUIDES THAT ARE THE RESPONSIBILITY OF THE COMMISSION FOR BASIC SYSTEMS

1. DESIGNATION OF RESPONSIBLE COMMITTEES

The Commission for Basic Systems (CBS) shall, for each Manual and Guide, designate one of its Open Programme Area Groups (OPAGs) as being responsible for that Manual and its associated technical guides. The Open Programme Area Group may choose to designate one of its Expert Teams as the designated committee for managing changes to all or part of that Manual; if no Expert Team is designated, the Implementation Coordination Team for the OPAG takes on the role of the designated committee.

2. GENERAL VALIDATION AND IMPLEMENTATION PROCEDURES

2.1 Proposal of amendments

Amendments to a Manual or a Guide managed by CBS shall be proposed in writing to the Secretariat. The proposal shall specify the needs, purposes and requirements and include information on a contact point for technical matters.

2.2 Drafting recommendation

The designated committee for the relevant part of a Manual or a Guide, supported by the Secretariat, shall validate the stated requirement (unless it is consequential to an amendment to the WMO Technical Regulations) and develop a draft recommendation to respond to the requirement, as appropriate.

2.3 Procedures for approval

After a draft recommendation of the designated committee is validated in accordance with the procedure given in section 7 below, depending on the type of amendments, the designated committee should select one of the following procedures for the approval of the amendments:

- (a) Simple (fast-track) procedure (see section 3 below);
- (b) Standard (adoption of amendments between CBS sessions) procedure (see section 4 below);
- (c) Complex (adoption of amendments during CBS sessions) procedure (see section 5 below).

2.4 Date of implementation

The designated committee should define an implementation date in order to give WMO Members sufficient time to implement the amendments after the date of notification. For procedures other than the simple (fast-track) one, if the time between the date of notification and implementation date is less than six months, the designated committee shall document the reasons for its decision.

2.5 **Urgent introduction**

Regardless of the above procedures, as an exceptional measure, the following procedure accommodates urgent user needs to introduce elements in lists of technical details, or to correct errors:

- (a) A draft recommendation developed by the designated committee shall be validated according to the steps defined in section 7 below;
- (b) The draft recommendation for pre-operational use of a list entry, which can be used in operational data and products, shall be approved by the chairperson of the designated committee and the chairperson of the responsible OPAG, and the president of CBS. A listing of pre-operational list entries is kept online on the WMO web server;
- (c) Pre-operational list entries shall then be submitted for approval by one of the procedures in 2.3 above for operational use;
- (d) Any version numbers associated with the technical implementation should be incremented at the least significant level.

2.6 **Issuing updated version**

Once amendments to a Manual or a Guide are adopted, an updated version of the relevant part of the Manual shall be issued in the languages agreed for its publication. The Secretariat shall inform all Members of the availability of a new updated version of that part at the date of notification mentioned in 2.4 above. If amendments are not incorporated into the published text of the relevant Manual or Guide at the time of the amendment, there should be a mechanism to publish the amendments at the time of their implementation and to retain a permanent record of the sequence of amendments.

3. **SIMPLE (FAST-TRACK) PROCEDURE**

3.1 **Scope**

The simple (fast-track) procedure shall be used only for changes to components of the Manual that have been designated and marked as “technical specifications to which the simple (fast-track) procedure for the approval of amendments may be applied”.

Note: An example would be the addition of code list items in the *Manual on Codes* (WMO-No. 306).

3.2 **Endorsement**

Draft recommendations developed by the responsible committee, including a date for implementation of the amendments, shall be submitted to the chairperson of the relevant OPAG for endorsement.

3.3 **Approval**

3.3.1 **Minor adjustments**

Correcting typographical errors in descriptive text is considered a minor adjustment, and will be done by the Secretariat in consultation with the president of CBS. See Figure 1.

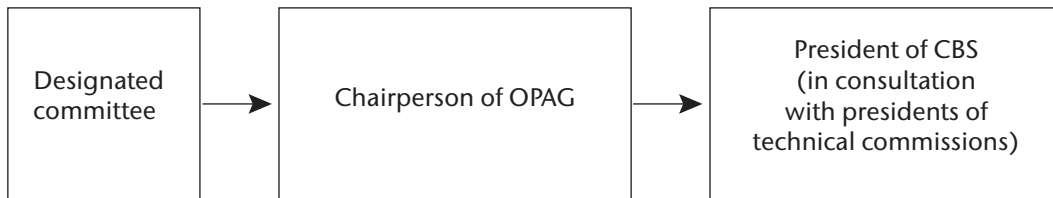


Figure 1. Adoption of amendments to a Manual by minor adjustment

3.3.2 **Other types of amendments**

For other types of amendments, the English version of the draft recommendation, including a date of implementation, should be distributed to the focal points for matters concerning the relevant Manual for comments, with a deadline of two months for the reply. It should then be submitted to the president of CBS for consultation with presidents of technical commissions affected by the change. If endorsed by the president of CBS, the change should be passed to the President of WMO for consideration and adoption on behalf of the Executive Council (EC).

3.3.3 **Frequency**

The implementation of amendments approved through the simple (fast-track) procedure can be twice a year in May and November. See Figure 2.

4. **STANDARD (ADOPTION OF AMENDMENTS BETWEEN CBS SESSIONS) PROCEDURE**

4.1 **Scope**

The standard (adoption of amendments between CBS sessions) procedure shall be used for changes that have an operational impact on those Members who do not wish to exploit the change, but that have only minor financial impact, or that are required to implement changes in the *Technical Regulations* (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation.

4.2 **Approval of draft recommendations**

For the direct adoption of amendments between CBS sessions, the draft recommendation developed by the designated committee, including a date of implementation of the amendments, shall be submitted to the chairperson of the responsible OPAG and president and vice-president of CBS for approval. The president of CBS shall consult with the presidents of technical commissions affected by the change. In the case of recommendations in response

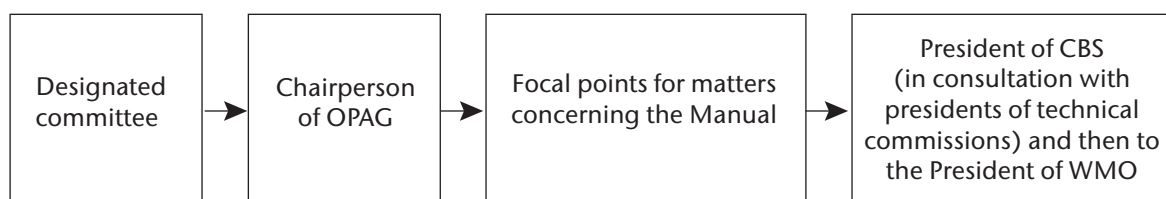


Figure 2. Adoption of amendments to a Manual by simple (fast-track) procedure

to changes in the *Technical Regulations* (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation, the president of CBS shall consult with the president of the Commission for Aeronautical Meteorology.

4.3 Circulation to Members

Upon approval of the president of CBS, the Secretariat sends the recommendation to all Members, in the languages in which the Manual is published, including a date of implementation of the amendments, for comments to be submitted within two months following the dispatch of the amendments. If the recommendation is sent to Members via electronic mail, there shall be public announcement of the amendment process including dates, for example by WMO Operational Newsletter on the WMO website, to ensure all relevant Members are informed.

4.4 Agreement

Those Members not having replied within the two months following the dispatch of the amendments are implicitly considered as having agreed with the amendments.

4.5 Coordination

Members are invited to designate a focal point responsible to discuss any comments/ disagreements with the designated committee. If the discussion between the designated committee and the focal point cannot result in an agreement on a specific amendment by a Member, this amendment will be reconsidered by the designated committee. If a Member cannot agree that the financial or operational impact is minor, the redrafted amendment shall be approved by the complex (adoption of amendments during CBS sessions) procedure described in section 5 below.

4.6 Notification

Once amendments are agreed by Members, and after consultation with the chairperson of the responsible OPAG, the vice-president of CBS and the president of CBS (who should consult with presidents of other commissions affected by the change), the Secretariat notifies at the same time the Members and the members of the Executive Council of the approved amendments and of the date of their implementation. See Figure 3.

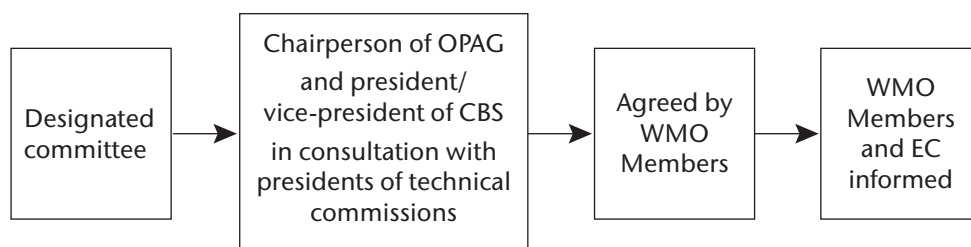


Figure 3. Adoption of amendments between CBS sessions

5. **COMPLEX (ADOPTION OF AMENDMENTS DURING CBS SESSIONS) PROCEDURE**

5.1 **Scope**

The complex (adoption of amendments during CBS sessions) procedure shall be used for changes for which the simple (fast-track) procedure or standard (adoption of amendments between CBS sessions) procedure cannot be applied.

5.2 **Procedure**

For the adoption of amendments during CBS sessions, the designated committee submits its recommendation, including a date of implementation of the amendments, to the Implementation Coordination Team of the responsible Open Programme Area Group. The recommendation is then passed to the presidents of technical commissions affected by the change for consultation, and to a CBS session that shall be invited to consider comments submitted by presidents of technical commissions. The document for the CBS session shall be distributed not later than 45 days before the opening of the session. Following the CBS session, the recommendation shall then be submitted to a session of the Executive Council for decision. See Figure 4.

6. **PROCEDURE FOR THE CORRECTION OF EXISTING MANUAL CONTENTS**

6.1 **Correcting errors in items within Manuals**

Where a minor error in the specification of an item that defines elements within a Manual is found, for example, a typing error or an incomplete definition, the item shall be amended and re-published. Any version numbers associated with items edited as a result of the change should be incremented at their lowest level of significance. If, however, the change has an impact on the meaning of the item, then a new item should be created and the existing (erroneous) item marked as deprecated. This situation is considered a minor adjustment according to 3.3.1 above.

Note: An example of an item for which this type of change applies is a code list entry for the Table Driven Code Forms or WMO Core Metadata Profile, in which the description contains typographical errors that can be corrected without changing the meaning of the description.

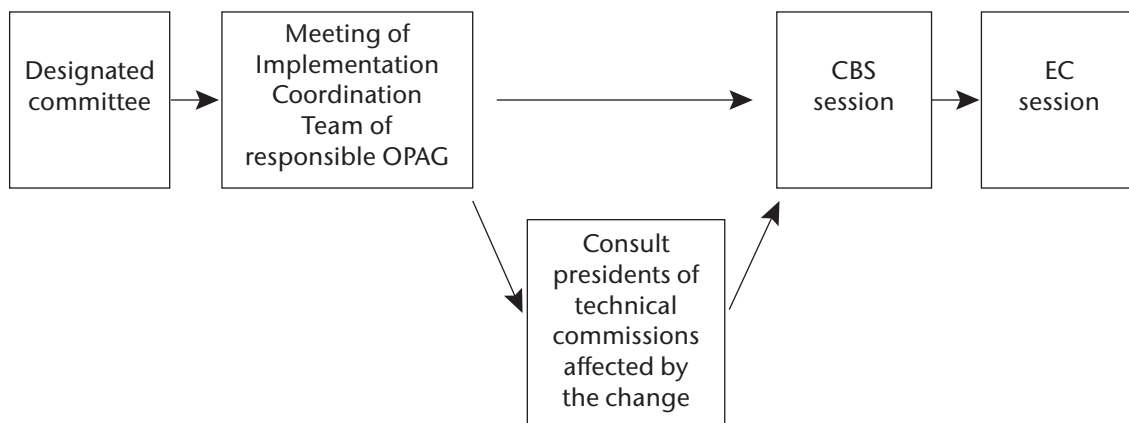


Figure 4. Adoption of amendments during CBS sessions

6.2 **Correcting an error in the specification of how conformance with the requirements of the Manual can be checked**

If an erroneous specification of a conformance-checking rule is found, the preferred approach is to add a new specification using the simple (fast-track) procedure or standard (adoption of amendments between CBS sessions) procedure. The new conformance-checking rule should be used instead of the old. An appropriate explanation shall be added to the description of the conformance-checking rule to clarify the practice along with the date of the change.

Note: An example of such a change would be correcting a conformance-checking rule in the WMO Core Metadata Profile.

6.3 **Submission of corrections to errors**

Such changes shall be submitted through the simple (fast-track) procedure.

7. **VALIDATION PROCEDURE**

7.1 **Documentation of need and purpose**

The need for, and the purpose of, the proposal for changes should be documented.

7.2 **Documentation of result**

This documentation shall include the results of validation testing of the proposal as described in 7.3 below.

7.3 **Testing with relevant applications**

For changes that have an impact on automated processing systems, the extent of the testing required before validation should be decided by the designated committee on a case-by-case basis, depending on the nature of the change. Changes involving a relatively high risk and/or impact on the systems should be tested by the use of at least two independently developed tool sets and two independent centres. In that case, results should be made available to the designated committee with a view to verifying the technical specifications.

INTRODUCTION

General

1. The *Manual on the Global Data-processing and Forecasting 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 Global Data-processing and Forecasting System (GDPFS) 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 GDPFS is established and shall be operated in accordance with the practices, procedures and specifications described in the present Manual.
3. The Global Data-processing and Forecasting System 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. GDPFS 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 Global Data-processing and Forecasting System* sets out standard and recommended practices and procedures. The General Provisions, included in this publication, 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 GDPFS – presenting the overall purpose of GDPFS, its organization and the general characteristics of the various activities to be performed;
 - (b) Part II: Specifications of GDPFS activities – providing detailed information on the various activities: mandatory functions including production, verification and documentation; and additional 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 designated GDPFS centres.

8. The reader seeking general information on GDPFS 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 GDPFS activity. This information is contained in Part II, 2.2, Tables 2–23. 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 GDPFS 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 designated GDPFS centres remain compliant with the activity specification.

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

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS/ET-OWFPS		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-OWFPS		
To be reported to:	CBS/ICT-DPFS	CBS	

Acronyms not previously defined: EC – WMO Executive Council; ET-OWFPS – Expert Team on Operational Weather Forecasting Process and Support; ICT-DPFS – Implementation Coordination Team on Data-processing and Forecasting Systems.

11. The following procedure is applied for the incorporation of new types of GDPFS 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 GDPFS;
- (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 CBS through its president;

- (c) The president of CBS 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.

PART I. OUTLINE OF THE WMO GLOBAL DATA-PROCESSING AND FORECASTING SYSTEM

1.1 PURPOSE AND SUPPORTED ACTIVITIES

1.1.1 General description

1.1.1.1 The Global Data-processing and Forecasting System 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 The Global Data-processing and Forecasting System 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 GDPFS 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 GDPFS 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 Global Data-processing and Forecasting System

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

1.1.2.2 The Global Data-processing and Forecasting System shall be organized as a three-tier system of activities as follows:

Note: A distinction is made between general-purpose and specialized activities: general-purpose activities are those that encompass essential data processing required for a wide range of end use, while specialized activities are those that make forecasting products, which may include guidance based on human interpretation, tailored for a specific

type of application or user community. In addition to these activities conducted in real time, non-real-time operational coordination activities are also part of GDPFS. Associated commitments and other appropriate details are specified in Part II.

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

- Global deterministic NWP
- Limited-area deterministic NWP
- Global ensemble NWP
- Limited-area ensemble NWP
- Global numerical long-range prediction
- Numerical ocean wave prediction
- Global numerical ocean prediction
- Nowcasting

(b) **Specialized activities:**

- Regional climate prediction and monitoring
- Coordination of multi-model ensemble prediction for long-range forecasts (LRFs)
- Annual to decadal climate prediction
- Coordination of annual to decadal climate prediction
- Regional severe weather forecasting
- Tropical cyclone forecasting, including marine-related hazards
- Nuclear environmental emergency response
- Non-nuclear environmental emergency response
- Atmospheric sandstorm and duststorm forecasts
- Volcano watch services for international air navigation
- Marine meteorological services
- Marine environmental emergency response

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

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

Note: It is hoped that other activities, including those related to hydrology, agriculture, polar regions, storm-surge prediction, and space weather, will be developed in future.

1.2 **GLOBAL DATA-PROCESSING AND FORECASTING 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 The Global Data-processing and Forecasting System shall be organized as a three-level system of World Meteorological Centres (WMCs), Regional Specialized Meteorological Centres (RSMCs) and National Meteorological Centres (NMCs), which carry out GDPFS functions at the global, regional and national levels, respectively. These centres are referred to as GDPFS 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 Regional Specialized Meteorological Centres

1.2.3.1 A Member, having accepted the responsibility for providing an RSMC, shall arrange for this centre to carry out operationally at least one of the general-purpose or specialized activities listed in 1.1.2.2, for which specified standards are described in Part II.

1.2.3.2 An RSMC for general-purpose activities should provide products that an RSMC carrying out at least one of the specialized activities considers necessary and makes a request to produce.

Notes:

- 1. The designation as RSMC does not preclude the use of other names as defined in other contexts, for example, Global Producing Centre for long-range forecasts (GPC-LRF).
- 2. An RSMC that leads a coordination activity is also referred to as a Lead Centre.

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 long-range prediction.

1.2.5 Regional Specialized Meteorological Centre Networks

1.2.5.1 An RSMC Network (an association of RSMCs participating in an identified activity of GDPFS) shall follow the same specifications and adhere to the same criteria and commitments as individual RSMCs 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 RSMC Network to distribute the tasks and responsibilities among the participating RSMCs. A unique focal point shall be designated to answer requests from users of the RSMC Network products.

1.2.6 Designation process

1.2.6.1 Each Member shall designate an NMC.

1.2.6.2 The WMCs, RSMCs and RSMC 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 RSMC shall be put forward by the Permanent Representative of the country 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)).

1.2.6.4 Requests for designation as an RSMC 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 2–23 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

The Global Data-processing and Forecasting System 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 GDPFS 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 GDPFS 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, LRFs 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 the 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

PART II. SPECIFICATIONS OF GLOBAL DATA-PROCESSING AND FORECASTING 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 GDPFS purposes. The objectives of the GDPFS quality control shall be:

- (a) To ensure the best possible quality of the observations that are used in the real-time operations of GDPFS;**
- (b) In non-real time, to protect and improve the quality and integrity of observations destined for storage and retrieval within GDPFS;**
- (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 GDPFS 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 GDPFS 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 GDPFS 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 GDPFS centres.

2.1.2 **Data collection and product dissemination**

2.1.2.1 **Global Data-processing and Forecasting System 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 GDPFS 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 GDPFS 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 Global Data-processing and Forecasting 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 2.2.34](#). A mandatory set will be provided by participating centres. Centres should also provide, if possible, additional statistics as recommended in [Appendix 2.2.34](#).

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 Global Data-processing and Forecasting System centres receiving RSMC products via WIS should carry out verification over appropriate areas using the standardized measures listed in [Appendices Appendix 2.2.34 to 2.2.38](#) 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 publically 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 is 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**

Global Data-processing and Forecasting System 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 GDPFS 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*

Regional Specialized Meteorological 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 and highly recommended global deterministic NWP products to be made available is given in [Appendix 2.2.1](#);
- (d) Produce verification statistics according to the standard defined in [Appendix 2.2.34](#), 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:	CBS/ET-OWFPS		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	CBS	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-OWFPS		
To be reported to:	CBS/ICT-DPFS	CBS	

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 and highly 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 2.2.34](#), 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:	CBS/ET-OWFPS		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	CBS	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-OWFPS		
To be reported to:	CBS/ICT-DPFS	CBS	

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 and highly recommended global ensemble NWP 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 2.2.35](#);
- (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 the table below.

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:	CBS/ET-OWFPS		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	CBS	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-OWFPS		
To be reported to:	CBS/ICT-DPFS	CBS	

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 and highly 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 2.2.35](#), 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 the table below.

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:	CBS/ET-OWFPS		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	CBS	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-OWFPS		
To be reported to:	CBS/ICT-DPFS	CBS	

2.2.1.5 **Global numerical long-range prediction**

2.2.1.5.1 Centres conducting global numerical long-range prediction (GPCs-LRF) shall:

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

- (a) **Generate LRF products with global coverage;**
- (b) **Make available on WIS a range of these products; mandatory and highly recommended products to be made available are listed in [Appendix 2.2.9](#);**
- (c) **Produce verification statistics according to the standard defined in [Appendix 2.2.36](#), and make them available to the Lead Centre(s) for the standardized verification system for long-range forecasts (Lead Centre(s) for SVSLRF) and on a website;**
- (d) **Make available on a website up-to-date information on the characteristics of their global long-range numerical prediction systems; the minimum information to be provided is given in [Appendix 2.2.10](#).**

2.2.1.5.2 In addition to the mandatory activities above, GPCs-LRF should:

- (a) Provide forecast output to the Lead Centre(s) for LRF multi-model ensembles (Lead Centre(s) for LRFMME), as detailed in [Appendix 2.2.17](#) (section 1);
- (b) Make available on WIS the highly recommended products listed in [Appendix 2.2.9](#);
- (c) Make available, on request by Regional Climate Centres (RCCs) or NMCs, the additional data, products and services listed in [Attachment 2.2.1](#), noting that these services may be subject to conditions attached by GPCs.

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

Table 6. WMO bodies responsible for managing information related to global numerical long-range prediction

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS–CCI/IPET-OPSLS		
To be recommended by:	CBS	CCI	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	CBS	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS–CCI/IPET-OPSLS		
To be reported to:	CBS/ICT-DPFS	CBS	

Acronyms not previously defined: CCI – Commission for Climatology; IPET-OPSLS – Inter-programme Expert Team on Operational Prediction from Sub-seasonal to Longer Timescales.

2.2.1.6 **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 highly 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 Manual related to numerical ocean wave prediction are specified in Table 7.

Table 7. 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:	JCOMM/ET-WCH		
To be recommended by:	CBS	JCOMM	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	CBS	JCOMM
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	JCOMM/ET-WCH		
To be reported to:	CBS	JCOMM	

Acronyms not previously defined: ET-WCH – Expert Team on Waves and Coastal Hazards Forecasting Systems; JCOMM – WMO–IOC Joint Technical Commission for Oceanography and Marine Meteorology.

2.2.1.7 **Global numerical ocean prediction**

Centres conducting global numerical ocean prediction shall:

- (a) Prepare global analyses of oceanographic parameters;
- (b) Prepare global forecast fields of basic and derived oceanographic parameters;
- (c) Make available on WIS a range of these products; the list of mandatory and highly 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 8.

Table 8. Bodies responsible for managing information related to global numerical ocean prediction

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	JCOMM/ET-OOFS		
To be recommended by:	CBS	JCOMM	
To be decided by:	EC/Congress		

<i>Responsibility</i>			
<i>Centres designation</i>			
To be recommended by:	RA	CBS	JCOMM
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	JCOMM/ET-OOFS		
To be reported to:	CBS	JCOMM	

Acronyms not previously defined: ET-OOFS – Expert Team on Operational Ocean Forecast Systems.

2.2.1.8 **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 9.

Table 9. WMO bodies responsible for managing information related to nowcasting

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS/ET-OWFPS		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	CBS	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-OWFPS		
To be reported to:	CBS/ICT-DPFS	CBS	

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 long-range forecasting, both dynamical and statistical, within the range of a one-month to two-year timescale, based on regional needs:

- Interpret and assess relevant LRF products from GPCs-LRF; make use of the products from the Lead Centre(s) for SVSLRF (refer to 2.2.3.3); distribute relevant information to users and provide feedback to GPCs (refer to guidelines given in Attachment 2.2.3);
 - 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 long-range forecasting 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 highly recommended, but not mandatory, RCC functions is given in [Attachment 2.2.2](#).
3. The bodies in charge of managing the information contained in the Manual related to regional climate prediction and monitoring are specified in Table 10.

Table 10. 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:	CCI–CBS/ET–RCC	CBS–CCI/IPET–OPSLs	
To be recommended by:	CBS	CCI	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	CBS	CCI
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CCI–CBS/ET–RCC		
To be reported to:	CBS/ICT–DPFS	CBS	

Acronyms not previously defined: ET-RCC – Expert Team on Regional Climate Centres.

2.2.2.2 **Coordination of multi-model ensemble prediction for long-range forecasts**

Centre(s) coordinating LRF multi-model ensembles (Lead Centre(s) for LRFMME) shall:

- (a) Collect an agreed set of forecast data from RSMCs participating in long-range forecast numerical prediction under activity 2.2.1.5 (GPCs-LRF);
- (b) Make available on a website appropriate minimum ([Appendix 2.2.17](#)) and additional (Attachment 2.2.4) products and GPC forecasts in standard format;
- (c) Redistribute digital forecast data as described in [Appendix 2.2.18](#) for those GPCs that allow it;
- (d) Maintain an archive of the real-time GPC and multi-model ensemble forecasts;
- (e) Maintain a repository of documentation for the system configuration of all GPC systems;
- (f) Verify the products using SVSLRF ([Appendix 2.2.36](#));
- (g) Based on comparison among different models, provide feedback to GPCs about model performance and make available on a website the verification results;
- (h) Promote research and experience in multi-model ensemble techniques and provide guidance and support on multi-model ensemble techniques to GPCs, RCCs and NMHSs.

Note: The bodies in charge of managing the information contained in the present Manual related to coordination of multi-model ensemble prediction for LRFs are specified in the table below.

Table 11. WMO bodies responsible for managing information related to multi-model ensemble prediction for LRFs

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS-CCI/IPET-OPSLS		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS-CCI/IPET-OPSLS		
To be reported to:	CBS/ICT-DPFS	CBS	

2.2.2.3 **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 parameters relevant to ADCP;
- (b) Prepare verification statistics as defined in [Appendix 2.2.21](#);
- (c) Provide an agreed set of forecast and hindcast variables (as defined in [Appendix 2.2.21](#)) 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 12.

Table 12. WMO bodies responsible for managing information related to ADCP

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS-CCI/IPET-OPSLS		
To be recommended by:	CBS	CCI	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS-CCI/IPET-OPSLS		
To be reported to:	CBS/ICT-DPFS	CBS	

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 IPET-OPSLS; 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 specification of their prediction systems;
- (c) Collect an agreed set of hindcast, forecast and verification data ([Appendices 2.2.20 and 2.2.21](#)) from the contributing centres;
- (d) Make available (on a password-protected website) agreed forecast products in standard format, including multi-model ensemble products ([Appendix 2.2.20](#));
- (e) Make available on the website agreed hindcast verification products in standard format, including verification of the multi-model ensemble products ([Appendix 2.2.21](#));
- (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) **Coordinate, in liaison with relevant World Climate Research Programme activities, an annual consensus prediction product giving 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 2.2.19](#).

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

Table 13. WMO bodies responsible for managing information related to coordination of ADCP

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS–CCI/IPET-OPSLS		
To be recommended by:	CBS	CCI	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS	CCI	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS–CCI/IPET-OPSLS		
To be reported to:	CBS/ICT-DPFS	CBS	

2.2.2.5 **Regional severe weather forecasting**

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

2.2.2.5.1 **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 for tropical cyclone forecasting and interpret it in terms of severe weather guidance.**

2.2.2.5.2 **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 14.

Table 14. 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:	CBS/ET-OWFPS	SG-SWFDP	
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	RA	CBS	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	SG-SWFDP		
To be reported to:	CBS/ICT-DPFS	CBS	

Acronyms not previously defined: SG-SWFDP – Steering Group for the Severe Weather Forecasting Demonstration Project.

2.2.2.6 **Tropical cyclone forecasting, including marine-related hazards**

Note: This activity is performed within the five Tropical Cyclone Programme regional bodies, each composed of an RSMC and a number of NMCs forming a network.

2.2.2.6.1 **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.

2.2.2.6.2 **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.

2.2.2.6.3 All six RSMCs for tropical cyclone forecasting together with Tropical Cyclone Warning Centre Darwin, which are designated as Tropical Cyclone Advisory Centres 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 meteorological watch offices for the flight information region concerned and shall be based on the tropical cyclone advisory information issued by the Tropical Cyclone Advisory Centres.*

2.2.2.6.4 Members holding Metareas under their 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 15.

Table 15. WMO bodies responsible for managing information related to tropical cyclone forecasting

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	Technical coordination meeting		
To be recommended by:	CBS	Regional tropical cyclone committee	
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS	Regional tropical cyclone committee	
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	Technical coordination meeting		
To be reported to:	CBS		

2.2.2.7 ***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 authority¹ 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 2.2.22](#);

¹ The person authorized by the Permanent Representative of the WMO Member to request support.

- (ii) Within two to three hours of reception of a request, make a range of products available to the NMHS operational contact point² and/or IAEA on WIS.³ The minimum list, including parameters, forecast range, time steps and frequency, is given in [Appendix 2.2.23](#);
- (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 2.2.24](#);
- (iv) Make available up-to-date information on the characteristics of their ATDM systems (minimum information to be provided is given in [Appendix 2.2.25](#)) 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 2.2.26](#).

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

Notes:

1. Arrangements for activation and product specifications are given in [Appendix 2.2.27](#).
2. The bodies in charge of managing the information contained in the Manual related to nuclear environmental emergency response are specified in Table 16.

Table 16. 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:	CBS/ET-ERA		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-ERA		
To be reported to:	CBS/ICT-DPFS	CBS	

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

2.2.2.8 **Non-nuclear environmental emergency response**

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

Centres conducting non-nuclear nuclear emergency response shall:

² Designated by the Permanent Representative.

³ Via a password-protected dedicated website.

- (a) Prepare, on request from an authorized person,⁴ 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 2.2.28](#) and [2.2.32](#), 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 point⁵ by email or retrieval from the RSMC password-protected designated website; the list of mandatory and highly recommended products to be made available, including parameters, forecast range, time steps and frequency, is given in [Appendix 2.2.29](#);
- (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 2.2.30](#);
- (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 2.2.31](#)) and a user interpretation guide for ATDM products ([Attachment 2.2.5](#)).

Note: The bodies in charge of managing the information contained in the present Manual related to non-nuclear emergency response are specified in Table 17.

Table 17. WMO bodies responsible for managing information related to non-nuclear emergency response

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS/ET-ERA		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-ERA		
To be reported to:	CBS/ICT-DPFS	CBS	

2.2.2.9 **Atmospheric sandstorm and duststorm forecasts**

Centres conducting atmospheric sandstorm and duststorm 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 sandstorms and duststorms;
- (c) Prepare limited-area forecast fields of variables relevant to atmospheric sandstorms and duststorms;
- (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 2.2.33](#).

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

⁵ Designated by the Permanent Representative.

Note: The bodies in charge of managing the information contained in the present Manual related to atmospheric sandstorm and duststorm forecasts are specified in Table 18.

Table 18. WMO bodies responsible for managing information related to atmospheric sandstorm and duststorm forecasts

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CAS/SDS-WAS Steering Committee	CBS/ET-ERA	
To be recommended by:	CAS (WWRP/SSC)	CBS	
To be decided by:	EC/Congress		
<i>Centres designation*</i>			
To be recommended by:	CAS (WWRP/SSC, SDS-WAS Steering Group)	CBS	RA
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-ERA		
To be reported to:	CBS/ICT-DPFS	CBS	

Acronyms not previously defined: CAS – Commission for Atmospheric Sciences; SDS-WAS – Sand and Dust Storm Warning Advisory and Assessment System; WWRP/SSC – WMO World Weather Research Programme Scientific Steering Committee.

* The detailed designation procedure of RSMCs with activity specialization on atmospheric sandstorm and duststorm 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).

2.2.2.10 **Volcano watch services for international air navigation**

Note: Volcanic ash advisory centres which provide services in support of international air navigation are designated by ICAO. This designation is made in consultation with WMO. Service provision arrangements in this respect and those for volcano observatories are described in *Technical Regulations* (WMO-No. 49), Volume II, 3.5 and 3.6, respectively.

2.2.2.11 **Marine meteorological services**

Note: Regulations specific to marine meteorological services are contained in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I.

2.2.2.12 **Marine environmental emergencies**

Note: Regulations specific to marine environmental emergencies are contained in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I.

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 GDPFS centres producing global NWP 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) **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 CBS 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 GDPFS-participating centres;**
 - **Contact details to encourage feedback from NMHSs and other GDPFS 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 19.

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

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS/ET-OWFPS		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-OWFPS		
To be reported to:	CBS/ICT-DPFS	CBS	

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 GDPFS centres producing global EPS data to automatically deposit their standardized verification statistics as defined in [Appendix 2.2.35](#), 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 CBS 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 GDPFS-participating centres;
 - Contact details to encourage feedback from NMHSs and other GDPFS 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 20.

Table 20. 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:	CBS/ET-OWFPS		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-OWFPS		
To be reported to:	CBS/ICT-DPFS	CBS	

2.2.3.3 **Coordination of long-range forecast verification**

2.2.3.3.1 The centre(s) conducting coordination of LRF verification (Lead Centre(s) for SVSLRF) shall:

- (a) Provide the facility for RSMCs participating in global numerical long-range prediction under activity 2.2.1.5 to automatically deposit their standardized verification statistics as defined in [Appendix 2.2.36](#), and provide access to these verification statistics;
- (b) Maintain an archive of 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 on their websites (for example, <http://www.bom.gov.au/wmo/lrfvs/>):

- Consistent up-to-date graphical displays of 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 GDPFS-participating centres;
- Contact details to encourage feedback from NMHSs and other GDPFS centres on the usefulness of the verification information;

(e) Provide access to verification datasets at an appropriate horizontal resolution.

2.2.3.3.2 Additionally, the Lead Centre(s) should:

- (a) Liaise with other groups involved in verification (for example, the Climate Variability and Predictability Programme Working Group on Seasonal to Interannual Prediction and CCI) on the effectiveness of the current standardized verification system and identify areas for future development and improvement;
- (b) Provide periodic reports to CBS and other relevant commissions assessing the effectiveness of the standardized verification system.

Notes:

1. Detailed tasks for Lead Centres for SVSLRF, and verification scores, are listed in [Appendix 2.2.36](#).
2. The bodies in charge of managing the information contained in the present Manual related to coordination of LRF verification are specified in Table 21.

Table 21. WMO bodies responsible for managing information related to the coordination of LRF verification

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS-CCI/IPET-OPSLS		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS-CCI/IPET-OPSLS		
To be reported to:	CBS/ICT-DPFS	CBS	

2.2.3.4 **Coordination of wave forecast verification**

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

- (a) Provide the facility for JCOMM-participating centres that produce global or ocean-basin scale wave forecasts to automatically deposit their gridded forecast fields as defined in [Appendix 2.2.37](#), 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 JCOMM-participating centres 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 JCOMM recommendations;
- (f) Provide on their websites:
 - Consistent up-to-date graphical displays of the verification results from JCOMM-participating centres 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 JCOMM-participating centres;
 - Contact details to encourage feedback from JCOMM-participating centres on the usefulness of the verification information.

2.2.3.4.2 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 22.

Table 22. Bodies responsible for managing information related to coordination of WFV

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS/ET-OWFPS	JCOMM/ET-WCH	
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-OWFPS		
To be reported to:	CBS/ICT-DPFS	CBS	

2.2.3.5 **Coordination of tropical cyclone forecast verification**

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

- (a) Provide the facility for GDPFS 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 2.2.38](#), 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 GDPFS-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 2.2.2.6;
- (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 GDPFS-participating centres;**
- **Contact details to encourage feedback from NMHSs and other GDPFS centres on the usefulness of the verification information.**

2.2.3.5.2 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 Manual related to TCFV are specified in Table 23.

Table 23. WMO bodies responsible for managing information related to coordination of TCFV

<i>Responsibility</i>			
<i>Changes to activity specification</i>			
To be proposed by:	CBS/ET-OWFPS	CAS/JWGFVR	WGNE
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Centres designation</i>			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
<i>Compliance</i>			
To be monitored by:	CBS/ET-OWFPS		
To be reported to:	CBS/ICT-DPFS	CBS	

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

2.2.3.6 **Coordination of observation monitoring**

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

2.2.3.6.2 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.

2.2.3.6.3 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.

2.2.3.6.4 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.

2.2.3.6.5 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.

2.2.3.6.6 Monitoring results, including follow-up actions, should be made available to CBS, 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
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 criteria, 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⁻¹ 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⁻¹)</i>	<i>Level (hPa)</i>	<i>Wind (m s⁻¹)</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 ± 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 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 CBS, 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 ≥ 4 hPa;
- Standard deviation ≥ 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 ≥ 30 m;
- Standard deviation ≥ 40 m;
- Percentage gross error $\geq 25\%$ (gross error limit: 100 m).

3.1.4 **Precipitation**

General guidance reflecting Global Precipitation Climatology Centre procedures for precipitation quality monitoring is given in the *Guide to the Global Data-processing System* (WMO-No. 305), 6.3.3.2 – GPCC 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 ≥ 4 hPa;
- Standard deviation ≥ 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 ≥ 5 m s⁻¹;
 - Percentage gross error $\geq 25\%$ (25 m s⁻¹ vector wind).

4.4.3 **List 3: Wind direction**

Data for which the wind speed is less than 5 m s⁻¹, 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⁻¹ 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 as follows:

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 ⁻¹)	30.0	30.0	40.0
Wind speed bias (m s ⁻¹)	3.0	2.5	2.5
Wind RMS (m s ⁻¹)	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 ≥ 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 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° box), 10 (in 5° box)
Gross error limit (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

<i>Geostationary satellite wind (centres must specify either SATOB or BUFR code, as assimilated, and channels)</i>	<i>Recommended criteria</i>
Orbital satellite	
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 HIGHLY RECOMMENDED GLOBAL DETERMINISTIC NUMERICAL WEATHER PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

<i>Parameter</i>	<i>Level (hPa)</i>	<i>Resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Geopotential height	850/500/250	1.5° x 1.5°	Up to 3 days/ Beyond 3 days up to 6 days	Every 6 hours/ Every 12 hours	Twice a day (0000 and 1200 UTC)/ Once a day
Temperature	850/500/250				
Wind zonal velocity (u) and vertical velocity (v)	925/850/700/500/250				
Relative humidity	850/700				
Divergence, vorticity	925/700/250				
MSLP	Surface				
2-m temperature	Surface				
10-m u, 10-m v					
Total precipitation					

Additional recommended products:

- Tropical storm tracks (latitudinal/longitudinal locations, maximum sustained wind speed, MSLP).

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. Further information

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

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

<i>Parameter</i>	<i>Level (hPa)</i>	<i>Resolution</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Geopotential height	925/850/700/500/250	0.5° x 0.5°	1 day	Every 6 hours	Twice a day
Temperature	925/850/700/500/250				
u, v	925/850/700/500/250				
Relative humidity	925/850/700/500				
Divergence, vorticity	925/850/700/500/250				
MSLP	Surface				
2-m temperature	Surface				
10-m u, 10-m v					
Total precipitation					

Additional recommended products:

- Vertical velocity;
- Cloud cover;
- Tropical storm tracks (latitudinal/longitudinal locations, maximum sustained wind speed, MSLP).

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 HIGHLY RECOMMENDED GLOBAL ENSEMBLE PREDICTION SYSTEM PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

<i>Parameter</i>	<i>Level (hPa)</i>	<i>Thresholds</i>	<i>Resolution (lat/lon grid)</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Probability of precipitation	Surface	1, 5, 10, 25, 50 and 100 mm/24 hours	1.5° x 1.5°	10 days (or the maximum range if less)	Every 12 hours	Once a day
Probability of 10-m sustained wind and gusts	Surface	10, 15 and 25 m s ⁻¹				
Probability of temperature anomalies	850	±1, ±1.5, ±2 standard deviations with respect to a reanalysis climatology specified by the Producing Centre				
Ensemble mean + spread (standard deviation) of geopotential height	500					
Ensemble mean + spread (standard deviation) of MSLP	Surface					
Ensemble mean + spread (standard deviation) of wind speed	850/250					

Additional highly 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 (latitude/longitude locations, maximum sustained wind speed, MSLP from EPS members).

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 the calculation, if the method is not unique:
- 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 HIGHLY RECOMMENDED LIMITED-AREA ENSEMBLE PREDICTION SYSTEM PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

<i>Parameter</i>	<i>Level (hPa)</i>	<i>Thresholds</i>	<i>Resolution (lat/lon grid)</i>	<i>Forecast range</i>	<i>Time steps</i>	<i>Frequency</i>
Probability of precipitation	Surface	1, 5, 10, 25, 50 and 100 mm/24 hours	0.5° x 0.5°	2 days (or the maximum range if less)	Every 6 hours	Once a day
Probability of 10-m sustained wind and gusts	Surface	10, 15 and 25 m s ⁻¹				
Probability of temperature anomalies	850	±1, ±1.5, ±2 standard deviations with respect to a reanalysis climatology specified by the Producing Centre				
Ensemble mean + spread (standard deviation) of geopotential height	500					
Ensemble mean + spread (standard deviation) of MSLP	Surface					
Ensemble mean + spread (standard deviation) of wind speed	850/250					

Additional highly 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, MSLP from EPS members).

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 HIGHLY RECOMMENDED GLOBAL NUMERICAL LONG-RANGE PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

Global Producing Centre mandatory products (maps)

<i>Parameter</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	Any forecast range (lead time) between zero and four months	Averages over one month or longer periods (seasons)	(1) Ensemble mean anomaly	Monthly
SST	Global oceans			(2) Probabilities for tercile forecast categories (where applicable)	
Total precipitation	Global				

Probabilities for extremes are not mandatory but are highly recommended.

Global Producing Centre highly recommended products (maps)

<i>Parameter</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	Any forecast range (lead time) between zero and four months	Averages over one month or longer periods (seasons)	(1) Ensemble mean anomaly	Monthly
MSLP				(2) Probabilities for tercile forecast categories	
850 hPa temperature					

Global Producing Centre highly 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 highly recommended, not mandatory) – the recommended definitions to be used for extremes are below 20th percentile and above 80th percentile.
 2. Output types – rendered images (for example, forecast maps and diagrams). Note: GPCs 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. GPCs are also encouraged to provide hindcast and forecast fields, as listed in Attachment 2.2.4 section 1, to the Lead Centre(s) for LRFMME.
 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 2.2.37](#).
-

APPENDIX 2.2.10. CHARACTERISTICS OF GLOBAL NUMERICAL LONG-RANGE PREDICTION SYSTEMS

- Date of implementation of the current seasonal forecast 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 HIGHLY RECOMMENDED NUMERICAL OCEAN WAVE PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

<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° x 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				

Additional highly recommended products:

- u and v component of 10-metre wind;
- Full 2-D wave spectra at subset of grid points;
- Wind sea and swell split at all grid points;
- 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 HIGHLY RECOMMENDED GLOBAL NUMERICAL OCEAN PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

<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	0.5° x 0.5°	Up to 6 days	Every 24 hours	Once a day
SST	Surface (mixed layer)				
Surface u, v	Surface				
Sea-surface salinity	Surface				
u, v	Depth to be determined				
Temperature	10/50/100/250/500 (m)				
Mixed layer depth					

Additional highly recommended products:

- None.

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:
- Bottom 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:
- Integration time step:
- Additional comments:

3. Initial conditions

- Data assimilation method:
- Additional comments:

4. Surface boundary conditions

- Surface forcing, briefly describe method(s):
- Lateral boundary conditions (for example, river discharge)? If so, briefly describe method(s):
- Additional comments:

5. Other details of the model

- What kind of mixing 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?:
- Data assimilation scheme?:
- Quality control scheme?:
- Verification approach?:
- Other relevant details?:

6. Further information

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

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>
Operational activities for LRF (both dynamical and statistical, within the range of a one-month to two-year timescale, based on regional needs)	Interpret and assess relevant LRF products from GPCs, make use of the Lead Centre(s) for SVSLRF, distribute relevant information to RCC users, and provide feedback to GPCs (see Attachment 2.2.2)	Product: Assessment of the reliability and outcomes of GPCs or Lead Centre(s) for LRFMME products, including the reasoning (make use of the Lead Centre(s) for SVSLRF), for the region of interest, in the form of texts, tables, figures, etc. Element: 2-m mean temperature, total precipitation Update frequency: Monthly or at least quarterly
	Generate regional and subregional tailored products, relevant to RCC user needs, including seasonal outlooks	Product: Probabilities for tercile (or appropriate quantile) categories for the region or subregion Element: 2-m mean temperature, total precipitation Output type: Rendered images (maps, charts), text, tables, digital data Forecast period: 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	Product: Consensus statement on regional or subregional forecast Element: 2-m mean temperature, total precipitation Output type: Report Forecast period: A climatologically significant period (from one month to one year) Update frequency: At least once per year (to be defined by the region)
	Perform verification of RCC quantitative LRF products, including the exchange of basic forecasts and hindcast data	Products: Verification datasets (e.g., SVSLRF scores, Brier skill score; relative operating characteristic (ROC); hit rate skill score) Element: 2-m mean temperature, total precipitation
	Provide online access to RCC products and services to RCC users	Product: An online data/information portal
	Assess use of RCC products and services through feedback from RCC users	Product: Analysis of feedback (which is made available using a template) Update frequency: Annually, as part of a regular reporting of RCCs to WMO RAs

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

APPENDIX 2.2.17. MINIMUM INFORMATION TO BE AVAILABLE FROM THE LEAD CENTRE(S) FOR LONG-RANGE FORECAST MULTI-MODEL ENSEMBLES

1. Global Producing Centre digital products

Global fields of forecast anomalies as supplied by GPCs, including (for GPCs that allow redistribution of their digital data) monthly mean anomalies for individual ensemble members and ensemble mean 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:

- (a) Surface (2 m) temperature;
- (b) SST;
- (c) Total precipitation rate;
- (d) MSLP;
- (e) 850 hPa temperature;
- (f) 500 hPa geopotential height.

Note: Definitions of the content and format for the supply of data to the Lead Centre(s) by GPCs and terms of exchange are available on the Lead Centre(s) for LRFMME websites.

Global Producing Centres not currently able to participate in this additional exchange of data are encouraged to do so in the future.

2. Graphical products

Plots and maps for each GPC forecast displayed in common format on the Lead Centre(s) website, for the variables listed in [Appendix 2.1.2](#) section 3.1 and for selectable regions where appropriate, showing for three-month means or accumulations:

- (a) Ensemble “plumes” of Niño indices (one-month means);
 - (b) Ensemble mean anomalies;
 - (c) Probabilities of above/below median;
 - (d) Model consistency plots, that is, maps showing the proportion of models predicting the same sign anomaly;
 - (e) Multi-model probabilities of above/below median.
-

APPENDIX 2.2.18. ACCESS TO GLOBAL PRODUCING CENTRE DATA AND VISUALIZATION PRODUCTS HELD BY THE LEAD CENTRE(S) FOR LONG-RANGE FORECAST MULTI-MODEL ENSEMBLES

- (a) Access to GPC data and graphical products from the Lead Centre(s) for LRFMME websites will be password protected.
 - (b) Digital GPC data will be redistributed only in cases where the GPC data policy allows it. In other cases, requests for GPC output should be referred to the relevant GPC.
 - (c) Formally designated GPCs and RCCs, NMHSs and institutions coordinating RCOFs are eligible for password-protected access to information held and produced by the Lead Centre(s) for LRFMME. 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 LRFMME, 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 LRFMME 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 LRFMME 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 LRFMME will refer the application to the CBS–CCI Expert Team on Operational Predictions from Sub-seasonal to Longer-time Scales (ET-OPSLS) 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 LRFMME and reviewed periodically by the CBS–CCI ET-OPSLS, to measure the degree of effective use and also to identify any changes in status of eligible users, and determine further necessary follow-up.
-

APPENDIX 2.2.19. ACCESS TO DATA AND VISUALIZATION PRODUCTS HELD BY THE LEAD CENTRE(S) FOR ANNUAL TO DECADEAL CLIMATE PREDICTION

- (a) Access to data and graphical products from Lead Centre(s) for ADCP 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 output should be referred to the relevant contributing centre.
 - (c) Contributing centres, RCCs, NMHSs and institutions coordinating RCOFs are eligible for password-protected access to information held and produced by the Lead Centre(s) for ADCP.
 - (d) Institutions other than those identified in (c) above may also request access to Lead Centre(s) for ADCP products. These institutions, including research centres, 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 to be eligible for access. Prior to access being granted to an applicant institution, the Lead Centre(s) for ADCP will refer the application to the CBS-CCI IPET-OPSLS 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 for ADCP and reviewed periodically by the CBS-CCI IPET-OPSLS, to measure the degree of effective use and also to identify any changes in status of eligible users, and determine further necessary follow-up.
-

APPENDIX 2.2.20. HINDCAST AND FORECAST DATA TO BE COLLECTED BY LEAD CENTRES AND PRODUCTS TO BE GENERATED AND DISPLAYED

Contributing centres shall provide necessary hindcast and forecast data to the Lead Centres 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 2.2.21. VERIFICATION INFORMATION TO BE COLLECTED BY THE LEAD CENTRES AND PRODUCTS TO BE DISPLAYED

Hindcast verification:

The Lead Centres 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 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 2.2.22. 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 authority¹ of any country in the RSMC region of responsibility or IAEA requests RSMC support. Upon receipt of a request from the delegated authority² or from IAEA, the RSMC shall provide basic information to the NMHS of that country 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 responsibility³ 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;

¹ The person authorized by the Permanent Representative of the country to request RSMC support.

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

³ 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 for 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 2.2.26](#)). 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 2.2.26](#)). 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 2.2.23](#)) 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 2.2.23](#)) 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.

APPENDIX 2.2.23. 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 Bq s m^{-3} for each of the three forecast periods;
- (c) Total deposition (wet + dry) in 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° 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 2.2.24. DEFAULT EMISSION SOURCE PARAMETERS (NUCLEAR)

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

- (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 ¹³⁷Cs.

¹ 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 2.2.25. 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.
-

**ENVIRONMENTAL EMERGENCY RESPONSE
REQUEST FOR WMO RSMC SUPPORT BY IAEA**

The IAEA sends the completed form by fax to all RSMCs and RTH Offenbach. At the same time the IAEA calls the 'Lead' RSMCs (selected on the form) to ensure receipt of this form.

STATUS: <input type="checkbox"/> EMERGENCY <input type="checkbox"/> EXERCISE		Date/time of request: yyyy-MM-dd/HH:mm (UTC)
REQUESTED RSMCs: (indicate the lead RSMCs by a checkmark below)		
<input type="checkbox"/> EXETER <input type="checkbox"/> TOULOUSE <input type="checkbox"/> MELBOURNE	<input type="checkbox"/> MONTREAL <input type="checkbox"/> WASHINGTON	
<input type="checkbox"/> BEIJING <input type="checkbox"/> TOKYO <input type="checkbox"/> OBNINSK	<input checked="" type="checkbox"/> RTH Offenbach	
SENDER'S NAME: INTERNATIONAL ATOMIC ENERGY AGENCY		
COMMUNICATION DETAILS:	Tel.: +43 1 2600 22023	Use to confirm receipt of request
	Fax: +43 1 26007 29309	Use to confirm receipt of request
	E-mail: iec3@iaea.org	Use to confirm receipt of request
NAME OF RELEASE SITE AND COUNTRY:..... (facility and place)		
GEOGRAPHICAL LOCATION OF RELEASE: (MUST BE COMPLETED)		
	. Decimal degrees	<input type="checkbox"/> N <input type="checkbox"/> S
	. Decimal degrees	<input type="checkbox"/> E <input type="checkbox"/> W

DECLARED EMERGENCY CLASS: <input type="checkbox"/> NONE <input type="checkbox"/> Other, specify:
ACTION REQUIRED: <input type="checkbox"/> NONE <input type="checkbox"/> GO ON STANDBY (request for products or for assistance on weather conditions is to be expected) <input type="checkbox"/> LEAD RSMCs ONLY GENERATE PRODUCTS AND SEND TO IAEA ONLY <input type="checkbox"/> ALL RSMCs GENERATE PRODUCTS AND DISTRIBUTE WITHIN THEIR REGIONS <input type="checkbox"/> OTHER ACTION:.....

<i>(essential accident information for model simulation — if not available, model will execute with standard default values)</i>	
RELEASE CHARACTERISTICS:	
START OF RELEASE: Date/time: - - / : (UTC)	
DURATION: (hours) or END OF RELEASE: Date/time: - - / : (UTC)	
RADIONUCLIDE SPECIES:.....	
TOTAL RELEASE QUANTITY:..... (Becquerel)	
OR POLLUTANT RELEASE RATE:..... (Becquerel/hour)	
EFFECTIVE HEIGHT OF RELEASE:	<input type="checkbox"/> Surface or
	<input type="checkbox"/> Release height: base: (m), top:..... (m)

<i>(helpful information for improved simulation)</i>	
SITE ELEVATION: (m)	
LOCAL METEOROLOGICAL CONDITIONS NEAR ACCIDENT:	
.....	
(wind speed and direction/weather/cloudiness, etc.)	
OTHER INFORMATION:.....	
.....	
(nature of accident, cause, fire explosion, controlled release, foreseeable development, normal activity, projected conditions, etc.)	

<i>(to be completed by RSMC)</i>	
DATE/TIME OF RECEIPT OF REQUEST:.....	(UTC)
FOR LEAD RSMC(S) ONLY	
DATE/TIME OF RETURN CONFIRMATION OF RECEIPT:	(UTC)

NOTE: All times in UTC.

APPENDIX 2.2.27. SPECIFICATIONS FOR SUPPORT TO THE COMPREHENSIVE NUCLEAR-TEST-BAN TREATY ORGANIZATION

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 backtracking 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 backtracking 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.

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

The CTBTO PTS requests support from RSMCs for ATDM (backtracking) 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 backtracking 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 backtracking are as follows:

- Simulate a release of $1.3 \cdot 10^{15}$ 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 Bq m^{-3} at a global $1^\circ \times 1^\circ$ grid, with an output frequency of three hours, time average of output three hours, 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

005

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

=====

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 2.2.28. 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, emissions from volcanic eruptions (excluding those service arrangements covered by 2.2.2.10 – Volcano watch services for international air navigation) and large chemical releases. Atmospheric sandstorm and duststorm forecasts are covered under activity 2.2.2.9.

National Meteorological and Hydrological Services may request RSMC support for releases that have the potential for large-scale (that is, mesoscale) and/or long-duration (hours to days) impacts, according to the capability of the RSMC. RSMC products are typically not applicable for shorter range incidents. RSMCs will advise NMHSs if requests are not within their capabilities.

National Meteorological and Hydrological Services requesting RSMC support shall:

- **Request via the authorized person¹ that an RSMC provides, in accordance to 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 2.2.32](#) 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.**

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

APPENDIX 2.2.29. MANDATORY LIST OF NON-NUCLEAR ENVIRONMENTAL EMERGENCY RESPONSE

The following list of mandatory non-nuclear responses shall be provided:

- Smoke from forest, grass or peat fires (default values in [Appendix 2.2.30](#) shall be used for source parameters not provided):
 - Forecast duration 36 hours;
 - Relative concentrations from the surface to 200 m;¹
 - Images at intervals of one, three or six hours;²
 - 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;¹
 - Images at intervals of one or three hours;²
 - 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;¹
 - Images at intervals of one or three hours;²
 - Contouring to be determined based on specifics of the event or the request.

All products shall be displayed following the general rules, as listed in [Attachment 2.2.5](#).

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.

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

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

APPENDIX 2.2.30. 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 per hour over 36 hours	Constant from the surface to 500 m
Major industrial fire	Smoke	Tracer	One unit per hour over 6 hours	Constant from the surface to 500 m
Chemical release not involving fire	Chemical	Tracer	One unit 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.

APPENDIX 2.2.31. 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 2.2.32. REQUEST FORM TO ACTIVATE REGIONAL SPECIALIZED METEOROLOGICAL CENTRE SUPPORT (NON-NUCLEAR)

Environmental emergency response request for WMO Regional Specialized Meteorological Centre support by authorized person¹

- (a) This form should be sent by email to an operational contact of the appropriate RSMC when support is needed for releases that have the potential for large-scale (that is, mesoscale) and/or long-duration (hours to days) impacts. The RSMC operational contact information is available on http://www.wmo.int/pages/prog/www/DPFSERA/transport_model_products.htm.
- (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

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

¹The 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:

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



APPENDIX 2.2.33. MANDATORY ATMOSPHERIC SANDSTORM AND DUSTSTORM 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 (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 (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.

APPENDIX 2.2.34. 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 GDPFS centres. The goal is to provide consistent verification information on the NWP products of GDPFS-participating centres for forecasters in the NMHSs and to help the GDPFS 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 (<http://apps.ecmwf.int/wmolcdnv/>) 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 850, 500 and 250 hPa.
- Additional recommended:
 - Geopotential height, temperature, wind at 100 hPa;
 - Relative humidity at 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 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° x 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 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 CBS 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.

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 CBS 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 included in the yearly Technical Progress Report on the Global Data-processing and Forecasting System (<https://www.wmo.int/pages/prog/www/DPFS/GDPFS-Progress-Reports.html>). These statistics 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). A table of the number of observations per month should also be part of the yearly report.

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., C. Côté, P.L. Houtekamer and G. Pellerin, 2007: Verification of an ensemble prediction system against observations. *Monthly Weather Review*, 135:2688–2699.

World Meteorological Organization, 2008: *Recommendations for the Verification and Intercomparison of QPFS and PQPFS from Operational NWP Models* (WMO/TD-No. 1485). Revision 2. Geneva.

6. STANDARDIZED VERIFICATION OF SURFACE FIELDS

6.1 Parameters and units

Mandatory:

- 2-metre temperature K
- 10-metre wind speed m s^{-1}
- 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 K m^{-1} . For two-metre dewpoint an analogous height-correction shall be applied using a constant lapse rate of 0.0012 K m^{-1} . This approximates the dewpoint lapse rate in an atmosphere with a temperature lapse rate of 0.0065 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° and 0° 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⁻¹;
- **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 π . 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 2.2.35. 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 GDPFS centres. The goal is to provide consistent verification information on the EPS products of GDPFS-participating centres for forecasters in NMHSs and to help the GDPFS 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 2.2.34](#) 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 2.2.34](#), 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 ± 1 , ± 1.5 and ± 2 standard deviation with respect to the defined climatology;
- 500-hPa geopotential height anomalies with thresholds ± 1 , ± 1.5 and ± 2 standard deviation with respect to the defined climatology;
- 850-hPa wind speed with thresholds of 10, 15 and 25 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 ± 1 , ± 1.5 and ± 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 m s⁻¹;
- 2-metre temperature anomalies with thresholds ± 1 , ± 1.5 and ± 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° x 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 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 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 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 website(s), which is the same climatology specified in [Appendix 2.2.34](#) 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 CBS 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.

APPENDIX 2.2.36. STANDARDIZED VERIFICATION SYSTEM FOR LONG-RANGE FORECASTS

1. INTRODUCTION

This appendix describes procedures for the production and exchange of a standard set of verification scores for LRFs produced by GDPFS centres. Provision of the verification products described is mandatory for GPCs-LRF. The goal is to provide consistent verification information on the LRF 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 exchange scores via the Lead Centre(s) for SVSLRF. The Lead Centre functions, as described in 2.2.3.3, include creating and maintaining a website for displaying standardized verification products from GPCs, so that potential users will benefit from a consistent presentation of the results. 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 SVSLRF website, together with supplementary information on score calculation, the observational datasets to be used for verification and procedures for submitting scores.

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 SVSLRF 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. PARAMETERS

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 operating coupled (1-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 11) 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 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 parameters except indices shall be interpolated to a regular 2.5° x 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 SVSLRF website(s). The Lead Centre(s) for SVSLRF 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 parameters:

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 SVSLRF website(s)).

10. EXCHANGE OF SCORES

Each centre should provide scores to the Lead Centre(s) for SVSLRF and update the scores on any change of the real-time prediction system. Details of the procedure and the required format for the data exchange are provided on the Lead Centre website(s).

11. 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 SVSLRF website(s).

12. DOCUMENTATION

Participating centres shall provide to the Lead Centre(s) information on the specification of their prediction system, and promptly update the specification when there are system changes.

APPENDIX 2.2.37. 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 JCOMM-participating centres. 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 JCOMM-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 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 JCOMM-participating centres, 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. JCOMM-participating centres 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 JCOMM-participating centre 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 JCOMM-participating centres to the Lead Centre(s) for WFV on any changes to the production of exchanged forecast fields and changes in their wave forecast systems.

APPENDIX 2.2.38. 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 GDPFS-participating centres. The goal is to provide consistent verification information on the tropical cyclone forecast products of GDPFS-participating centres for forecasters in NMHSs, and to help the GDPFS-participating centres compare and improve their forecasts. The Lead Centre functions, as described in 2.2.3.5, 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 GDPFS-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 2.2.2.6.

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 GDPFS-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

Global Data-processing and Forecasting System-participating centres shall provide to the Lead Centre(s) on TCFV information on any changes to the production of the exchanged forecast fields.

ATTACHMENT 2.2.1. ADDITIONAL GLOBAL NUMERICAL LONG-RANGE PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WMO INFORMATION SYSTEM

Other long-range seasonal forecast data, products or other information, in addition to the minimum list in [Appendix 2.2.9](#), which could also be provided by GPCs on request by RCCs or NMCs (the RCCs and NMCs would adhere to conditions, if any, attached by the GPCs to these data and products):

1. **Grid-point data values:**

- Hindcast and forecast data for downscaling algorithms;
- Data for regional climate model boundary and initial conditions;
- Predicted global weekly values of SST.

2. **Information to assist in building capacity in areas such as:**

- Interpretation and use of seasonal forecast products;
 - Downscaling techniques (both statistical and dynamical);
 - Verification techniques (to be used for local verification of RCC-generated products);
 - Development of local user applications for RCC downscaled products;
 - Use and implementation of regional climate models.
-

ATTACHMENT 2.2.2. ADDITIONAL HIGHLY 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 forecasts 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 LRF 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 LRF 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 2.2.3. 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.
-

ATTACHMENT 2.2.4. ADDITIONAL INFORMATION TO BE AVAILABLE FROM THE LEAD CENTRE(S) FOR LONG-RANGE FORECAST MULTI-MODEL ENSEMBLES

As part of research and development, the Lead Centre(s) for LRFMME may make available products based on forecast and hindcast data from the subset of GPCs that are able to supply them. These products are additional information to help GPCs, RCCs and NMCs to further develop multi-model ensemble techniques and their application.

Global Producing Centres not currently able to participate in this additional exchange of data are encouraged to do so in the future.

1. Global Producing Centre digital products

Products should include global forecast fields and corresponding hindcasts for the fields listed in [Appendix 2.2.17](#), and additional variables to be agreed, for those GPCs that allow redistribution.

2. Graphical products

Graphical products should include forecast maps for each GPC displayed in common format on the Lead Centre website(s), for the variables listed in [Appendix 2.2.17](#) and for selectable regions where appropriate, showing for three-month means or accumulations:

- (a) Tercile category probabilities;
- (b) Model consistency plots for most likely tercile category;
- (c) Multi-model probabilities for probabilities for tercile categories, using various established and experimental multi-modelling methods.

These additional products will be distinguished from Lead Centre core products listed in [Appendix 2.2.17](#).

ATTACHMENT 2.2.5. USER INTERPRETATION GUIDE FOR NON-NUCLEAR ATMOSPHERIC TRANSPORT AND DISPERSION MODELLING PRODUCTS PROVIDED BY REGIONAL SPECIALIZED METEOROLOGICAL CENTRES

The designated centres will make available in Documentation on RSMC Support for Environmental Emergency Response (WMO/TD-No. 778) on the WMO Emergency Response Activities website an interpretation guide for users.

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 regular intervals and sufficient geographic map background (shorelines, country borders, rivers, and the like, and possibly roads and town names for localized events) to be able to locate precisely the trajectories and contours;
- (b) Indicate the source location with a highly visible symbol (▲, ●, ■, 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 (UTC) of release, 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 or a requested service.

Specific guidelines for concentration maps:

- (a) Adopt a maximum of five concentration contours;
- (b) A legend should indicate contours used on the chart;
- (c) Contours may be colour filled but should be clearly distinguishable from map background lines;
- (d) Indicate the following input characteristics:
 - (i) Source assumption (height, duration, pollutant type, amount released);
 - (ii) Units of concentration;
- (e) In addition, charts should specify:
 - (i) “Surface to xxx-metre layer concentrations”, where xxx depends on the pollutant type, and whether the default source is used;
 - (ii) “Results based on default initial values”;
- (f) Indicate, if possible, the location of the maximum concentration with a symbol on the map and include a legend indicating the symbol used and the maximum numerical value;

(g) Indicate the start and end date and time (UTC).

Specific guidelines for back-trajectory maps:

- (a) Distinguish each trajectory (levels chosen will depend on the specifics of the event or the request) with a symbol (▲, ●, ■, etc.) at synoptic hours (UTC);
- (b) Use solid lines (darker than map background lines) for each trajectory.

Provide a time–height (m or hPa) diagram, preferably directly below the trajectory map, to indicate vertical movement of trajectory parcels.

The RSMCs will distribute their standard products to the NMHS operational contact points by email or enable retrieval by the NMHS from an RSMC password-protected designated website. Standard products in the ITU-T T.4 format suitable for group 3 facsimile machines 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.

PART III. CURRENT DESIGNATED GLOBAL DATA-PROCESSING AND FORECASTING SYSTEM CENTRES

LOCATION OF WORLD METEOROLOGICAL CENTRES, AND REGIONAL SPECIALIZED METEOROLOGICAL CENTRES WITH GEOGRAPHICAL SPECIALIZATION OR ACTIVITY SPECIALIZATION

1. The World Meteorological Centres are located at:

- Beijing
- ECMWF
- Exeter
- Melbourne (southern hemisphere only)
- Montreal
- Moscow
- Tokyo
- Washington

2. The Regional Specialized Meteorological Centres with geographical specialization are located at:

Algiers	Khabarovsk	Pretoria
Beijing	Melbourne	Rome
Brasilia	Miami	Tashkent
Buenos Aires	Montreal	Tokyo
Cairo	Moscow	Tunis/Casablanca
Dakar	Nairobi	Washington
Darwin	New Delhi	Wellington
Exeter	Novosibirsk	
Jeddah	Offenbach	

Broadened RSMC functions:

- Offenbach – Provision of ultraviolet-index forecasts for Region VI (Europe)

3. General purpose activities

Provision of global deterministic numerical weather prediction:

RSMC Beijing
RSMC Exeter
RSMC ECMWF
RSMC Montreal
RSMC Moscow
RSMC Tokyo
RSMC Washington

Provision of limited area deterministic weather prediction:

RSMC Khabarovsk
RSMC Moscow
RSMC Novosibirsk
RSMC Offenbach
RSMC Pretoria

RSMC Rome

Provision of global ensemble numerical weather prediction:

RSMC Beijing
 RSMC Exeter
 RSMC ECMWF
 RSMC Montreal
 RSMC Moscow
 RSMC Tokyo

Provision of limited area ensemble numerical prediction:

RSMC Offenbach
 RSMC Rome

Provision of nowcasting:

RSMC Offenbach
 RSMC Tokyo

Global Producing Centres for long-range prediction:

GPC Beijing	GPC Offenbach
GPC CPTEC (Brazil)	GPC Pretoria
GPC ECMWF	GPC Seoul
GPC Exeter	GPC Tokyo
GPC Melbourne	GPC Toulouse
GPC Montreal	GPC Washington
GPC Moscow	

Acronyms not previously defined : CPTEC – Centro de Previsão de Tempo e Estudos Climáticos; ECMWF – European Centre for Medium-range Weather Forecasts.

4. **The Regional Specialized Meteorological Centres for specialized activities are the following:**

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

Provision of atmospheric sandstorm and duststorm forecasts:

- RSMC-ASDF Barcelona
- RSMC-ASDF Beijing (RA II)

Provision of atmospheric transport and dispersion modelling (for environmental emergency response and/or backtracking):

RSMC Beijing	RSMC Offenbach (backtracking only)
RSMC Exeter	RSMC Tokyo
RSMC Melbourne	RSMC Toulouse
RSMC Montreal	RSMC Vienna (backtracking only)
RSMC Obninsk	RSMC Washington

Provision of volcano watch services for international air navigation:

- RSMC Tokyo

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)
- RCC network (RA VI): De Bilt node on climate data services, Offenbach node on climate monitoring, and Toulouse and Moscow node on long-range forecasting
- RCC Network Northern Africa (RA I)
- RCC Network Southern South America (RA III)
- RCC Pune (RA II)
- RCC Tokyo (RA II)
- 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) long-range forecasting, 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, Meteorologisk Institutt (met.no)/Norway, Republic Hydrometeorological Service (RHMS)/Serbia, Swedish Meteorological and Hydrological Institute/Sweden and the Turkish State Meteorological Service (TSMS)/Turkey;
 - RA VI RCC node on climate monitoring: DWD (lead), Armstatehydromet/Armenia, Météo-France, KNMI, RHMS and TSMS;
 - RA VI RCC node on long-range forecasting: Météo-France and Roshydromet (joint leads), met.no, RHMS and TSMS;
 - Overall coordination: DWD is responsible for the overall coordination.

5. **The Regional Specialized Meteorological Centres for non-real-time coordination activities:**

Lead Centre for coordination of DNV:

- ECMWF

Lead Centre for coordination of EPS verification:

- Tokyo

Lead Centre for coordination of LRF verification:

- Melbourne and Montreal (joint centre)

Lead Centre for coordination of LRFMME:

- Seoul and Washington (joint centre)

Lead Centre for coordination of ADCP:

- Exeter
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For more information, please contact:

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