

**REVISED MANUAL ON THE GLOBAL DATA-PROCESSING AND FORECASTING SYSTEM
(WMO-No. 485)**

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PART III. GDPFS IMPLEMENTATION

INTRODUCTION

General

1. The *Manual on the Global Data-processing and Forecasting System (GDPFS)* is the single source of technical regulations for all operational data-processing and forecasting systems of WMO Members designated meteorological centres.
2. The advances in Numerical Weather Prediction (NWP) since the previous full edition of this *Manual* in 1992 have been tremendous: higher accuracy, higher resolution, longer lead-time, and a wider range of relevant applications. Consequently the emphasis in operational meteorology, hydrology and climatology has shifted towards the implementation of increasingly sophisticated and diverse numerical models and applications, for an ever-increasing variety of users.
3. The Global Data-processing and Forecasting System (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.
4. The main support for the exchange and delivery of these data – that is, GDPFS products – is the WMO Information System (WIS). One of the key features of the WIS compared to the previous GTS is the expansion of the range of centres that can connect to the system; this in turn supports growth in the range of GDPFS applications.
5. A large number of amendments to the *Manual on the GDPFS* have been adopted by Members over the past 20 years since the previous edition, and the pace at which new changes will be required in the coming years is not likely to slow down. Therefore, the World Meteorological Congress requested that this edition should be flexible enough to allow an easy incorporation of technical and organizational aspects that may arise from the development of new application areas, e.g. in relation to the GFCS.
6. In addition, noting that there are fundamental changes underway in the Basic Systems, Congress requested that this edition of the *Manual* should take account of the existing structure of the GDPFS and of its likely future evolution, such as the inclusion of all WMO operated meteorological centres that provide operational data-processing and forecasting services (including those coordinated by CBS and joint CBS-other technical commissions and/or WMO Programmes, as well as joint WMO-other international organizations centres).
7. It should be noted that this edition has been developed in accordance with quality management principles, which will ensure its sustainability as part of the WMO Quality Management Framework.

How to read this *Manual*

8. The *Manual* consists of three Parts, as follows:
 - (a) Part I. Outline of the WMO GDPFS – it presents the overall purpose of the GDPFS, its organization and the general characteristics of the various activities to be performed;
 - (b) Part II. Specification of GDPFS activities – it gives detailed information on the various activities: mandatory functions including production, verification and documentation, and additional recommended functions and products. It also specifies overall requirements applicable to all types of activities, regarding dissemination, verification, training, etc.;
 - (c) Part III. GDPFS implementation – it presents the status of implementation of the GDPFS from the user's point of view: table of performed activities with indication of the participating centres, as well as from the producer's point of view: table of GDPFS centres with indication of the performed activities.

9. The reader seeking general information on the 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.

10. 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, technique, and user requirements, will continue to induce developments requiring frequent changes to Parts II and III.

11. 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 is done in Part II, item 2.2, through Tables under "Note" labelled "Responsibility" (cf. example hereafter), where:

- (a) The three lines under "Changes to activity specification" indicate the team(s) and bodies in charge of preparing specification updates, approving them, and deciding to update the *Manual* accordingly;
- (b) The two lines 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 lines under "Compliance" indicate the team(s) and bodies in charge of ensuring that the designated GDPFS centres remain compliant with the activity specification.

RESPONSIBILITY			
<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	

12. The following procedure is applied for the incorporation of new types of GDPFS centres into this *Manual*:

- (1) Relevant technical commission or programme expert team to develop the criteria/functions for new type of centres, including the list of mandatory products to be made available in the context of the GDPFS;
- (2) The criteria/functions for new type of centres to be endorsed by the relevant technical commission management group or programme steering committee, and submitted to CBS through its president;
- (3) The president of the commission responsible for maintaining this Manual decides on an expert team of that commission to be responsible for reviewing the proposal and applies the standard procedure for amendments as defined in the General Provisions

PART I. OUTLINE OF THE WMO GLOBAL DATA PROCESSING AND FORECASTING SYSTEM (GDPFS)

1.1 PURPOSE AND SUPPORTED ACTIVITIES

1.1.1 General description

1.1.1.1 The GDPFS shall be the world-wide 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 GDPFS 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 the 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 minimizing duplication.

1.1.1.4 A key objective of the GDPFS should be to facilitate cooperation and the exchange of information, thereby also contributing to capacity development amongst 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 GDPFS

1.1.2.1 Through the 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 GDPFS shall be organized as a three-tier system of activities as follows:

Note: A distinction is made between general purpose activities and specialized activities: general purpose activities are those which encompass essential data processing required for a wide range of end-usage, while specialized activities are those which 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 the GDPFS. The list of GDPFS activities is given in this paragraph; however associated commitments and other appropriate details are specified in Part II.

- (a) **General purpose activities:**
- Global deterministic numerical weather prediction
 - Limited area deterministic numerical weather prediction
 - Global ensemble numerical weather prediction
 - Limited area ensemble numerical weather prediction
 - 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
 - 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 sand and dust storm forecasts
 - Volcanic watch services for international air navigation
 - Marine meteorological services
 - Marine environmental emergency response
- (c) **Non real-time coordination activities:**
- Coordination of deterministic numerical weather prediction (NWP) verification
 - Coordination of ensemble prediction system (EPS) verification
 - Coordination of long-range forecast (LRF) verification
 - Coordination of wave forecast verification
 - Coordination of tropical cyclone forecast verification
 - Coordination of observation monitoring

Note: Other activities, including those related to hydrology, agriculture, Polar Regions, storm surge prediction, and space weather would be developed in future.

1.2 GDPFS 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 GDPFS 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 Centre (NMC)

1.2.2.1 A National Meteorological Centre (NMC) shall carry out functions to meet the national and international requirements of the Member concerned.

Note: In order to fulfill their national and international obligations, National Meteorological Centres need to be adequately staffed and equipped to enable it to play its part in the World Weather Watch (WWW) system.

1.2.2.2 The functions of a 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 a NMC should include the production of:

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

1.2.3 Regional Specialized Meteorological Centre (RSMC)

1.2.3.1 A Member, having accepted the responsibility for providing a Regional Specialized Meteorological Centre (RSMC), shall arrange for this centre to carry out operationally at least one of the General Purpose or Specialized activities listed in paragraph 1.1.2.2, which specified standards are described in Part II.

1.2.3.2 An RSMC for General Purpose activities should provide products which an RSMC for at least one of the Specialized activities consider necessary and make request to produce.

Notes:

1. The designation as RSMC does not preclude the use of other names as defined in other contexts, e.g. Global Producing Centre for Long-Range Forecasts (GPCLRFs).
2. An RSMC that leads a coordination activity is also referred as Lead Centre.

1.2.4 World Meteorological Centre (WMC)

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

- (a) **Global deterministic numerical weather prediction;**
- (b) **Global ensemble numerical weather prediction; and,**
- (c) **Global numerical long-range prediction.**

1.2.5 RSMC Network

1.2.5.1 An RSMC Network (that is an association of RSMCs participating in an identified activity of the 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's products.

1.2.6 Designation process

1.2.6.1 Each Member shall designate a National Meteorological Centre.

1.2.6.2 World Meteorological Centres, Regional Specialized Meteorological Centres 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/function (or activities/functions) to be carried out.

1.2.6.3 Requests for designation as a World Meteorological Centre or Regional Specialized Meteorological Centre shall be put forward by the Permanent Representative of the country of the candidate centre, or in the case of international organizations by the Permanent Representative of the country where the candidate centre is located or the president of the relevant regional association(s).

1.2.6.4 Requests for designation as an RSMC Network shall be put forward by the president of the relevant regional association, or in the case of Networks established across two or more RAs, jointly by their presidents.

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

1.2.6.5 Requests for designation shall be addressed to the WMO Secretariat, who will forward them to the relevant constituent bodies as indicated in the tables labeled "Responsibility" given for each activity in Part II, item 2 of the 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 regional association(s) and technical commission(s) may be required before designation by Congress or EC, as specified in Part II, section 2, of the Manual.

1.3 COORDINATION WITH OTHER SYSTEMS OR PROGRAMMES

1.3.1 The GDPFS 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

- (1) The specific requirements defined by the relevant structure; and
- (2) The general GDPFS criteria regarding operational quality and reliability, verification, documentation and compliance (described in Part II of this 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

[Insert the current APPENDIX I-4, with the following change:

7.1 Annual to decadal climate ~~variability~~-prediction ...]

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PART II. SPECIFICATIONS OF GDPFS ACTIVITIES

2.1 OVERALL REQUIREMENTS AND STANDARDS

2.1.1 Quality control of incoming observations

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

2.1.1.2 WMCs 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 which are used in the real-time operations of the GDPFS;**
- (b) In non-real-time, to protect and improve the quality and integrity of observations destined for storage and retrieval within the 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 the GDPFS should adhere to the 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 (WIGOS)* (WMO-No. 1160), item 2.4.3.

2.1.1.4 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, and for each satellite by identifier, and for various geographic areas and levels in the atmosphere.

2.1.1.5 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, etc.) 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 GDPFS Centres shall be connected to the WIS to ensure suitable exchange of information with other Centres.

2.1.2.2 WMCs and RSMCs shall describe their required products and services according to WMO metadata standards and make them available to other GDPFS Centres through the WMO Information System in a timely manner for operational use.

Note: Details on the 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 the GDPFS include long-term (i.e. around 10 years) storage of observations, products and verification results for operational and research use.

2.1.3.1 WMCs and RSMCs shall operate an archiving and retrieval system to serve the needs of their continual improvement process; this process should 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 / performance of GDPFS 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 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 shall be provided by participating Centres. Centres should also provide, if possible, additional statistics as recommended in Appendix 2.2.34.

2.1.4.2 Lead Centres for verification shall play an essential role in the coordination of verification and have responsibility for maintaining websites containing verification results and relevant guidance (cf. in Part II, section 2.2.3), ensuring that users benefit from a consistent presentation of the results.

2.1.4.3 GDPFS Centres receiving RSMC products via the WIS should carry out verification over appropriate areas using the standardized measures listed in Appendixes 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 WMCs and RSMCs shall make available, on a publically available website, documentation on the technical characteristics of their operational system and on the products it delivers. RSMCs shall ensure that the information provided is kept current by updating it as required after every significant change to their operational system. The mandatory (minimum) information to be provided is specified for every activity separately in the following section 2.2.

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

Note: Addresses of WMCs and RSMC websites containing such system documentation are in Part III section 2 of this Manual. *[In development]*

2.1.6 Training

2.1.6.1 WMCs 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 WMCs and RSMCs may be 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 WMCs and RSMCs shall provide information about the current implementation of their system. This information should be available on the same website as that used for providing system and products documentation and described in section 2.1.5.

2.1.7.2 WMCs 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 WMCs and RSMCs that have a mandate of chart-based analysis shall maintain standardized weather forecasting process, 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 XXX of the *Manual on Codes* (WMO-No. 306). *[Appendix II-4 of the current Manual on the GDPFS to be incorporated into the Manual on Codes]*

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

[Insert Part II, paragraphs 3.1.1 to 3.1.3 of the current Manual on the GDPFS]

2.1.8.3.2 Preparation of upper-air charts

[Insert Part II, paragraph 3.2.1 of the current Manual on the GDPFS, and replace “Members” by “GDPFS Centres”]

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 its network and as agreed by the regional associations.

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

[Insert Part II, paragraphs 4.1.1 to 4.1.3 of the current Manual on the GDPFS]

2.1.8.4.2 Symbols used on meteorological charts

[Insert Part II, paragraphs 4.2.1 to 4.2.2 of the current Manual on the GDPFS, and replace Appendix II-4 of the current Manual on the GDPFS by XXX of the Manual on Codes]

2.1.8.4.3 Construction of aerological diagrams

[Insert Part II, paragraphs 4.3.1 to 4.3.2 of the current Manual on the GDPFS]

2.1.8.4.4 Preparation of charts and diagrams for facsimile transmission

[Insert Part II, paragraphs 4.4.1 to 4.4.6 of the current Manual on the GDPFS, and replace Appendix II-4 of the current Manual on the GDPFS by XXX of the Manual on Codes]

APPENDIX 2.1.1. TECHNIQUES FOR MONITORING THE QUALITY OF OBSERVATIONS

1. Compilation of statistics on the difference between observed values and the analysis and first-guess field;
2. Compilation of statistics on observations which fail the routine quality-control checks;
3. Examination of time series of observations from a particular station (particularly useful in data-sparse areas);
4. 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;
5. For surface stations which report both mean sea-level pressure and station-level pressure, compilation of statistics on differences between reported mean sea-level pressure and mean sea-level pressure recomputed from reported station-level pressure and temperature and published values of station elevation;
6. Compilation of co-location statistics.

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

[Insert ATTACHMENT II.9 of the current Manual on the GDPFS]

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

2.2.1.1.1 Centres conducting global deterministic numerical weather prediction (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 the 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 Deterministic NWP Verification;
- (e) Make available on a website up-to-date information on the characteristics of its global numerical weather prediction system. 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 *Manual* related to global deterministic NWP are specified in the Table below.

RESPONSIBILITY			
<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

2.2.1.2.1 Centres conducting limited area deterministic numerical weather prediction (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 the 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 its limited area numerical weather prediction system. 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 *Manual* related to limited area deterministic NWP are specified in the Table below.

RESPONSIBILITY			
<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

2.2.1.3.1 Centres conducting global ensemble numerical weather prediction (NWP) shall:

- (a) **Produce global ensemble forecast fields of basic and derived atmospheric parameters;**
- (b) **Make available on the 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 its global ensemble numerical weather prediction system. 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 *Manual* related to global ensemble NWP are specified in the Table below.

RESPONSIBILITY			
<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

2.2.1.4.1 Centres conducting limited area ensemble numerical weather prediction (NWP) shall:

- (a) Produce limited area ensemble forecast fields of basic and derived atmospheric parameters;
- (b) Make available on the 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 its limited area ensemble numerical weather prediction system. 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 *Manual* related to limited area ensemble NWP are specified in the Table below.

RESPONSIBILITY			
<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 (known as Global Producing Centres for Long-Range Forecasts (GPCLRFs)) shall:

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

- (a) Generate seasonal forecast products with global coverage;
- (b) Make available on the WIS a range of these products. Mandatory 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 Standardized Verification System for Long-Range Forecast and on a website;
- (d) Make available on a website up-to-date information on the characteristics of its global seasonal numerical prediction system. 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, the following activities are highly recommended:

- (a) Provide forecast output to the LC-LRFMME, as detailed in Appendix 2.2.17 (section 1);
- (b) Make available on the WIS the highly recommended products listed in Appendix 2.2.9;
- (c) Make available, on request by 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 *Manual* related to global numerical long-range prediction are specified in the Table below.

RESPONSIBILITY			
<i>CHANGES TO ACTIVITY SPECIFICATION</i>			
To be proposed by:	CBS/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	

2.2.1.6 Numerical ocean wave prediction

2.2.1.6.1 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 the 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 Wave Forecast Verification;
- (e) Make available on a website up-to-date information on the characteristics of its global numerical ocean wave prediction system. 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 the Table below.

RESPONSIBILITY			
<i>CHANGES TO ACTIVITY SPECIFICATION</i>			
To be proposed by:	JCOMM/ETWCH		
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/ETWCH		
To be reported to:	CBS	JCOMM	

2.2.1.7 Global Numerical Ocean Prediction

2.2.1.7.1 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 the 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 its global numerical ocean prediction system. 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 *Manual* related to global numerical ocean prediction are specified in the Table below.

RESPONSIBILITY			
<i>CHANGES TO ACTIVITY SPECIFICATION</i>			
To be proposed by:	JCOMM/ETOOFS		
To be recommended by:	CBS	JCOMM	
To be decided by:	EC/Congress		
DESIGNATION			
To be recommended by:	RA	CBS	JCOMM
To be decided by:	EC/Congress		
COMPLIANCE			
To be monitored by:	JCOMM/ETOOFS		
To be reported to:	CBS	JCOMM	

2.2.1.8 Nowcasting

2.2.1.8.1 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 in several hours ahead (~~0-6 hours~~) over their area of interest or parts of that area;
- (b) Provide access to this service to 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 the system. 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 *Manual* related to nowcasting are specified in the Table below.

RESPONSIBILITY			
<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

2.2.2.1.1 Centres conducting regional climate prediction and monitoring (known as Regional Climate Centres (RCCs)) shall:

- (a) **Operational activities for Long Range Forecasting (LRF), both dynamical and statistical, within the range of a 1-month to 2-year timescale, based on regional needs:**
- Interpret and assess relevant LRF products from Global Producing Centres for Long-Range Forecasts (GPCs), make use of the products from the Lead Centre for Standard Verification for LRF (refer to 2.2.3.3), distribute relevant information to users, and provide feedback to GPCs (guidelines are given in Attachment 2.2.3);
 - Generate regional and sub-regional tailored products relevant to user needs, including seasonal outlooks;
 - Generate “consensus” statement 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) **Operational activities for climate monitoring:**
- Perform climate diagnostics including analysis 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) **Operational data services, to support operational LRF and climate monitoring;**

- **Develop quality controlled regional climate datasets, gridded where applicable;**
 - **Provide climate database and archiving services;**
- (d) 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 Regional Association, and will be referred to as RCC users.

2. Details on 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, 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 the Table below.

RESPONSIBILITY			
<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	

2.2.2.2 Coordination of Multi-Model Ensemble Prediction for Long-Range Forecasts

2.2.2.2.1 Centres conducting coordination of multi-model ensemble prediction for long-range forecasts (known as Lead Centre for Long-Range Forecast of Multi-Model Ensemble prediction (LC-LRFMME)) shall:

- (a) Collect an agreed set of forecast data from RSMCs participating in seasonal numerical prediction under activity 2.2.1.5 (GPCs);**
- (b) Make available on a website appropriate minimum (Appendix 2.2.17) and additional (Attachment 2.2.4) products and GPC's 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 MME forecasts;**
- (e) Maintain a repository of documentation for the system configuration of all GPC systems;**
- (f) Verify their products using the 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 MME techniques and provide guidance and support on MME techniques to GPCs, RCCs and NMHSs.**

Note: The bodies in charge of managing the information contained in the *Manual* related to coordination of multi-model ensemble prediction for long-range forecasts are specified in the Table below.

RESPONSIBILITY			
<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 (ADCP)

2.2.2.3.1 Centres conducting annual to decadal climate prediction (ADCP) (known as Global Producing Centres for annual to decadal climate prediction (GPCs-ADCP)) shall:

- (a) **Prepare, with at least annual frequency, global forecast fields of parameters relevant to multi-annual to decadal prediction;**
- (b) **Prepare verification statistics as defined in Appendix 2.2.21;**
- (c) **Provide an agreed set of forecast and hindcast variables (as per Appendices 2.2.20 and 2.2.21) to the Lead Centre for annual to decadal climate prediction (LC-ADCP);**
- (d) **Make available on a website up-to-date information on the characteristics of its global decadal prediction system.**

Notes:

1. Non-designated centres with capacity to provide the minimum requirement may also contribute ADCP to the LC-ADCP;
2. Centres who wish to make available their products worldwide, may use the WIS as the a dissemination platform;
3. The bodies in charge of managing the information contained in the *Manual* related to coordination of multi-annual to decadal prediction are specified in the Table below.

RESPONSIBILITY			
<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	
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2.2.2.4 Coordination of annual to decadal climate prediction

2.2.2.4.1 Centres conducting coordination of annual to decadal climate prediction (known as Lead Centres for annual to decadal climate prediction (LC-ADCP)) shall:

- (a) **Select a group of modelling centres to contribute to the LC-ADCP (the “contributing centres”) that meet the GPC-ADCP designation criteria and the approval by IPET-OPSLs; 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 (Appendix 2.2.20) from the contributing centres;**
- (d) **Make available (on a password protected website) agreed forecast products in standard format, including multi-model ensemble (MME) products (Appendix 2.2.20);**
- (e) **Make available on the website agreed hindcast verification products in standard format, including verification of the MME (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 MME;**
- (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 WCRP 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 the LC-ADCP should follow the rules as detailed in Appendix 2.2.19.

Note: The bodies in charge of managing the information contained in the *Manual* related to coordination of near-term climate prediction are specified in the Table below.

RESPONSIBILITY			
<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 Regional Centre(s) and associated National Meteorological Centres (NMCs).

2.2.2.5.1 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, the centre 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 (NMCs) associated in this activity shall:

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

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

RESPONSIBILITY			
<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	

2.2.2.6 Tropical Cyclone Forecasting, including marine-related hazards

Note: This activity includes a single network of a Regional Centre and associated National Meteorological Centres (NMCs) within every Tropical Cyclone Regional Body.

2.2.2.6.1 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 annual basis). Issue such data to the tropical cyclone community including the International Best Track Archive for Climate Stewardship;**
- (g) **Promote research and development (R&D) and training in tropical cyclone analysis, forecasting and warning techniques.**

2.2.2.6.2 National Meteorological Centres (NMCs) 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 TC RSMCs and TCWC Darwin, which are designated as a Tropical Cyclone Advisory Centre (TCAC) by regional air navigation agreement within the framework of the tropical cyclone watch of ICAO, shall issue Tropical Cyclone Advisories for aviation in accordance with the provisions made in ICAO Annex 3- Meteorological Service for International Air Navigation/WMO Technical Regulations [C3.1]. SIGMET information concerning tropical cyclones shall be issued by Meteorological Watch Offices (MWO) for the concerned flight information region and should be based on the tropical cyclone advisory information issued by the TCACs.

2.2.2.6.4 Members holding Metareas of their responsibility under the Global Maritime Distress and Safety System (GMDSS) protocols established by the International Convention of Safety Of Life At Sea (SOLAS) 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 *Manual* related to tropical cyclone forecasting are specified in the Table below.

RESPONSIBILITY			
<i>CHANGES TO ACTIVITY SPECIFICATION</i>			
To be proposed by:	Technical Coordination Meeting		
To be recommended by:	CBS	Regional TC Committee	
To be decided by:	EC/Congress		
<i>CENTRES DESIGNATION</i>			
To be recommended by:	CBS	Regional TC 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

2.2.2.7.1 Centres conducting nuclear environmental emergency response shall:

- (a) **Contribute to support for WMO Members and International Atomic Energy Agency (IAEA):**
- (1) **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 support for nuclear emergency response is described in Appendix 2.2.22;**
 - (2) **Within two to three hours of reception of a request, make a range of products available to the NMHS operational contact point² and/or the IAEA on the WIS³. The minimum list, including parameters, forecast range, time steps and frequency, is given in Appendix 2.2.23;**
 - (3) **Use agreed standard emission source parameters for atmospheric transport modelling when source information is not available. Default source parameters are given in Appendix 2.2.24;**
 - (4) **Make available up-to-date information on the characteristics of their atmospheric transport modelling (ATM) systems (minimum information to be provided is given in Appendix 2.2.25) and a user interpretation guide for ATM products.**

Note: The forms to request WMO support by a Delegated Authority and by the IAEA are in Appendix 2.2.26.

- (b) **Contribute to support for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO)**
- (1) **Prepare, on request from CTBTO, relevant atmospheric backtracking products**
 - (2) **Make the requested products available to CTBTO.**

Note: Arrangements for activation and product specifications are in Appendix 2.2.27.

Note: The bodies in charge of managing the information contained in the *Manual* related to nuclear environmental emergency response are specified in the Table below.

RESPONSIBILITY			
<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	

2.2.2.8 Non-nuclear environmental emergency response

2.2.2.8.1 Centres conducting non-nuclear emergency response shall:

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

² Designated by the Permanent Representative

³ Password protected dedicated website

- (a) Prepare on request, from an authorized person⁴, atmospheric transport and dispersion 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;
- (b) As soon as possible, but usually within 2 hours of a request from an authorized person¹, make available a range of products to the NMHS operational contact point⁵ by e-mail 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 its atmospheric transport and dispersion modelling (ATDM) system (minimum information to be provided is given in Appendix 2.2.31) and a users interpretation guide for ATDM products (Attachment 2.2.5).

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

RESPONSIBILITY CHANGES TO ACTIVITY SPECIFICATION			
To be proposed by:	CBS/ET-ERA		
To be recommended by:	CBS		
To be decided by:	EC/Congress		
DESIGNATION			
To be recommended by:	CBS		
To be decided by:	EC/Congress		
COMPLIANCE			
To be monitored by:	CBS/ET-ERA		
To be reported to:	CBS/ICT-DPFS	CBS	

2.2.2.9 Atmospheric sand and dust storm forecasting

2.2.2.9.1 Centres conducting atmospheric sand and dust storm forecasts shall:

- (a) Operate a numerical weather prediction model incorporating parameterizations of all the major phases of the atmospheric dust cycle;
- (b) Prepare limited area analyses of variables relevant to atmospheric sand and dust storms;
- (c) Prepare limited area forecast fields of variables relevant to atmospheric sand and dust storms;
- (d) Make available on the 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.

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

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.

RESPONSIBILITY			
<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	

(*) The detailed designation procedure of RSMC ASDF is referred to Chapter 7 of the SDS-WAS Science Implementation Plan.

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 the International Civil Aviation Organization (ICAO). This designation is consulted with WMO. Service provision arrangements in this respect and those for volcano observatories are described in WMO *Technical Regulations* (WMO-No. 49), Volume II, sections 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).

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).

2.2.3 Non-real-time coordination activities

2.2.3.1 Coordination of deterministic NWP verification

2.2.3.1.1 Centres conducting coordination of deterministic NWP verification (known as Lead Centre for deterministic NWP verification) 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 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 centre if data is 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, changes in additional statistics) and changes in their NWP models;
- (e) Provide access to standard data sets needed to perform the standard verification, including climatology and lists of observations and keep this up to date according to CBS recommendation;

(f) Provide on its (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 The Lead Centre(s) for deterministic NWP verification may 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 coordination of deterministic NWP verification are specified in the Table below.

RESPONSIBILITY			
<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 EPS verification

2.2.3.2.1 Centres conducting coordination of EPS verification (known as Lead Centre for EPS verification) shall:

- (a) Provide the facility for the GDPFS Centres producing global EPS to automatically deposit their standardized verification statistics as defined in Appendix 2.2.35, and 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 centre if data is missing or suspect;**
- (d) Provide access to standard data sets needed to perform the standard verification, including climatology and lists of specified observation sites and keep this up to date according to CBS recommendation;**
- (e) Provide on its (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.**

2.2.3.2.2 The Lead Centre(s) for EPS verification may 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 coordination of EPS verification are specified in the Table below.

RESPONSIBILITY			
<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 LRF verification

2.2.3.3.1 Centres conducting coordination of LRF verification (known as Lead Centre for Standardized Verification System for Long-Range Forecast (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 to 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 centre if data is missing or suspect;**
- (d) **Provide on its (their) website(s):**
 - **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 data sets at an appropriate horizontal resolution.**

2.2.3.3.2 Additionally, these Lead Centre(s) should:

- (a) Liaise with other groups involved in verification (e.g. WGSIP, CCI, etc.) on the effectiveness of the current standardized verification system (SVS) and identify areas for future development and improvement;

- (b) Provide periodic reports to CBS and other relevant Commissions assessing the effectiveness of the SVS.

Note: Detailed tasks for the Lead Centres for the SVSLRF, and verification scores, are listed in Appendix 2.2.36.

Note: The bodies in charge of managing the information contained in the *Manual* related to coordination of LRF verification are specified in the Table below.

RESPONSIBILITY			
<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:	ET-OPSLS		
To be reported to:	CBS/ICT-DPFS	CBS	

2.2.3.4 Coordination of wave forecast verification

2.2.3.4.1 Centres conducting coordination of wave forecast verification (known as Lead Centres for wave forecast verification (LC-WFV)) shall:

- (a) Provide the facility for JCOMM participating Centres producing global or ocean basin scale wave forecasts to automatically deposit their gridded forecast fields as defined in Appendix 37, and have access to the verification statistics computed for these fields;
- (b) Maintain an archive of the verification statistics to allow the generation and display of trends in performance;
- (c) Monitor the received forecast fields and consult with the relevant JCOMM participating Centre 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 data sets used to perform the standard verification, including lists of observations and keep this up to date according to JCOMM recommendation;
- (f) Provide on its (their) website(s):
 - 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) may 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 wave forecast verification are specified in the Table below.

RESPONSIBILITY			
<i>CHANGES TO ACTIVITY SPECIFICATION</i>			
To be proposed by:	CBS/ET-OWFPS	JCOMM-ETWCH	
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 Centres conducting coordination of tropical cyclone forecast verification (known as Lead Centres for tropical cyclone forecast verification (LC-TCFV)) shall:

- (a) Provide the facility for GDPFS Centres, including RSMCs participating in global deterministic numerical weather prediction defined in 2.2.1.1, who produce tropical cyclone forecasts, to deposit their gridded forecast fields as defined in Appendix 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 participating GDPFS Centre if data are missing or suspect;
- (d) Provide access to the data sets 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 its (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 participating GDPFS 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) may 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 tropical cyclone forecast verification are specified in the Table below.

RESPONSIBILITY			
<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	

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 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 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 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 should be rigorous so as to identify only those stations where they are confident that the observations are of consistently low quality. It should state which elements of the observation are considered to be of low quality and provide as much information as possible identifying the problem. The list should be passed on to the participating centres and to the WMO Secretariat.

2.2.3.6.5 Where focal points have not been identified, the Secretariat should notify Members of agencies responsible for the observations which 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 action 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 centres for data-quality monitoring are given in the *Guide to the Global Observing System* (WMO-No. 488), Part VII, paragraph 7.2.2.1.

2. WIGOS Quality Management System is being developed to incorporate observational quality monitoring process described above. The coordination will be defined in this section in due course.

**APPENDIX 2.2.1. MANDATORY AND HIGHLY RECOMMENDED GLOBAL DETERMINISTIC
NWP PRODUCTS TO BE MADE AVAILABLE ON THE WIS**

Parameter	Level	Resolution	Forecast range	Time steps	Frequency
Geopotential height	850/500/250	1.5° x 1.5°	Up to 3d / Beyond 3d up to 6d	Every 6h / Every 12h	Twice a day (00 and 12 UTC) / Once a day
Temperature	850/500/250				
u,v	925/850/700/500/250				
Relative humidity	850/700				
Divergence, vorticity	925/700/250				
MSL pressure	Surface				
2m Temp 10m u, 10m v Total precipitation	Surface				

Additional recommended products:

- Tropical storm tracks (lat/lon locations, maximum sustained wind speed, MSLP)

APPENDIX 2.2.2. CHARACTERISTICS OF GLOBAL DETERMINISTIC NWP 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 an ocean, waves, 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 parametrized?

What kind of Large scale dynamics is in use (e.g. gridpoint semi-Lagrangian)?

Hydrostatic or Nonhydrostatic?

What kind of boundary layer parametrization is in use?

What kind of convection parametrization 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 NWP PRODUCTS TO BE MADE AVAILABLE ON THE
WIS**

Parameter	Level	Resolution	Forecast range	Time steps	Frequency
Geopotential height	925/850/700/500/250	0.5° x 0.5°	1d	Every 6h	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				
MSL pressure	Surface				
2m Temp 10m u, 10m v Total precipitation	Surface				

Additional recommended products:

- Vertical velocity
- Cloud cover
- Tropical storm tracks (lat/lon locations, maximum sustained wind speed, MSLP)

APPENDIX 2.2.4. CHARACTERISTICS OF LIMITED AREA DETERMINISTIC NWP 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 an ocean, waves, 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 parametrized?

What kind of Large scale dynamics is in use (e.g. gridpoint semi-Lagrangian)?

Hydrostatic or Nonhydrostatic?

What kind of boundary layer parametrization is in use?

What kind of convection parametrization 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 EPS PRODUCTS
TO BE MADE AVAILABLE ON THE WIS**

Parameter	Level	Thresholds	Resolution (lat/lon grid)	Forecast range	Time steps	Frequency
Probability of Precipitation	Surface	1, 5, 10, 25, 50 mm and 100 mm/24 hours	1.5° x 1.5°	10d (or the maximum range if less)	Every 12h	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 MSL pressure	Surface					
Ensemble mean + spread (standard deviation) of wind speed	850/250					

Additional 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 (lat/long locations, maximum sustained wind speed, MSLP from EPS members)

APPENDIX 2.2.6. CHARACTERISTICS OF GLOBAL EPS

1. Ensemble System

Ensemble name (version)

Date of implementation

2. Configuration of the EPS

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? (Y/N)

Number of perturbed ensemble members (excluding control)

Is model coupled to an ocean, waves, 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? (Y/N)

(If Yes, which observation types are perturbed?)

Perturbations added to control analysis or derived directly from ensemble analysis

Perturbations in +/- pairs? (Y/N)

Additional comments

4. Model Uncertainty Perturbations

Is model physics perturbed? If yes, 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 yes, briefly describe method(s)

Are the above model uncertainty perturbations applied to the control forecast?

Additional comments

5. Surface Boundary Perturbations

Perturbations to sea-surface temperature? If yes, briefly describe method(s)

Perturbations to soil moisture? If yes, briefly describe method(s)

Perturbations to surface wind stress or roughness? If yes, briefly describe method(s)

Any other surface perturbations? If yes, 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 parametrized?

What kind of Large scale dynamics is in use (e.g. gridpoint semi-Lagrangian)? Hydrostatic or nonhydrostatic?

What kind of boundary layer parametrization is in use?

What kind of convection parametrization 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 EPS PRODUCTS TO BE MADE AVAILABLE ON THE WIS

Parameter	Level	Thresholds	Resolution (lat/lon grid)	Forecast range	Time steps	Frequency
Probability of Precipitation	Surface	1, 5, 10, 25, 50 mm and 100 mm/24 hours	0.5° x 0.5°	2d (or the maximum range if less)	Every 6h	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 MSL pressure	Surface					
Ensemble mean + spread (standard deviation) of wind speed	850/250					

Additional 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 (lat/long locations, maximum sustained wind speed, MSLP from EPS members)

APPENDIX 2.2.8. CHARACTERISTICS OF LIMITED AREA EPS

1. Ensemble System

Ensemble name (version)

Date of implementation

2. Configuration of the EPS

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? (Y/N)

Number of perturbed ensemble members (excluding control)

Is model coupled to an ocean, waves, 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? (Y/N)

(If Yes, which observation types are perturbed?)

Perturbations added to control analysis or derived directly from ensemble analysis

Perturbations in +/- pairs? (Y/N)

Additional comments

4. Model Uncertainty Perturbations

Is model physics perturbed? If yes, 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 yes, briefly describe method(s)

Are the above model uncertainty perturbations applied to the control forecast?

Additional comments

5. Surface Boundary Perturbations

Perturbations to sea-surface temperature? If yes, briefly describe method(s).

Perturbations to soil moisture? If yes, briefly describe method(s)

Perturbations to surface wind stress or roughness? If yes, briefly describe method(s)

Any other surface perturbations? If yes, 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 parametrized?

What kind of Large scale dynamics is in use (e.g. gridpoint semi-Lagrangian)?

Hydrostatic or nonhydrostatic?

What kind of boundary layer parametrization is in use?

What kind of convection parametrization is in use?

What cloud/microphysics scheme is in use?

Other relevant details

7. Regional Ensemble specifics

Regional domain descriptor (lat/long 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 WIS

GPC mandatory products (maps)

Parameter	Coverage	Forecast range or Lead Time	Temporal Resolution	Output Type	Issuance Frequency
2-meter Temperature	Global	Any forecast range (lead time) between 0 and 4 months	Averages over 1-month or longer periods (seasons)	(1) Ensemble mean anomaly	Monthly
Sea Surface Temperature	Global oceans			(2) Probabilities for tercile forecast categories (where applicable)	
Total Precipitation	Global			(3) Probabilities for extremes <i>(Note: highly recommended, not mandatory)</i>	

GPC highly recommended products (maps)

Parameter	Coverage	Forecast range or Lead Time	Temporal Resolution	Output Type	Issuance Frequency
500 hPa Height	Global	Any forecast range (lead time) between 0 and 4 months	Averages over 1-month or longer periods (seasons)	(1) Ensemble mean anomaly	Monthly
Mean Sea Level Pressure				(2) Probabilities for tercile forecast categories	
850 hPa Temperature					

GPC highly recommended products (SST indices)

Index	Description	Coordinates
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	Southeastern 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 (e.g. forecast maps and diagrams). Note: GPCs are encouraged to make available the retrospective forecast (hindcast) and forecast fields underlying the products. GRIB-2 format should be used for fields posted on FTP sites or disseminated through the WIS. GPC are also encouraged to provide hindcast and forecast fields, as listed in Attachment 2.2.4 (section 1), to the LC-LRFMME.
3. Definition of lead time: for example, a three-monthly forecast issued on 31 December has a lead time of 0 months for a January to March seasonal mean forecast, and a lead time of 1 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 shall be provided in accordance with Appendix 2.2.23.

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 (Y/N)
Whether the system is a Tier-2 forecast system (Y/N)
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 11. MANDATORY AND HIGHLY RECOMMENDED NUMERICAL OCEAN WAVE PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WIS

Parameter	Level	Minimum Resolution	Forecast range	Time steps	Frequency
Significant Wave Height	surface	0.5° x 0.5°	Up to 3d / Beyond 3d up to 7d	Every 3h / Every 6h	Twice a day
Peak Wave Period and Mean Zero-upcrossing Period	surface				
Prevailing Direction - Mean Wave Direction and/or - Principle Wave Direction	surface				

Additional recommended products:

- U and V component of 10 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, rogue wave potential

APPENDIX 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 an ocean, atmosphere, 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 e.g., 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 data base 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 13. MANDATORY AND HIGHLY RECOMMENDED GLOBAL NUMERICAL OCEAN PREDICTION PRODUCTS TO BE MADE AVAILABLE ON THE WIS

Parameter	Level	Minimum Resolution	Forecast range	Minimum Time steps	Frequency
Sea surface elevation	Surface	0.5 ° x 0.5 °	Up to 6d	Every 24h	Once a day
Sea surface Temperature	Surface (mixed layer)				
Surface u, v	Surface				
Sea surface salinity	Surface				
U, V	Depth TBD				
Temperature	10/50/100/250/500 (m)				
Mixed layer depth					

Additional recommended products:

- None

APPENDIX 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 an atmosphere, waves, 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 e.g., river discharge ? If yes, briefly describe method(s).
Additional comments
5. Other details of model
What kind of mixing scheme is in use?
How are radiations parametrized?
What kind of Large scale dynamics is in use (e.g. gridpoint semi-Lagrangian)? Hydrostatic?
Data assimilation scheme?
QC scheme?
Verification approach?
Other relevant details?
6. Further Information
Operational contact point
URLs for system documentation
URL for list of products

APPENDIX 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...*)

Additional comments

3. Input data

(observations, analyses, numerical forecasts, ...)

Additional comments

4. NWP

Refer to Appendices related to the characteristics of Global Deterministic and Limited Area NWP systems, and characteristics of Global and Limited Area EPS (no need to repeat system description if available under those sections).

5. Output data (Product)

6. Data visualization system

7. Verification system

(Verified parameters, performance matrix, ...)

8. Further Information

Operational contact point

URLs for system documentation

URL for list of products

APPENDIX 2.2.16. RCC mandatory functions

[Insert APPENDIX II-11 of the current Manual on the GDPFS, and replace reference to Attachment II.13 by Attachment 2.2.2]

APPENDIX 2.2.17. Minimum information to be available from LCs-LRFMME

[Insert section 3. of the ATTACHMENT II.12 of the current Manual on the GDPFS, and replace reference to paragraph 3.1 by Appendix 2.2.12]

APPENDIX 2.2.18. Access to GPC data and visualization products held by the Lead Centres for LRFMME

[Insert section 6. of the ATTACHMENT II.12 of the current Manual on the GDPFS]

APPENDIX 19: ACCESS TO DATA AND VISUALIZATION PRODUCTS HELD BY THE LEAD CENTRE(S) FOR ANNUAL TO DECADAL CLIMATE PREDICTION (LC-NTCP)

- (a) Access to data and graphical products from LC-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 LC-ADCP;
- (d) Institutions other than those identified in (c) above, may also request access to LC-ADCP products. These institutions, including research centres may not use LC-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 LC-ADCP will refer the application to the CBS-CCI Inter-Programme Expert Team on Operational Prediction from Subseasonal to Longer time Scales (IPET-OPSLs) through the WMO Secretariat, for final consultation and review. Decisions to allow access must be unanimous. The Lead Centre 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 LC-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 20. HINDCAST AND FORECAST DATA TO BE COLLECTED BY THE LEAD CENTRE(S) AND PRODUCTS TO BE GENERATED AND DISPLAYED

Contributing centres shall provide necessary hindcast and forecast data to the LC to allow generation of the following minimum products for each contributing centre and for the MME.

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 2 years of designation of the LC-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 21. VERIFICATION INFORMATION TO BE COLLECTED BY THE LEAD CENTRE(S) AND PRODUCTS TO BE DISPLAYED

Hindcast verification:

The LC 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 MME

- global maps of Relative Operating Characteristic (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 LC-ADCP. In accord with the DCPD protocol, hindcasts will ideally be initialized in each year from 1960 to present, with initialization every other year (specified as 1960, 1962 etc.) a minimum requirement. Hindcasts shall be of sufficient range to verify performance out to at least 5 years ahead.

Real-time verification (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 will be updated each year and a graphic generated to compare the past-predicted and observed timeseries.

APPENDIX 2.2.22. Activation of support for nuclear emergency response and standards in the provision of international services by RSMCs

[Insert APPENDIX I-3 of the current Manual on the GDPFS, followed by the: (a) first three paragraphs of APPENDIX II-7 with the following amendments and addition; and (b) last paragraph of APPENDIX II-7, item 5.]

STANDARDS IN THE PROVISION OF INTERNATIONAL SERVICES BY RSMCs FOR NUCLEAR ERA

The Delegated Authority requests support from WMO RSMC for atmospheric transport modelling products by using the form entitled "Environmental Emergency Response – Request for WMO RSMC Support by Delegated Authority" ([Appendix 2.2.26](#)). [...].

The IAEA requests support from WMO RSMCs for atmospheric transport modelling products by using the form agreed between the WMO and the IAEA ([Appendix 2.2.26](#)). [...].

The designated RSMCs shall [...]:

- (a) [...];
- (b) [...];
- (c) [...] (~~Appendix I 3, Regional arrangements~~, paragraphs 9 and 10 of the REGIONAL ARRANGEMENTS);
- (d) [...].

The RSMCs will distribute their standard products to the NMS Operational Contact Points by [...]. The RSMC may also make use of other appropriate technologies.

APPENDIX 2.2.23. Mandatory products and rules for displaying products

[Insert APPENDIX II-7, items 2, 3 and 5.]

APPENDIX 2.2.24. Default emission source parameters

[Insert APPENDIX II-7, item 1.]

APPENDIX 2.2.25. Characteristics of atmospheric transport modelling system

The designated Centres shall document and maintain in WMO/TD-No. 778 and on the WMO Emergency Response Activities website up-to-date information on the characteristics of their atmospheric transport modelling (ATM) system. The information will contain at a minimum:

For ATM:

- Name of model(s) and type (Lagrangian, Eulerian)
- Horizontal grid(s) 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 Numerical Weather Prediction data used for ATM:

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

APPENDIX 2.2.26. Request form to activate RSMC support

[Insert APPENDIX II-7, the form to request WMO support by a Delegated Authority, and the form to request WMO support by IAEA.]

APPENDIX 2.2.27. Specifications for support to CTBTO

[Insert APPENDIX I-6, with the following amendments, followed by APPENDIX II-9]

GLOBAL ARRANGEMENTS FOR ALL RSMCs TO DISTRIBUTE THE PRODUCTS TO CTBTO

~~NOTIFICATION~~

In the framework of the cooperation agreement between the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) and WMO that [...].

1. All notified RSMCs shall [...].
2. [...].
3. [...].
4. [...].

~~REGIONAL ARRANGEMENTS FOR ONE OR MORE RSMCs TO DISTRIBUTE PRODUCTS TO AN NMHS~~

~~If support is required for response to an incident requiring backtracking using atmospheric transport models, then the Permanent Representative with WMO, or the person authorized of the requesting country may direct the request for support to the operational contact point of the designated RSMC(s) for its regional association.~~

- ~~1. The RSMC shall consider each request with regard to its capabilities and the suitability of its products to address the requirements and will then respond accordingly.~~
- ~~2. The RSMC shall inform the WMO Secretariat of the request and the agreed actions, and may inform all other designated RSMCs of the request.~~
- ~~3. The RSMC products will be provided to the NMS Operational Contact Point designated by the Permanent Representative.~~

PRODUCTS PROVIDED BY RSMCs WITH ACTIVITY SPECIALIZATION IN ATMOSPHERIC TRANSPORT MODELLING (BACKTRACKING FOR CTBT VERIFICATION SUPPORT)

The CTBTO Provisional Technical Secretariat (PTS) requests support from WMO [...].

[...]

APPENDIX 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 ERA 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 sand and dust storm forecasts are covered under activity 2.2.2.9.

NMHSs may request RSMC support for releases that have the potential for large-scale (i.e. 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.

NMHSs requesting RSMC support shall:

- Request via the authorized person⁶ 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.
- Requests should be made by e-mailing (preferred) or faxing the completed form in Appendix 10 to the appropriate RSMC. If the RSMC has not confirmed reception within 20 minutes, the requester should contact the RSMC by phone or e-mail.
- Provide the RSMCs with the essential information specified on the request form.
- NMHSs will distribute the products within their State based on their national arrangements.

⁶ The person authorized by the Permanent Representative of the WMO Member to request RSMC support; normally the NMHS operational contact point.

APPENDIX 29. MANDATORY AND HIGHLY RECOMMENDED LIST OF NON-NUCLEAR ENVIRONMENTAL EMERGENCY RESPONSE

Smoke from forest, grass or peat fires (default values in Appendix 8 will be used for source parameters not provided)

- Forecast duration 36 hours
- Relative concentrations⁷ from the surface to 200 m²
- Images at intervals of 1, 3 or 6 hours⁸
- 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 concentrations⁴ from the surface to 200 m²
- Images at intervals of 1 or 3 hours²
- 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 concentrations⁴ from the surface to 100 m²
- Images at intervals of 1 or 3 hours²
- Contouring to be determined based on specifics of the event or the request

All products shall include a list of parameters that were used for the dispersion modelling as listed in Attachment 2.2.5.

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

⁷ Absolute concentrations may be provided if an estimate of the total mass released or actual mass rate are provided.

⁸ Additional products (e.g. GIS-format files) may be provided to requesting NMHSs if possible.

APPENDIX 30. DEFAULT EMISSION SOURCE PARAMETERS

Scenario*	Type of Event	Material released	Rate of Emission	Vertical Distribution
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, date and time of the reception of the request will be used.

APPENDIX 31. CHARACTERISTICS OF ATMOSPHERIC TRANSPORT AND DISPERSION MODELLING SYSTEM

The designated Centres will document and maintain in WMO/TD-No. 778 and on the WMO Emergency Response Activities website up-to-date information on the characteristics of their atmospheric transport and dispersion modelling (ATDM) system. The information will contain at a minimum:

For ATDM:

- Name of model(s) and type (Lagrangian, Eulerian)
- Horizontal grid(s) 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 Numerical Weather Prediction data used for ATDM:

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

APPENDIX 32. REQUEST FORM TO ACTIVATE RSMC SUPPORT

ENVIRONMENTAL EMERGENCY RESPONSE REQUEST FOR WMO RSMC SUPPORT BY AUTHORIZED PERSON⁹

1. This form should be sent by e-mail to one the RSMCs operational contact in the regional association when support is needed for releases that have the potential for large-scale (i.e. 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.
2. If the RSMC does not confirm the reception of the request within 20 minutes, requester will phone the RSMC.
3. The RSMC shall make available its products as soon as possible but usually within 2 hours. An e-mail will be sent by the RSMC with information on where to access the products. The requester will confirm reception by e-mail.

DATE AND TIME OF REQUEST:

1) MANDATORY INFORMATION:

- Status: (Exercise/Event)
- Name, title, Organization/Agency, Country, phone number and e-mail of the requester:
- Select type of event and provide brief description or details:

Forest, grass or peat fire:

Chemical incident:

Industrial Fire/Smoke:

Other:

- Date and Start time of release (DD/MM/YYYY and UTC):
-
- Location of release (as accurately as possible) in order of preference:

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

Latitude	
Longitude	

2) (*if appropriate*) Address, City, Country:

2) 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):

⁹ The person authorized by the Permanent Representative of the WMO Member to request RSMC support; normally the NMHS operational contact point.

- 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 (top of smoke plume for example).
- 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 sand and dust storm products to be made available on the WIS

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

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

Forecasts shall cover the period from the starting forecast time (00 and/or 12 UTC) up to a forecast time of at least 72 hours, with an output frequency of at least 3 hours. They shall cover the whole designated area. The horizontal resolution shall be finer than 0.5×0.5 degrees.

Forecasts shall be disseminated through the 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 NWP products

[Insert ATTACHMENT II.7, Table F, section I of the current Manual on the GDPFS and amend as follows]

1. Introduction

[...]The Lead Centre functions, as described in ~~H.2.2.3.1~~, [...]

[...]

[...] implementation across participating centres.

The mathematical formulation of the scores is documented on the LC-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 ~~subsections~~sections define two sets of verification statistics. A mandatory set shall be provided by all participating centres. A set of additional recommended statistics is also defined which all centres should provide if possible. ~~The current specifications are for the verification of upper-air fields. The specifications will be expanded as recommended procedures for surface parameters (including 2m temperature, wind, total precipitation) are developed and in response to changing user requirements. 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.

~~3.3~~ Exchange of scores

Each centre shall provide scores monthly to the LC-DNV. Details of the procedure and the required format for the data are provided on the website of the LC-DNV. All scores for all forecasts verifying within a month shall be provided as soon as possible after the end of that month.

~~4.1~~ Documentation

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

I – STANDARDIZED VERIFICATION OF UPPER-AIR FIELDS

~~1.1~~ Parameters

[...]

~~1.2~~ Forecast times

[...]

~~1.3~~ Forecast steps

[...]

~~6.4.~~ Areas

[...]

~~7.5.~~ Verification against analyses

~~7.5.1~~ Grid and interpolation

[...]

~~6.~~ Verification against observations

~~8.6.1~~ Observations

[...]

[...] to compute verification statistics. Whenever possible, these correction procedures should be documented (e.g. by reference to a technical report or journal paper).

~~8.6.2~~ Interpolation

[...]

~~8.6.3~~ Areas

[...] Section ~~6.4.~~

[...] (see subsection ~~8.6.1~~)

~~9.-----~~ ~~6.4~~ Scores ~~move~~ for individual stations

It is recommended that, in addition to ~~Part II, 1.41~~ the areas listed in Section 4, scores against observations should be computed for each station individually. The exchange of scores over areas is to be phased out over time.

~~7.-----~~ Scores

[...]

~~9.1-----~~ Score definitions

The following definitions should be used

~~Mean error-----~~

$$M = \left(\sum_{i=1}^n w_i (x_f - x_v)_i \right) / \sum_{i=1}^n w_i$$

~~Root mean square (rms) error-----~~

$$rms = \sqrt{\sum_{i=1}^n w_i (x_f - x_v)_i^2} / \sqrt{\sum_{i=1}^n w_i}$$

~~Correlation coefficient between forecast and analysis anomalies~~

$$r = \frac{\sum_{i=1}^n w_i (x_f - x_c - M_{f,c})_i (x_v - x_c - M_{v,c})_i}{\left(\sum_{i=1}^n w_i (x_f - x_c - M_{f,c})_i^2 \right)^{1/2} \left(\sum_{i=1}^n w_i (x_v - x_c - M_{v,c})_i^2 \right)^{1/2}}$$

rms vector wind error

$$rms = \sqrt{\sum_{i=1}^n w_i (\vec{V}_f - \vec{V}_v)_i^2} / \sqrt{\sum_{i=1}^n w_i}$$

Mean absolute error

$$MAE = \sum_{i=1}^n w_i |x_f - x_v|_i / \sum_{i=1}^n w_i$$

rms anomaly

$$rmsa = \sqrt{\sum_{i=1}^n w_i (x - x_c)_i^2} / \sqrt{\sum_{i=1}^n w_i}$$

standard deviation mathematical formulation of field

$$sd = \sqrt{\sum_{i=1}^n w_i (x - M_x)_i^2} / \sqrt{\sum_{i=1}^n w_i}$$

where

$$M_x = \sum_{i=1}^n w_i x_i / \sum_{i=1}^n w_i$$

S1 score

$$S_1 = 100 \frac{\sum_{i=1}^n w_i (e_g)_i}{\sum_{i=1}^n w_i (G_L)_i}$$

Where:

x_f = the forecast value of the parameter in question

x_v = the corresponding verifying value

x_c = the climatological value of the parameter

n = the number of grid points or observations in the verification area

$M_{f,c}$ = the mean value over the verification area of the forecast

anomalies from climate

$M_{v,c}$ = the mean value over the verification area of the analysed

anomalies from climate

\vec{v}_f = the forecast wind vector

$$e_g = \left\{ \left| \frac{\partial}{\partial x} (x_f - x_v) \right| + \left| \frac{\partial}{\partial y} (x_f - x_v) \right| \right\}$$

$$G_L = \max \left(\left| \frac{\partial x_f}{\partial x} \right|, \left| \frac{\partial x_v}{\partial x} \right| \right) + \max \left(\left| \frac{\partial x_f}{\partial y} \right|, \left| \frac{\partial x_v}{\partial y} \right| \right)$$

where the differentiation scores is approximated by differences computed documented on the verification grid LC-DNV website, together with supplementary information on score calculation.

The weights w_i applied at each grid point or observation location are defined as

Verification against analyses: $w_i = \cos \phi_i$, cosine of latitude at grid point i

Verification against observations: $w_i = 1/n$, all observations have equal weight

10. Exchange of scores

Each centre shall provide scores monthly to the LC-DNV. Details of the procedure and the required format for the data are provided on the website of the LC-DNV. All scores (12-hourly) for all forecasts verifying within a month shall be provided as soon as possible after the end of that month.

11.8. Climatology

[...]

11.9. Monthly and annual averaged scores

[...]

11.10. Confidence Intervals

[...]

12. STANDARDIZED VERIFICATION OF SURFACE FIELDS

1. Parameters and units

Mandatory

- 2-m temperature _____ K
- 10-m wind speed _____ $m s^{-1}$
- 10-m wind direction _____ deg
- 24-h precipitation _____ mm

Additional recommended

- Total cloud cover _____ 0-1 (convert to okta for contingency tables)

- 6-h precipitation _____ mm
- 2-m relative humidity _____ %
- 2-m dewpoint _____ K

For 2-m 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 2-m 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.

2. Forecast times

Scores shall be computed daily for forecasts initialized at 00 UTC and 12 UTC separately. For those: ~~Documentation~~

~~Participating~~ centres not running forecasts from either 00 UTC or 12 UTC, scores may be provided for forecasts initiated at other times and must be labelled as such.

3. Forecast steps

Mandatory: __

6-hourly up to T+72, 12-hourly up to T+240 or end of the forecast

____ For 24-h precipitation: 24-hourly up to T+240 or end of the forecast

Additional recommended:

3-hourly up to T+72, 6-hourly up to T+240 or end of the forecast (for improved representation of diurnal cycle)

For 6-h precipitation: 6-hourly up to T+240 or end of the forecast

4. Grid and interpolation

Verification shall be based on the native model grid using the grid point nearest to the observation location.

5. Observations

Verification ~~shall provide to~~ shall be carried out for SYNOP surface stations distributed via the GTS. Each participating centre should 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 will 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 which has been systematically rejected over a certain time period. Whenever possible, the quality control procedures should be documented (e.g. by reference to a technical report or journal paper).

6. Scores

Scores are computed for each station individually. A station for which scores are computed should have at least 90% data availability during the verification period.

For 2-m temperature, 2-m relative humidity, 2-m dewpoint, 10-m wind speed, 10-m wind direction, and total cloud cover the following error scores are computed:

- Mean error (ME)
- Mean absolute error (MAE)
- Root mean square error (RMSE)

10-m wind direction is verified only when the observed wind speed is $\geq 3 \text{ m s}^{-1}$. For 10-m wind direction the equivalence of 360 and 0 degrees needs to be taken into account (cyclic continuation).

For 10-m wind speed, precipitation, and total cloud cover, contingency-tables for the following thresholds shall be provided:

- 10-m wind speed: ___ 5, 10, and 15 m s^{-1}
- 24-h precipitation: ___ 1, 10, and 50 mm
- 6-h precipitation: ___ 1, 5, and 25 mm
- Total cloud cover: ___ 2 okta, 7 okta

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 4 significant digits, e.g. 3.142 for an error of n . 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 LC-DNV website, together with supplementary information on ~~their implementation of the standardized verification system annually, shall confirm~~ score calculation.

7.1.1.1 Temporal and spatial aggregation

For any given 1 month period, error scores and contingency tables are computed for each station individually. It 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 verifying 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 get 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 LC-DNV ~~any changes to its implementation (including the annual change of station list, changes in additional statistics) and changes in their NWP model website~~ 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 global EPS

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 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 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.

EPS 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 as easy to implement as possible, and ensuring a consistent implementation across participating centres, in particular in the interpolation to verification grid, and use of a common climatology and set of observations.

2. Verification statistics

The following subsections define four sets of verification statistics. A mandatory set shall be provided by all participating centres. A set of additional recommended statistics is also defined which all centres should provide if possible. The detailed procedures are required to ensure it is possible to compare results from the different participating centres in a scientifically valid manner.

The four sets of statistics are summarized as:

Mandatory

- 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 Centre(s) 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 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:

- Mean Sea Level Pressure (PMSL)

- 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:

- PMSL anomalies ± 1 , ± 1.5 , ± 2 standard deviation with respect to the defined climatology
- 500 hPa geopotential height anomalies with thresholds ± 1 , ± 1.5 , ± 2 standard deviation with respect to the defined climatology
- 850 hPa wind speed with thresholds of 10, 15, 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 , ± 2 standard deviation with respect to the defined climatology.
- Precipitation with thresholds 1, 5, 10, and 25 mm/24 hours
- 10m wind speed with thresholds 10 and 15 m s^{-1}
- 2m temperature anomalies with thresholds ± 1 , ± 1.5 , ± 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.

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 should include all forecast cycles made available on the WIS.

5. Forecast steps

Every 24h 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 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 (paragraph 8), but may alternatively be against a proxy analysis (i.e. a short-range forecast from the control or high-resolution deterministic forecast, e.g. 12-36h forecast to avoid spin-up problems).

8. Verification against observations

8.1 Observations

Observations for EPS verification of precipitation should be based on the GCOS list of surface networks (GSN). Producing centres shall have the right to omit certain observation sites should they 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 in the form specified on the Lead Centre website.

The following scores are to be calculated for all parameters (*computed by Lead Centre(s) based on reliability tables provided by participating centres*):

- Brier Skill Score (with respect to climatology);
- Relative Operating Characteristic (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 in the format specified on the Lead Centre website. 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. Details of the procedure and the required format for the data are provided on the Lead Centre website. 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, which is the same climatology specified in Appendix 2.2.34 and available from the LC-DNV website.

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 is made available in GRIB format. Information on access to the data and further documentation are provided on the LC-DNV website.

12. Documentation

Participating centres shall provide to the Lead Centre information on their implementation of the standardized verification system annually, shall confirm to the Lead Centre 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 (SVSLRF)

1. Introduction

This Appendix describes procedures for the production and exchange of a standard set of verification scores for long-range forecasts (LRF) produced by GDPFS centres. Provision of the verification products described is mandatory for Global Producing Centres of Long-Range Forecasts (GPCs). 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 for Standardized Verification System for Long-Range Forecasts (LC-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 LC-SVSLRF website(s), 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 LC-SVSLRF website.

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 level 1 and level 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. 3-month-mean T2m (screen temperature): ensemble mean and probabilities for 3 tercile categories;
- b. 3-month precipitation accumulation: ensemble mean and probabilities for 3 tercile categories;
- c. Monthly Niño3.4 Sea Surface Temperature (SST) indices (for GPCs operating coupled (1-tier) prediction systems): ensemble mean and probabilities for 3 tercile categories.

The variables and categorical stratifications to be verified for level 2 are:

- a. As (a);
- b. As (b);

- c. 3-month-mean SST: ensemble mean and probabilities for 3 tercile categories.

Where the terciles of the climatology are defined over the hindcast period used (see section 11) and the 3-month-mean periods are 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 next section).

5. Forecast target periods and lead-times

Level 1: T2m and precipitation

Target periods: The 3-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 1-month lead time. For example, forecasts issued e.g. on 15 May for the JJA season are considered to have a nominal lead time of 1 month.

Level 1: Niño3.4 indices (for GPCs operating coupled systems)

Target periods: each calendar month of the forecast;

Lead times: 1, 2, 3, 4 and 5 months.

Level 2: T2m and precipitation

Target periods: Twelve rolling 3-month periods (e.g. 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 Niño3.4 region index, SST averaged over the Niño3.4 region (5°N - 5°S; 170°W - 120°W) shall be used.

7. Verification against analyses

7.1 Grid and interpolation

All parameters (excepting 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 LC-SVSLRF website. The LC-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;
- Relative Operating Characteristic (ROC) diagram with standardized area under the ROC curve.

Deterministic forecasts:

- Mean Square Skill Score (MSSS) with respect to climatology.

Level 1: Niño3.4 indices (for GPCs operating coupled systems)

Probability forecasts:

- Relative Operating Characteristic (ROC) diagram with standardized area under the ROC curve.

Deterministic forecasts:

- Mean Square Skill Score (MSSS) with respect to climatology and its 3-term decomposition.

Level 2: T2m and precipitation

Probability forecasts:

- Relative Operating Characteristic (ROC) diagram with standardised area under the ROC curve.

Deterministic forecasts:

- Mean Square Skill Score (MSSS) with respect to climatology and its 3-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 LC-SVSLRF website).

10. Exchange of scores

Each centre should provide scores to the LC-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.

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 LC-SVSLRF website.

12. Documentation

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

APPENDIX 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 for Wave Forecast Verification (LC-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

a) Atmospheric forcing

- 10m wind speed U and V components (10u, 10v)

b) Wave fields

- Significant wave height (Hs)
- Peak period (Tp)
- Mean wave period based on the second moment of the frequency spectrum (Tz)
- Mean wave direction (mdir)

3. Forecast times

If available, forecasts from 00, 06, 12, and 18 UTC should be provided.

4. Forecast steps

In as fine temporal granularity as available but at least every 6 h 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 LC-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 are to be calculated for all parameters against observations.

- Mean error (ME)

- Root mean square error (RMSE)
- Error standard deviation (SDEV)
- Scatter index (SDEV normalized by observed mean)
- Symmetric slope (variance ratio)
- Quantile-quantile (Q-Q) plots

8. Exchange of forecast fields

Each JCOMM participating Centre shall provide fields to the LC-WFV on a regular latitude-longitude grid at the resolution that is best matching the native resolution of the direct model output. Details of the procedure and the required format for the data are provided on the website of the LC-WFV.

9. Documentation

JCOMM participating Centres shall provide to the LC-WFV information on any changes to its production of the exchanged forecast fields and changes in their wave forecast system.

APPENDIX 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 (TC) forecasts produced by the Lead Centre for Tropical Cyclone Forecast Verification (LC-TCFV) based on gridded forecast fields provided by participating GDPFS centres. The goal is to provide consistent verification information on the TC forecast products of participating GDPFS centres for forecasters in the NMHSs and to help the participating GDPFS centres compare and improve their forecasts. The Lead Centre functions, as described in 2.2.3.5, include creating and maintaining a website for TC forecast verification 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 participating GDPFS centres.

2. Tropical cyclones to be verified

TCs which intensity reached tropical storm (TS) with the maximum sustained wind of 34 knots or stronger are set as targets for this verification. The tropical depression (TD) stage of the targeted TCs is also included in this verification. However, the TCs which never evolve from TD to TS stage during their life time are excluded.

TCs which are not recorded in the best track dataset (ref. section 7) are also excluded.

3. Parameters

Mandatory

- Mean sea-level pressure

Recommended

- u and v wind components at 850hPa

4. Forecast times

Scores shall be computed for forecasts initialised at 12 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, respectively.

5. Forecast steps

Every 6h to 192h of the forecast range.

6. Verification areas

Scores are to be calculated separately for each verification area shown below.

Verification Area	Specification of Area
Western North Pacific:	EQ - 90°N, 100°E -180°
Eastern North Pacific including Central North Pacific	EQ - 90°N, 180° - West coast of North and South American Continent (*) TCs that generate in this area are categorized as those in this area through its life-time.
North Atlantic Ocean	Caribbean Sea, The Gulf of Mexico, and EQ - 90°N, East coast of North and South American Continent - 35°W (*) TCs that generate in this area are categorized as those in

	this area through its life-time.
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 dataset available at the Lead Centre. Best track dataset are originally provided by RSMCs participating in tropical cyclone forecasting 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 shall calculate position and pressure of TC centres by linear interpolation using five data of the nearest grid point and its four neighboring grid points in 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 TC centres;
 - ATCT-bias (shown in the pictorial form of scatter diagram):
 - AT(along-track)-bias: The bias in the direction of cyclone movement;
 - CT(cross-track)-bias: The bias in the rectangular direction of cyclone;
- (c) Bias of central pressure.

The mathematical formulation of the scores is documented on the LC-TCFV website, together with supplementary information on score calculation.

10. Exchange of forecast fields

Each participating GDPFS centre shall provide global fields annually to the LC-TCFV on a regular latitude-longitude grid at the resolution of 1.5° longitude by 1.5° latitude or finer resolution. Details of the procedure and the required format for the data are provided on the website of the LC-TCFV.

11. Exchange of scores

All calculated scores in the text or binary form shall be made available on the LC-TCFV website.

The LC-TCFV shall also make available the scores in the pictorial form on the LC-TCFV website as follows:

- (a) Detection rate of tropical storm: the score is drawn every 12h till 120h;
- (b) Storm track verification: position error and ATCT-bias are shown every 24 till 192h. Position error is shown as map. ATCT-bias is shown in scatter diagram form;
- (c) Bias of central pressure: scatter diagram of analysed and predicted central pressure is shown every 24h till 192h.

12. Documentation

Participating GDPFS centres shall provide to the LC-TCFV information on any changes to its production of the exchanged forecast fields.

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

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 RCM 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 RCC FUNCTIONS

[Insert ATTACHMENT II.10 of the current Manual on the GDPFS]

ATTACHMENT 2.2.3. GUIDELINES FOR FEEDBACK FROM RCCS/NHMSS TO GPCS

[Insert ATTACHMENT II.13 of the current Manual on the GDPFS, and replace reference to Appendix II-6, section 4.2 by Appendix 2.2.9 and insert a new item 6. as follows]

[...]

6. Report on the comparative performance of GPCs for the region of RCC/NMHSs responsibility; both for real-time forecasts and, if available, from retrospective forecasts.

[...]

**ATTACHMENT 2.2.4. ADDITIONAL INFORMATION TO BE AVAILABLE FROM LCs-
LRFMME**

[Insert section 4. of the ATTACHMENT II.12 of the current Manual on the GDPFS, and replace reference to paragraph 3.1 by Appendix 2.2.12 and to Appendix II-6, section 4.2 by Appendix 2.2.9]

ATTACHMENT 2.2.5. USERS INTERPRETATION GUIDE FOR NON-NUCLEAR ATMOSPHERIC TRANSPORT AND DISPERSION MODELLING PRODUCTS PROVIDED BY RSMCs

The designated Centres will make available in WMO/TD-No. 778 on the WMO Emergency Response Activities website an interpretation guide for users.

General rules for displaying results:

In order 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 (shore lines, country borders, rivers, etc. 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/time of release (UTC), and the meteorological model initialization date/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 requested services.

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); and (ii) the units of concentration. In addition, charts should specify: (i) "surface to xxx-m layer concentrations", where xxx depends on the pollutant type, and if the default source is used; and (ii) "Results based on default initial values";
- (e) 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;
- (f) Indicate the starting and ending date/time (UTC).

Specific guidelines for backtrajectory maps:

- (a) Distinguish each trajectory (levels chosen will depend on 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 e-mail or enabling retrieval by the NMHS from RSMCs password protected designated website. Standard products in the ITU-T T4 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. GDPFS IMPLEMENTATION

[Insert Appendix I-1 of the current Manual with the following additions (not necessarily by this order):]

World Meteorological Centres (WMCs)

WMC Beijing

WMC Exeter

WMC ECMWF

WMC Montreal

WMC Tokyo

Regional Specialized Meteorological Centres (RSMCs) for Limited-area Deterministic Weather Prediction

RSMC Khabarovsk

RSMC Moscow

RSMC Novosibirsk

RSMC Offenbach

RSMC Pretoria

RSMC Rome

Regional Specialized Meteorological Centres (RSMCs) for Limited-area Ensemble Numerical Prediction

RSMC Offenbach

RSMC Rome

Regional Specialized Meteorological Centres (RSMCs) for Nowcasting

RSMC Offenbach

RSMC Tokyo

Regional Specialized Meteorological Centres (RSMCs) for Volcano Watch Services for International Air Navigation

RSMC Tokyo

Lead Centre for Coordination of Multi-annual to Decadal Prediction (LC-MDP)

LC-MDP Exeter

Global numerical long-range prediction (known as Global Producing Centre for Long-range Forecasts (GPCLRF))

GPCLRF Offenbach

Provision of atmospheric sand and dust storm forecasts (ASDF)

RSMC-ASDF Beijing (RA II)

Regional Climate Centres (RCCs) providing regional climate prediction and monitoring

RCC Intergovernmental Authority on Development (IGAD) hosted by the IGAD Climate Prediction and Applications Centre (ICPAC) (RA I)

RCC-Network Northern Africa (RA I)

RCC Pune (RA II)

RCC-Network Southern South America (RA III)

RCC Caribbean hosted by the Caribbean Institute for Meteorology and Hydrology (CIMH) (RA IV)