WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

COORDINATION GROUP ON FORECAST VERIFICATION (CG-FV)

READING, UK, 15-17 MAY 2012

FINAL REPORT

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EXECUTIVE SUMMARY

The third meeting of the Commission for Basic Systems (CBS) Coordination Group on Forecast Verification (CG-FV) was held at the European Centre for Medium-range Weather Forecasts (ECMWF), in Reading, UK, from 15 to 17 May 2012.

The meeting reviewed the status of implementation of the new CBS procedures for upper-air verification and was pleased to note that significant advances have been made by most of the NWP centres. It noted that a number of NWP centres have already initiated the implementation of the new procedures for scores computation or plan to do so by mid-2012. The operational production of new scores in the new file format was expected by end 2012. Almost all NWP centres have requested access to the climatology, which is provided by the LC-DNV through its ftp server (ftp.ecmwf.int). The meeting encouraged NWP centres to present the updated CBS standard verification procedures in various conferences, symposia and seminars.

The meeting noted that a number of studies have been made by NWP centres to evaluate the impact of the new procedures on values of verification scores, including (1) the comparison of verification statistics computed by old and new procedures at ECMWF: the impact of the resolution, smoothing and climatology on values of selected verification scores and the effect of time averaging method; (2) the comparison of scores calculated using various methods of interpolation by CMC and the evaluation of the impact of the use of the nearest model grid-point for scores against observations; and (3) the impact of changing climatologies in anomaly correlation scores by JMA. It agreed that all these aspects and results from these impact studies related to the revised standard verification procedures should be addressed in the paper on updated verification procedures to be produced by members of the CG-FV.

The meeting reviewed the Lead Centre for Deterministic NWP Verification (LC-DNV) web site (http://apps.ecmwf.int/wmolcdnv/), expressed its appreciation to ECMWF for its work in developing the LC-DNV web site, and recommended that it should be declared operational. The meeting noted that login accounts have been provided to CG-FV members and recommended that access to the LC-DNV web site should be provided to all WMO Members through their WMO accounts. For further improvement, the meeting encouraged NWP centres to provide feedback, including comments and questions, on anything related to the LC-DNV by e-mail to wmolcdnv@lists.ecmwf.int.

The meeting discussed the potential application of CBS standard verification procedures for Polar Regions and noted the results of the studies on CBS scores for Polar Regions. It agreed that there was a need for including two new geographical areas (polewards of 60º) in the CBS standard verification procedures stated in the Manual on the GDPFS (WMO-No. 485).

The meeting noted the results of the studies to evaluate the sensitivity to analysis differences on verification metrics. It agreed that these studies are very helpful to users in the interpretation and use of verification results, and therefore agreed to make a summary of the results of these studies available on the LC-DNV web site.

The meeting noted the results of a study on the sensitivity to differences in observation availability/usage. It encouraged all NWP centres to participate in this research. The meeting recommended that exchange periods should be at least one month for summer and winter, and agreed that preferable months would be July 2012 and January 2013. The meeting stressed the need to exchange daily scores against observation in addition to the used observation lists, and agreed that the file format of used observation lists should be the one used by the Met Office UK and the ECMWF. The meeting agreed to the use of the LC-DNV ftp server for exchanging the data.

The meeting was presented with reports by NWP centres on verification of surface fields and noted that in general NWP centres have been performing verification of surface fields. So far, operationally, the main focus had been on verification of precipitation, 2m temperature and 10m wind speed forecasts, and especially over their countries or specified geographical regions. Verification of other surface parameters (e.g. wind direction, clouds and dew point) is being done mostly on an experimental basis. The meeting recognized the importance of the inclusion of surface parameter verification into the operational verification activity for WMO, however it agreed that verification of surface fields is very complex, in particular for those parameters (such as wind and temperature) that are significantly localized due to topographic and coastline effects, and therefore stressed that more research and studies are required to allow recommendations to be developed. These include studies on the sensitivity of verification results to differences in use of a fixed versus an evolving list of stations, and on the quality control of the observations; and interpolation methods. The meeting agreed that other aspects that require agreement include: (1) scores (ME, MAE, RMSE, contingency table based scores); (2) reference (climatology, persistence); (3) confidence intervals (resampling in space and/or time); (4) spatial aggregation; and (5) temporal aggregation.

The meeting reviewed the existing text in the Manual on the GDPFS and proposed editorial corrections or clarifications, as well as the inclusion of the two new areas for the Polar Regions (Annex IV). It also reviewed the draft text for the New Manual, as presented in Annex III.

GENERAL SUMMARY OF THE WORK OF THE SESSION

1. OPENING

1.1 The third meeting of the Commission for Basic Systems (CBS) Coordination Group on Forecast Verification (CG-FV) was opened by its Chairperson, Mr David Richardson (ECMWF), at 09.30 hours on Tuesday, 15 May 2012, at the European Centre for Medium-range Weather Forecasts (ECMWF), in Reading, UK. Mr Richardson welcomed participants to the meeting, and introduced Dr Erik Andersson, Head of Meteorological Division, Operations Department, to address the meeting.

1.2 Dr Erik Andersson, on behalf of the Director General of ECMWF, Professor Alan Thorpe, welcomed all participants to the third meeting of the CBS Coordination Group on Forecast Verification and expressed pleasure in hosting the meeting at the ECMWF for the second time. He highlighted the importance of performing verification of weather forecasts to ECMWF and the significant role of the CG-FV in developing verification procedures and defining standards for exchange of information, which ECMWF promotes among its Member States. Dr Andersson noted that the meeting would address verification of surface fields. This is a very important topic for NWP centres, which would therefore be able to report to their users on forecast performance and impact of observational data, including satellite-based, on their systems in terms of surface parameters. He concluded by welcoming all participant to ECMWF, and by wishing them a successful meeting.

1.3 Mr Peter Chen, on behalf of the Secretary-General of WMO, Mr Michael Jarraud, welcomed participants to the meeting and expressed his appreciation to ECMWF for hosting this meeting, for the continuous and productive collaboration with WMO, and for the important progress made in establishing the Lead Centre for Deterministic NWP Verification (LC-DNV) at ECMWF. Mr Chen recalled that the establishment of a CG-FV was proposed at the meeting of the Implementation Coordination Team on Data-processing and Forecasting Systems (ICT-DPFS), in Toulouse, in 2008, by the ICT-DPFS chairperson, and endorsed by CBS, at its fourteenth session, in 2009, with the aim to update the CBS standard procedures for verification of upper air fields, which had been developed many years ago. He also recalled that the first meeting of the CG-FV reviewed and proposed amendments to the Manual on Global Data-processing and Forecasting System (GDPFS) (WMO-No. 485) on the standard procedures for verification of upper air fields; the second meeting defined a timeline for implementing them and initiated the discussion on the verification of surface fields; and the third and current meeting would assess the status of the implementation of the revised standard procedures for verification of upper air fields and would develop recommendations for consideration by CBS on verification of surface fields. Mr Chen stressed that participation of as many NWP centres as possible in the work of the CG-FV to develop verification standards is highly desirable. He concluded by thanking the ECMWF for its leadership on forecast verification, and by wishing a very productive meeting.

2. ORGANIZATION OF THE MEETING

2.1 Adoption of the agenda

2.1.1 The meeting adopted the provisional agenda, as provided in Annex I.

2.2 Working arrangements

2.2.1 All documents submitted for the meeting are referenced and hyperlinked in the Documentation Plan (INF. 1), which had been posted on the WMO web site at:

http://www.wmo.int/pages/prog/www/DPFS/Meetings/CG-FV_Reading2012/DocPlan.html

2.2.2 The participants agreed its hours of work and other practical arrangements for the meeting, including the tentative work programme. Noting that a number of participants were new to the CG-FV, they briefly introduced themselves, to facilitate interactions throughout the meeting. The list of participants in the meeting is provided in Annex II.

3. INTRODUCTION / REPORT OF THE CHAIR, INCLUDING REVIEW OF THE ACTIONS FROM THE LAST MEETING

3.1 The meeting recalled the major outcomes of and actions from its second meeting (Montreal, January 2011), including those related to the revised standard verification procedures for upper air fields as part of the Manual on the GDPFS, to the establishment/development of and specific issues to be addressed by the Lead Centre for Deterministic NWP Verification (LC-DNV), and to the verification of surface fields.

3.2 The chairperson highlighted the general aims of this meeting, including:

(a) assessing the status of the implementation of the updated standard verification system by NWP centres;

(b) reviewing the LC-DNV web site;

(c) addressing aspects related to (1) the promotion of the revised standard verification procedures; (2) the possibility of computing CBS scores for the Polar Regions; (3) the evaluation of the differences between centres' analysis and estimate the uncertainty in the analysis errors; and (4) the sensitivity of verification results to differences in observation usage in the verification centres;

(d) developing recommendations and guidelines for the inclusion of surface parameters verification into the operational verification activity for WMO;

(e) reviewing the draft text for the revised Manual on the GDPFS related to verification.

4. REPORT ON THE OUTCOMES OF Cg-XVI RELATED AND/OR RELEVANT TO THE CG-FV

4.1 The meeting was presented with a report on the outcomes of the sixteenth World Meteorological Congress (Cg-XVI, May 2011) related and/or relevant to CG-FV. The meeting noted that Cg-XVI reaffirmed that NWP forecast verification activities are critical to quality assurance and management of the outputs of the GDPFS, and some "core" verification activities should be defined and considered as essential, and their results be made available for use by operational centres. Therefore, Cg-XVI requested the NWP verification Lead Centres, including ECMWF for Deterministic NWP, JMA (Japan) for EPS, and NMOC (Australia) jointly with CMC (Canada) for Long-range Forecasts, to coordinate and facilitate "core" verification activities. In this context, the meeting was informed that Cg-XVI emphasized the need for practical guidance to facilitate the implementation of NWP verification requirements and best practices, including those stated in the Manual on the GDPFS, so as to promote and ensure coordinated verification activities across these centres, and therefore requested all Lead Centres for NWP verification to assist in this regard. The meeting noted that a number of NWP centres, including the LC-DNV, have been assisting other NWP centres in the implementation of the revised CBS standard procedures for verification of upper air fields upon request.

4.2 The meeting was informed that Cg-XVI, noting the importance of the Manual on the GDPFS (WMO-No. 485) as the single source of technical regulations for all operational data-

processing and forecasting systems of Members, including their designated meteorological centres, endorsed the request by CBS-XIV (2009) to undertake a comprehensive review of this Manual. The meeting noted the significant progress made with the revision of the Manual, including the development of a new outline, which was adopted by Cg-XVI through Resolution 6 (Cg-XVI). Noting that the text for the new Manual would be considered at CBS-XV, the meeting agreed to review the draft new text on coordination of deterministic NWP verification under agenda item 7.

5. CBS STANDARD PROCEDURES FOR VERIFICATION OF UPPER AIR FIELDS

5.1 Implementation of revised procedures by NWP Centres

5.1.1 The meeting was pleased to note that significant advances have been made by most of the NWP centres in the implementation of the updated CBS procedures on standardized verification. A summary of the progress in implementing the new CBS procedures for upper air verification (as of May 2012) is provided in Table 5.1. The meeting noted that a number of NWP centres have already initiated the implementation of the new procedures for scores computation or plan to do so by mid-2012. The operational production of new scores in the new file format was expected by end 2012. Almost all NWP centres have requested access to the climatology, which is provided by the LC-DNV through its ftp server (ftp.ecmwf.int). The meeting agreed that this Table should be made available on the LC-DNV web site and, for completeness, it requested the Secretariat to send the report of the current CG-FV meeting to all NWP centres and request them to fill in the Table **(Action, Secretariat)**.

Table 5.1 – Summary of the progress in implementing the new CBS procedures for upper air verification (as of May 2012)

Centre	Implementation of new procedures for scores computation	Operational production of new scores in new file format	Access to climatology
BoM	Estimated in November 2012	November 2012	✔
CMC	Partly operational since October 2011	Autumn 2012	✔
NCMRWF	Estimated in October 2012	October 2012	
CMA			
ECMWF	Operational since 2010	Since January 2012	✔
DWD			✔
UK MetOffice	Most of components operational since January 2012; new climatology in May 2012	November 2012	✔
NCEP	Planned for July 2012	November 2012	✔
FNMOC			
Meteo-France	Estimated in December 2012	December 2012	✔
JMA	Scheduled for July 2012	July 2012	✔
KMA	Estimated for July 2012	August 2012	✔
RuMS	Operational (against analysis) since January 2012	July 2012	✔
CPTEC			

5.1.2 The meeting noted that a number of studies have been made by NWP centres to evaluate the impact of the new procedures on values of verification scores, including (1) the comparison of verification statistics computed by old and new procedures at ECMWF: the impact of the resolution, smoothing and climatology on values of selected verification scores and the effect of time averaging method; (2) the comparison of scores calculated using various methods of interpolation by CMC and the evaluation of the impact of the use of the nearest model grid-point for scores against observations; and (3) the impact of changing climatologies in anomaly correlation scores by JMA. The meeting agreed that all these aspects and results from these impact studies related to the revised standard verification procedures should be addressed in the paper on updated verification procedures to be produced by members of the CG-FV (see agenda item 5.3). The meeting stressed the need to clarify a few aspects in the revised standard verification procedures as part of the Manual on the GDPFS (WMO-No. 485) and agreed to address this issue under agenda item 7.

5.1.3 The meeting noted with interest the work done by the Met Office UK on the use of additional observational data (air motion vectors and AMDAR data) on global indices and encouraged other NWP centres to compute scores using these additional data. It requested the Met Office UK to continue this study and keep other NWP centres up-to-date on the developments **(Action, Met Office UK)**.

5.2 Review of the Lead Centre on Deterministic NWP Verification (LC-DNV) Web site

5.2.1 The meeting recalled that, at its previous session (in 2011), CG-FV agreed on developments and specific needs, including those related to standard products and data formats, processing and monitoring of scores, display of verification results on the Lead Centre for Deterministic NWP Verification (LC-DNV) web site (http://apps.ecmwf.int/wmolcdnv/), and the maintenance of standards. The meeting reviewed the LC-DNV web site and noted the significant progress made in its development. A test web site for the LC-DNV has been available from January 2012, which shows a range of plots of the scores that are exchanged between NWP centres. The LC-DNV web site has a few interactive features on the plots, including zoom; switch each centre on/off on plots; choice of area, score, parameter, etc.; and click to show values. The web site also includes a selection of plots of the scores computed at ECMWF for precipitation - SEEPS and a few others for comparison. They are shown for the ECMWF model and other centres whose precipitation forecast fields have been provided to ECMWF. An option to save "personalized" versions of the plots and a login so that the system remembers the users' preferences have been introduced following the preliminary feedback from CG-FV members.

5.2.2 The meeting noted that login accounts have been provided to CG-FV members and recommended that access to the LC-DNV web site should be provided to all WMO Members through their WMO accounts **(Action, LC-DNV)**. For further improvement, the meeting encouraged NWP centres to provide feedback, including comments and questions, on anything related to the LC-DNV by e-mail to wmolcdnv@lists.ecmwf.int **(Action, NWP Centres)**. It expressed its appreciation to ECMWF for these developments and recommended that the LC-DNV web site should be declared operational. In this context, the meeting requested the WMO Secretariat to announce the LC-DNV web site by sending out a circular letter to WMO Members **(Action, Secretariat)**, and all NWP centres to present the LC-NDV web site in various conferences, symposia and seminars **(Action, NWP Centres)**.

5.3 Paper on the updated verification procedures

5.3.1 The meeting recalled that, at its last session (Montreal, January 2011), it agreed to prepare a paper focused on the updated CBS standard verification procedures rather than on the results (within a quality management framework). The aim of the paper was to emphasize the importance of standardized verification procedures, promote the new procedures, and

demonstrate the impact of these changes. The meeting agreed that the paper should include corresponding input from as many NWP centres as possible and explain how standardized procedures are essential for the inter-comparison and quality assurance of NWP forecasts. Noting that most of the NWP centres have initiated the implementation of the updated verification procedures or plan to do so by end 2012, the meeting requested the CG-FV chairperson to check progress made by all NWP centres in having at least one year of data; and to lead the preparation of this paper (which should include results of the various impact studies – see agenda item 5.1) by circulation of a draft outline among those NWP centres in order to participate by end 2012 **(Action, Chairperson)**.

5.3.2 The meeting noted that a few presentations on the updated CBS standard verification procedures have been made at the meetings of the European Meteorological Society and the Canadian Meteorological and Ocean Society, in 2011. It encouraged NWP centres to present the updated CBS standard verification procedures in various conferences, symposia and seminars, including at the meeting of the American Meteorological Society (AMS), in 2013 **(Action, NWP Centres)**.

5.4 Scores for polar region

5.4.1 In response to the request by other WMO technical groups, including the Working Group on Numerical Experimentation (WGNE) and the Executive Council Panel of Experts on Polar Observations, Research and Services (EC-PORS), the meeting, at its previous session (Montreal, January 2011), discussed the potential application of CBS standard verification procedures for Polar Regions and encouraged global NWP centres to explore the possibility of computing CBS scores for Polar Regions (north of 60ºN and south of 60ºS). In this context, the meeting noted the results of the studies made by the Met Office UK and by the ECMWF on CBS scores for Polar Regions and agreed that there was a need for including two new geographical areas (polewards of 60º) in the CBS standard verification procedures, and that this would be addressed under agenda item 7.

5.5 Sensitivity to analysis differences

5.5.1 The meeting recalled that, at its previous session (Montreal, January 2011), it noted that each global NWP centre produces its own analysis depending on the data assimilated and therefore the verification against analysis is not standardized across centres. In this context, at that time, it recommended a study to evaluate the differences between different centres' analysis and estimate the uncertainty in the analysis errors (which are likely to vary with parameter and geographical area). The meeting noted the results of the studies carried out by the Met Office UK and JMA to evaluate the sensitivity to analysis differences on verification metrics. It agreed that these studies are very helpful to users in the interpretation and use of verification results, and therefore requested the representatives from the Met Office UK and JMA to summarize the results of these studies **(Action, Met Office UK and JMA)**. It also requested the LC-DNV to make these summaries available on the LC-DNV web site **(Action, LC-DNV)**. The meeting encouraged other NWP centres to carry out further studies to evaluate the differences between different centres' analysis and estimate the uncertainty in the analysis **(Action, NWP Centres)**.

5.6 Review of sensitivity to differences in observation availability/usage

5.6.1 The meeting recalled that, at its previous session (Montreal, January 2011), it noted that the CBS standard verification procedures require the use of a standard list of radiosonde stations, to be updated annually by the Lead Centre for radiosonde monitoring. However, it noted that the procedures also require each centre to screen observations for gross errors and to apply operational bias correction. Therefore the centres would not use exactly the same observations in their verification. It realized that there was at that time no simple solution that

would guarantee both the exclusion of poor data and that all centres use exactly the same observations. It proposed a study to investigate the sensitivity of verification results to differences in observation usage in the verification between centres. In this context, the meeting noted that the CMC representative has coordinated the exchange of the station lists over a 5-day period among the four NWP centres (CMC, ECMWF, JMA and Met Office UK), and that JMA has carried out a study on the sensitivity to differences in observation availability/usage.

5.6.2 The meeting noted the results of the JMA study and agreed that further research is required with extended periods to clarify the sensitivity to differences in observation availability/usage **(Action; CMC)**. It encouraged all NWP centres to participate in this research **(Action, NWP Centres)**. The meeting recommended that exchange periods should be at least one month for summer and winter, and agreed that preferable months would be July 2012 and January 2013. The meeting stressed the need to exchange daily scores against observation in addition to the used observation lists, and agreed that the file format of used observation lists should be the one used by the Met Office UK and the ECMWF. The meeting agreed to the use of the LC-DNV ftp server for exchanging the data.

6. VERIFICATION OF SURFACE FIELDS

6.1 The meeting was presented with a report by the WWRP/WGNE Joint Working Group on Forecast Verification Research (JWGFVR) on its activities, which would guide the work of the CG-FV in further developing the CBS operational procedures for forecast verification. The meeting noted that the JWGFVR has been contributing to a number of projects, including the SNOW-V10 (focusing on nowcasting and regional model verification of wind speed and visibility at observation sites), the FROST-14 (addressing neighbourhood verification of high-resolution NWP and spatial verification of ensembles), and the SWFDP – Eastern Africa (dealing with verification of 24h accumulated precipitation from global models at the synoptic stations).

6.2 The meeting was informed that the JWGFVR had produced one document containing guidelines and describing methods for cloud verification (WMO technical document WCRP 2012-1: “Recommended methods for evaluating cloud and related parameters”, available at http://www.wmo.int/pages/prog/arep/wwrp/new/documents/WWRP_2012_1_web.pdf), which has recommendations for standard verification of cloud amount and related variables, such as cloud base height, vertical profile of cloud amount, using both point-based and spatial observations (satellite, cloud radar, etc.). In addition, the meeting noted that the JWGFVR was preparing a document describing methods for verifying tropical cyclone forecasts, in support of GIFS-TIGGE and the WMO Typhoon Landfall FDP. This document would include standard methods for assessing track and intensity forecasts, probabilistic and ensemble forecast verification, and a review of recent developments in this field. In addition to track and intensity, this document also contains recommend methodologies for TC-related hazards (including storm structure and size, precipitation, storm surge, landfall time/position/intensity, etc.).

6.3 The meeting welcomed the work that was in progress by the JWGFVR to develop a document on verification of forecasts from mesoscale models and expected this to again provide useful guidance to CG-FV. The meeting noted that the precipitation verification phase of the Spatial Verification Inter-comparison Project had been completed, with many new verification methods demonstrated, and that a proposal for a second Spatial Verification Inter-comparison Project in collaboration with Short-Range NWP (SRNWP) would be included into the above-mentioned document. Recognizing that these new verification methods and scores could be considered for inclusion in the CBS standard verification procedures at a certain stage, the meeting strongly recommended that the liaison between the CG-FV and the JWGFVR, as well as with the WGNE, be continued and further explored.

6.4 The JWGFVR also carries out training activities, including organizing workshops to promote verification in research and operational activities. The meeting noted that the 5th International Verification Methods Workshop was held in Melbourne, Australia, in December 2011. The workshop included 3 days of tutorial prior to the scientific conference, aimed at introducing basic concepts and scores to a group of students. The meeting noted this training included lab sessions on the SWFDP – Eastern Africa verification of 24h accumulated precipitation from global models at the synoptic stations. In addition, the meeting noted that the JWGFVR had been focusing its work on developing web tools for verification, including EUMETCAL modules for distance learning activities, and promoting best practice of verification.

6.5 The meeting was presented with reports on verification of surface fields at CMC, JMA, Met Office UK, and the ECMWF. Full reports are available on the WMO web site at http://www.wmo.int/pages/prog/www/DPFS/Meetings/CG-FV_Reading2012/DocPlan.html (item 6). The meeting noted that in general global NWP centres have been performing verification of surface fields. So far, operationally, the main focus had been on verification of precipitation, 2m temperature and 10m wind speed forecasts, and especially over their countries or specified geographical regions. Verification of other surface parameters (e.g. wind direction, clouds and dew point) is being done mostly on an experimental basis. The meeting noted with interest that the Met Office UK has recently developed and applied a prototype surface weather index (comprised by a combination of surface parameters for certain thresholds) over the UK and globally (at selected airport locations), and requested the Met Office UK to keep the CG-FV informed of further developments **(Action, Met Office UK)**.

6.6 The meeting noted that since the CBS exchange of scores did not include any surface parameters, it had not been possible to make the same routine comparison of scores for any surface parameter as is done for the upper-air fields. However, it acknowledged that ECMWF has been receiving global precipitation forecast fields from a number of NWP centres, specifically for verification purposes, and has been computing the SEEPS score for precipitation forecasts from the JMA, NCEP and the Met Office UK deterministic global forecast models, and making the results available on the LC-DNV web site. The meeting encouraged other NWP centres to send/make available the global precipitation forecast fields from their models to ECMWF **(Action, NWP Centres)**, who would compute the SEEPS score and display the results on the LC-DNV web site **(Action, LC-DNV)**. At the same time, the meeting noted that, following its request, in the previous session (Montreal, January 2011), to carry out an inter-comparison of precipitation forecasts from global NWP centres using the SEEPS score, together with other traditional scores, results of this inter-comparison have been published in a paper co-authored by CG-FV members.

6.7 Recognizing the potential benefits of using climatological thresholds for contingency table based verification (including the SEEPS score), the meeting encouraged other NWP centres to compute such a score using climatological thresholds. It stressed that for consistency the use of the same climatology for the synoptic stations is required. Noting that in accordance with the WMO Resolution 40, the distribution of such climatology would be allowed, the meeting requested the ECMWF to make available such climatology on the Lead Centre ftp site (password protected) **(Action, LC-DNV)**. The meeting also encouraged other NWP centres to compute the SEEPS score and send it to the LC-DNV for display **(Action, NWP Centres)**.

6.8 The meeting noted that standard verification procedures would require the use of a list of stations and that each NWP centre screens observations for gross errors, and may apply operational bias correction. In this context, NWP centres would not use exactly the same observations in their verification. The meeting realized that there is at present no simple solution that would guarantee both the exclusion of poor data and that all NWP centres use exactly the same observations. At the same time, the meeting agreed that the sensitivity of verification results to differences in use of a fixed versus an evolving list of stations would need to be

investigated, and therefore proposed a study on this issue, including a study on the quality control of the observations **(Action, Met Office UK)**.

6.9 The meeting agreed that for the purpose of surface weather verification (as well as model development), more data, and more frequent data, should be exchanged on the GTS. The meeting stressed that availability (over some regions) and quality control of observations for verification are of concern and need to be taken into account in developing verification systems. Additionally, the meeting agreed that greater standardization of observing practices is also required, as well as better precision of location of stations and their metadata, including reference to manual/automatic weather stations. It therefore recommended this issue should be followed up through the appropriate WMO Expert Team(s) and/or Group(s), including the CBS ET on Evolution of the Global Observing System (ET-EGOS). The meeting also recommended that any other near-real-time data not being transmitted on the GTS be made available for verification purposes.

6.10 The meeting stressed the need to reach an agreement regarding the interpolation methods from model grid to observation location prior to developing any surface verification procedures. The most appropriate method may be different for different parameters; nearest native model grid point is recommended for parameters such as precipitation and cloud; different interpolations are used at different NWP centres for these and other parameters (**Action, ECMWF**). Other aspects that require agreement include: (1) scores (ME, MAE, RMSE, contingency table based scores); (2) reference (climatology, persistence); (3) confidence intervals (resampling in space and/or time); (4) spatial aggregation; and (5) temporal aggregation (**Action, Chairperson**).

6.11 The meeting recognized the importance of the inclusion of surface parameter verification into the operational verification activity for WMO, however it agreed that verification of surface fields is very complex, in particular for those parameters (such as wind and temperature) that are significantly localized due to topographic and coastline effects, and therefore stressed that more research and studies are required to allow recommendations to be developed. In this context, the meeting encouraged NWP centres to share their studies on surface weather verification, focused on the aspects identified in paragraphs 6.8 to 6.10 with members of the CG-FV **(Action, NWP Centres)**.

7. MANUAL ON THE GDPFS

7.1 The meeting recalled that the World Meteorological Congress, at its sixteenth session (Cg-XVI, May 2011) endorsed the request by CBS-XIV (2009) to undertake a comprehensive review of this Manual and adopted the outline for the revised Manual through Resolution 6 (Cg-XVI). In this context, the meeting was informed of the outcomes of the Expert Meeting on the Revision of the Manual of the GDPFS (Geneva, October 2011).

7.2 Noting that a first version of the new Manual would be presented to CBS-XV, in September 2012, for consideration, the meeting agreed that any proposed amendments to the Manual on the GDPFS (as those proposed under previous agenda items) should be reflected in the new version, with the exception that the two new areas for the Polar Regions that will be recommended as an amendment to the Manual at CBS-XV. The meeting agreed in principle that the set of parameters to be available on the WIS by the centres participating in global NWP should also be verified, however it discussed whether scientifically it is feasible to do for all parameters, and which verification should be mandatory or recommended. It agreed that specifications for the verification of upper air fields can be provided, but recommended procedures for surface parameters are still to be developed. With this in mind and taking into account that the proposed amendments to the CBS standard verification procedures are expected to be in force by 2014/2015, the meeting reviewed the draft text for the new Manual, on coordination of deterministic NWP verification as provided in Annex III.

7.3 The meeting noted editorial corrections or clarifications to the current Manual (2012 Update), as presented in Annex IV **(Action, Secretariat)**.

8. REVIEW THE TERMS OF REFERENCE OF THE COORDINATION GROUP ON FORECAST VERIFICATION (CG-FV)

8.1 The meeting reviewed the group's Terms of Reference (ToR) as adopted at CBS-Ext.(10), and agreed that there was no need to propose any changes. The group's ToR are provided in Annex V.

9. ANY OTHER BUSINESS (AOB)

9.1 There were no other issues raised during the meeting.

10. CLOSING

10.1 The meeting of the Commission for Basic Systems Coordination Group on Forecast Verification (CG-FV) closed at 12:30 on Thursday, 17 May 2012.

Annex I

AGENDA

1. OPENING

2. ORGANIZATION OF THE MEETING
- 2.1 Adoption of the agenda
- 2.2 Working arrangements

3. INTRODUCTION / REPORT OF THE CHAIR, INCLUDING REVIEW OF THE ACTIONS FROM THE LAST MEETING

4. REPORT ON THE OUTCOMES OF Cg-XVI RELATED AND/OR RELEVANT TO THE CG-FV

5. CBS STANDARD PROCEDURES FOR VERIFICATION OF UPPER AIR FIELDS
- 5.1 Implementation of revised procedures by NWP Centres
- 5.2 Review of the Lead Centre on Deterministic NWP Verification (LC-DNV) Web site
- 5.3 Paper on the updated verification procedures
- 5.4 Scores for polar region
- 5.5 Sensitivity to analysis differences
- 5.6 Review of sensitivity to differences in observation availability/usage

6. VERIFICATION OF SURFACE FIELDS

7. MANUAL ON THE GDPFS

8. REVIEW THE TERMS OF REFERENCE OF THE COORDINATION GROUP ON FORECAST VERIFICATION (CG-FV)

9. ANY OTHER BUSINESS

10. CLOSING

Annex II

LIST OF PARTICIPANTS

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Annex III

DRAFT TEXT FOR THE NEW MANUAL ON CORDINATION OF DETERMINISTIC NWP VERIFICATION

II.2.3.1 – Coordination of deterministic NWP verification

SPECIFICATION

The centre(s) participating in activity 2.3.1, coordination of deterministic NWP verification, shall be designated as Lead Centre(s) for deterministic NWP verification.
These centre(s) shall:

- Provide the facility for the GDPFS Centres producing global NWP to automatically deposit their standardized verification statistics as defined in appendix A.II.2.3.1, and access to these verification statistics
- Maintain an archive of the verification statistics to allow the generation and display of trends in performance
- Monitor the received verification statistics and consult with the relevant participating centre if data is missing or suspect
- 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.
- 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
- 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

These centre(s) may also provide access to standardized software for calculating scoring information.

RESPONSIBILITY AND *(if required)* COORDINATION *(Changes to Activity Specification)*			
To be proposed by:	CBS/CG-FV	CBS/ICT-DPFS	
To be approved by:	CBS		
To be decided by:	EC / Congress		
DESIGNATION			
To be approved by:	CBS		
To be decided by:	EC / Congress		
COMPLIANCE			
To be monitored by:	CBS/CG-FV		
To be reported to:	CBS/ICT-DPFS	CBS	

Appendix A.II.2.3.1

I – STANDARDIZED VERIFICATION OF DETERMINISTIC NWP PRODUCTS

1. Introduction

This Appendix presents detailed procedures for the production and exchange of a standard set of verification scores for deterministic NWP forecasts produced by GDPFS centres. The goal is to provide consistent verification information on the NWP products of GDPFS participating centres for forecasters in the NMHSs and to help the GDPFS Centres compare and improve their forecasts. Scores will be exchanged between the participating producing centres via the Lead Centre for DNV. The Lead Centre functions, as described in II.2.3.1, include creating and maintaining a website for Deterministic NWP verification information, so that potential users will benefit from a consistent presentation of the results.

The term "deterministic NWP" refers to single integrations of NWP models providing products defining single future states of the atmosphere (as distinct from ensemble prediction systems where multiple integrations provide a range of future states).

The standardized verification should provide key relevant information appropriate to the state-of-the-art in NWP, while being as simple and as easy to implement as possible, and ensuring a consistent implementation across participating centres, 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 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 Temp, wind, total precipitation) are developed and in response to changing user requirements. The detailed procedures are required to ensure it is possible to compare results from the different participating centres in a scientifically valid manner.

3. Parameters

Extra-tropics

Mandatory

- Mean sea-level pressure (verification against analysis only)
- Geopotential height at 850, 500 and 250 hPa
- Temperature at 850, 500 and 250 hPa
- Wind at 925, 850, 700, 500 and 250 hPa
- Relative humidity at 850 and 700 hPa

Additional recommended

- Geopotential height, temperature, wind at 100 hPa

Tropics

Mandatory

- Geopotential height at 850 and 250 hPa
- Temperature at 850 and 250 hPa
- Wind at 850 and 250 hPa
- Relative humidity at 850 and 700 hPa

4. Forecast times

Scores shall be computed daily for forecasts initialised at 00 UTC and 12 UTC separately. For those 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.

5. Forecast steps

Every 12h 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
North America	25°N–60°N 50°W–145°W
Europe/North Africa	25°N–70°N 10°W–28°E
Asia	25°N–65°N 60°E–145°E
Australia/New Zealand	10°S–55°S 90°E–180°E
Northern polar region	90°N - 60°N, inclusive, all longitudes
Southern polar region	90°S - 60°S, inclusive, all longitudes

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

7. Verification against analyses

7.1 Grid and interpolation

All parameters shall be verified against the centre's own analysis on a regular 1.5° x 1.5° grid.

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

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

- Spectral fields: truncate to equivalent spectral resolution (T120) for verification grid
- Grid point fields: use area-weighting to interpolate to verification grid

For scores requiring a climatology the climatology is made available via the LC-DNV website on the verification grid and needs no further interpolation.

8. Verification against observations

8.1 Observations

All parameters listed in section 3, except mean sea-level pressure, shall be verified against a common set of radiosondes. The list of radiosonde observations for each area is updated annually by the CBS Lead Centre for radiosonde monitoring. The chosen stations' data must be available to all the centres and be of sufficient quality on a regular basis. Consultation with all centres (usually by electronic mail) is desirable before establishing the final list. The current list

is available via the website of the LC-DNV. The LC-DNV will contact all participating centres when the new list is available and inform them of the date from which the new list shall be used.

The observations used for verification shall be screened to exclude those with large errors. In order to do this, it is recommended that centres exclude values rejected by their objective analysis. Moreover, centres which apply a correction to the observations received on the GTS to remove biases (e.g. radiation correction), should use the corrected observations to compute verification statistics.

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 radiosondes consist of radiosonde stations located in the areas listed in Section 6.

The list of radiosonde stations to be used for each area is updated annually by the CBS Lead Centre for radiosonde monitoring (see subsection 8.1)

9. Scores *[move to Part II, 1.4]*

The following scores are to be calculated for all parameters against both analysis and (except mean sea-level pressure) observation.

Wind

Mandatory:

- rms vector wind error
- mean error of wind speed

Other parameters:

Mandatory

- Mean error
- Root mean square (rms) error
- Correlation coefficient between forecast and analysis anomalies (not required for obs)
- S1 score (only for MSLP and only against analysis)

Additional recommended

- mean absolute error
- rms forecast and analysis anomalies (not required for observations)
- standard deviation of forecast and analysis fields (not required for observations)

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

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

Mean absolute error $$MAE = \sum_{i=1}^{n} w_i \left| x_f - x_v \right|_i \Big/ \sum_{i=1}^{n} w_i$$

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

standard deviation of field $$sd = \sqrt{\sum_{i=1}^{n} w_i (x - M_x)_i^2} \Big/ \sqrt{\sum_{i=1}^{n} w_i}$$ where $$M_x = \sum_{i=1}^{n} w_i x_i$$

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

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

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

where the differentiation is approximated by differences computed on the verification grid.

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. 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 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. Monthly and annual averaged scores

Where average scores are required over a defined period, the averaging shall be made using the following procedures:

Linear scores (mean error, mean absolute error) - mean
Non-linear score should be transformed to appropriate linear measure for averaging
- mean of MSE;
- Z-transform for correlation

For a defined period, the average shall be computed over all forecasts verifying during the period. Averages shall be computed separately for forecasts initiated at 00 UTC and 12 UTC and both sets of average values provided.

13. Confidence Intervals

Confidence intervals will be computed by the LC-DNV using the daily scores. The method used will be documented on the LC-DNV web site.

14. 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, changes in additional statistics) and changes in their NWP model.

Annex IV

EDITORIAL CORRECTIONS OR CLARIFICATIONS TO THE CURRENT MANUAL (2012 UPDATE) (Track changes)

I – STANDARDIZED VERIFICATION OF DETERMINISTIC NWP PRODUCTS

1. Introduction

This section presents detailed procedures for the production and exchange of a standard set of verification scores for deterministic NWP forecasts produced by GDPFS centres. The goal is to provide consistent verification information on the NWP products of GDPFS participating centres for forecasters in the NMHSs and to help the GDPFS Centres compare and improve their forecasts. Scores will be exchanged between the participating producing centres via the Lead Centre for DNV. The Lead Centre functions, as described in Attachment II.14, include creating and maintaining a website for Deterministic NWP verification information, so that potential users will benefit from a consistent presentation of the results.

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

The standardized verification should provide key relevant information appropriate to the state-of-the-art in NWP, while being as simple and as easy to implement as possible, and ensuring a consistent implementation across participating centres, 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 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 are developed and in response to changing user requirements. The detailed procedures are required to ensure it is possible to compare results from the different participating centres in a scientifically valid manner.

3. Parameters

Extra-tropics

Mandatory

- Mean sea-level pressure (verification against analysis only)
- Geopotential height at 850, 500 and 250 hPa
- Temperature at 850, 500 and 250 hPa
- Wind at 850, 500 and 250 hPa

Additional recommended

- Geopotential height, temperature, wind at 100 hPa
- Relative humidity at 700 hPa

Tropics

Mandatory

- Geopotential height at 850 and 250 hPa
- Temperature at 850 and 250 hPa

- Wind at 850 and 250 hPa

Additional recommended
- Relative humidity at 700 hPa

4. Forecast times

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

5. Forecast steps

Mandatory: forecast steps 24h, 48h, 72h, ..., 240h or end of the forecast
Additional recommended: 12-hourly throughout forecast (12h, 24h, 36h, ...)

6. Verification against analyses

6.1 Grid and interpolation

All parameters shall be verified against the centre's own analysis on a regular 1.5° x 1.5° grid.

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

Interpolation of higher resolution model fields to the verification grid shall be performed to retain features at the scale of the verification grid but not to introduce any additional smoothing. The following procedures shall be used:
- Spectral fields: truncate to equivalent spectral resolution (T120) for verification grid
- Grid point fields: use area-weighting to interpolate to verification grid

For scores requiring a climatology the climatology is made available via the LC-DNV website on the verification grid and needs no further interpolation.

6.2 Areas

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

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

7. Verification against observations

7.1 Observations

All parameters defined in section 3, except mean sea-level pressure, shall be verified against a common set of radiosondes. The list of radiosonde observations for each area is updated annually by the CBS Lead Centre for radiosonde monitoring. The chosen stations' data must be available to all the centres and be of sufficient quality on a regular basis. Consultation with all centres (usually by electronic mail) is desirable before establishing the final list. The current list is available via the website of the LC-DNV. The LC-DNV will contact all participating centres when the new list is available and inform them of the date from which the new list shall be used.

The observations used for verification shall be screened to exclude those with large errors. In order to do this, it is recommended that centres exclude values rejected by their objective analysis. Moreover, centres which apply a correction to the observations received on the GTS to remove biases (e.g. radiation correction), should use the corrected observations to compute verification statistics.

7.2 Interpolation

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

7.3 Areas

The networks used in verification against radiosondes consist of radiosonde stations located in the following geographic areas:

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

The list of radiosonde stations to be used for each area is updated annually by the CBS Lead Centre for radiosonde monitoring (see subsection 7.1)

8. Scores

The following scores are to be calculated for all parameters against both analysis (except mean sea-level pressure) and observation.

Wind

Mandatory:

- rms vector wind error
- mean error of wind speed

Other parameters:

Mandatory

- Mean error
- Root mean square (rms) error
- Correlation coefficient between forecast and analysis anomalies (not required for obs)
- S1 score (only for MSLP and only against analysis)

Additional recommended

- mean absolute error
- rms forecast and analysis anomalies (not required for observations)
- standard deviation of forecast and analysis fields (not required for observations)

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

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

standard deviation of field $$sd = \sqrt{\sum_{i=1}^{n} w_i (x - M_x)_i^2} \; / \sqrt{\sum_{i=1}^{n} w_i} \quad \text{where} \quad M_x = \sum_{i=1}^{n} w_i x_i$$

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

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

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

where the differentiation is approximated by differences computed on the verification grid.

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

9. 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.

10. 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 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.

11. Monthly and annual averaged scores

Where average scores are required over a defined period, the averaging shall be made using the following procedures:

Linear scores (mean error, mean absolute error): mean

Non-linear score should be transformed to appropriate linear measure for averaging

mean of MSE;

Z-transform for correlation

For a defined period, the average shall be computed over all forecasts verifying during the period. Averages shall be computed separately for forecasts initiated at 00 UTC and 12 UTC and both sets of average values provided.

Annual averages of the daily scores are included in the yearly Technical Progress Report on the Global Data-processing and Forecasting System. These statistics are for the 24, 72 and 120 h forecast and include the rms vector wind error at 850 hPa (tropics area only) and 250 hPa (all areas) as well as the rms error of geopotential heights at 500 hPa (all the areas except for tropics). A table of the number of observations per month should also be part of the yearly report.

12. Confidence Intervals

Bootstrapping*. Will be done by LC-DNV if daily scores are provided.

*Note: Introduction:

Any verification score must be regarded as a sample estimate of the "true" value for an infinitely large verification dataset. There is therefore some uncertainty associated with the score's value, especially when the sample size is small or the data are not independent. Some estimate of uncertainty (confidence intervals) must be used to set bounds on the expected value of the verification score. This also helps to assess whether differences between competing forecast systems are statistically significant. Typically confidence intervals of 5 per cent and 95 per cent are used.

Suggested method to calculate the Confidence Intervals (CI):
Mathematical formulae are available for computing CIs for distributions which are binomial or normal. In general, most verification scores cannot be expected to satisfy these assumptions. Moreover, the verification samples are often spatially and temporally correlated, especially at longer forecast ranges. A non parametric method such as the block bootstrap method handles spatially or temporally correlated data.

As described in Candille et al. (2007), a bootstrap technique for computing CIs involves recomputing scores numerous times after randomly extracting samples from the data set and then replacing them, again randomly, from the original data set. The correlation between forecasts on subsequent days is accounted for by extracting and replacing blocks of samples from the data set, rather than individual samples. Based on a calculation of the autocorrelation between forecasts on subsequent days, it is concluded that blocks of 3 days may be used to calculate the 5 per cent and 95 per cent confidence intervals.

References:
– WMO/TD No. 1485 Recommendations for verification of QPF.
– G. Candille, C. Côté, P. L. Houtekamer and G. Pellerin, 2007: Verification of an Ensemble Prediction System against Observations, *Monthly Weather Review*, Vol. 135, pp. 2688–2699.

13. 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, changes in additional statistics) and changes in their NWP model.

Annex V

TERMS OF REFERENCE FOR THE CG-FV

Coordination Group on Forecast Verification

(a) In consultation with the relevant Expert Teams, review procedures for verification of the performance of forecasting systems to ensure that they are adequate and meet CBS needs;

(b) Ensure that verification systems are appropriate to emerging forecast types such as probabilistic forecasts, very high resolution NWP products, and nowcasting products;

(c) Develop suitable verification procedures for severe weather forecasts and warnings;

(d) Review Lead Centre activities and provide guidance as appropriate;

(e) Liaise with WWRP/WGNE as required;

(f) Provide guidance on how to implement verification systems.

Annex VI

LIST OF ACTIONS

Para	Action	By whom	By when
5.1.1	To send the report of the current CG-FV meeting to all NWP centres and request them to fill in the Table 5.1	Secretariat / NWP Centres	ASAP
5.1.3	To continue the study on the use of additional observational data (air motion vectors and AMDAR data) on global indices and keep other NWP centres up-to-date on the developments	Met Office UK	Ongoing
5.2.2	To provide access to all WMO Members through their WMO accounts	LC-DNV	ASAP
5.2.2	To provide feedback, including comments and questions, on anything related to the LC-DNV by e-mail to wmolcdnv@lists.ecmwf.int	NWP Centres	Ongoing
5.2.2	To announce the LC-DNV web site by sending out a circular letter to WMO Members	Secretariat	Upon receipt confirmation by the LC-DNV
5.2.2	To present the LC-NDV web site in various conferences, symposia and seminars	NWP Centres	Ongoing
5.3.1	To check progress made by all NWP centres in having at least one year of data; and to lead the preparation of a paper on the updated CBS standard verification procedures (which should include results of the various impact studies) by circulation of a draft outline among those NWP centres in order to participate	NWP Centres, lead by Chairperson	End 2012
5.3.2	To present the updated CBS standard verification procedures in various conferences, symposia and seminars, including at the meeting of the American Meteorological Society (AMS), in 2013	NWP Centres	Ongoing
5.5.1	To summarize the results of the studies which evaluate the sensitivity to analysis differences on verification metrics	Met Office UK and JMA	Mid-June 2012
5.5.1	To make the summaries of the results of the studies available on the LC-DNV web site	LC-DNV	Upon receipt the studies
5.5.1	To carry out further studies to evaluate the differences between different centres' analysis and estimate the uncertainty in the analysis	NWP Centres	End 2013
5.6.2	To carry out further research on the sensitivity of differences in observation availability/usage with extended periods to clarify the sensitivity to differences in observation availability/usage	NWP Centres, lead by CMC	End 2013
6.5	To keep the CG-FV informed of further developments and application of a prototype surface weather index (comprised by a combination of surface parameters for certain thresholds)	Met Office UK	End 2013
6.6	To send/make available the global precipitation forecast fields from their models to ECMWF	NWP Centres	Ongoing
6.6	To compute the SEEPS score for precipitation forecasts for all NWP Centres and display the	LC-DNV	Ongoing

	results on the LC-DNV web site		
6.7	To make available the climatology for the synoptic stations on the LC-DNV ftp site (password protected)	LC-DNV	ASAP
6.7	To compute the SEEPS score and send it to the LC-DNV for display	NWP Centres	Ongoing
6.8	To carry out a study on the sensitivity of verification results to differences in use of a fixed versus an evolving list of stations, including a study on the quality control of the observations	Met Office UK	End 2013
6.10	To carry out a study on interpolation methods for each surface parameter	ECMWF	End 2013
6.10	To review and follow up the studies on verification of surface parameters	Chairperson	End 2013
6.11	To share their studies on surface weather verification	NWP Centres	End 2013
7.3	To make the editorial corrections or clarifications to the current Manual (2012 Update), as per Annex IV	Secretariat	ASAP