WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

CBS IMPLEMENTATION COORDINATION TEAM
OF THE OPEN PROGRAMME AREA GROUP (OPAG)
ON DATA-PROCESSING AND FORECASTING SYSTEMS
(ICT-DPFS)

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FINAL REPORT

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EXECUTIVE SUMMARY

The Meeting of the CBS Implementation Coordination Team of the Open Programme Area Group (OPAG) on Data-Processing and Forecasting Systems (ICT-DPFS) was held in Paris, France, from 21 to 25 May 2012.

The ICT discussed the future evolution of the Severe Weather Forecasting Demonstration Project (SWFDP), including resources necessary for setting up new regional subprojects and further development of the entire SWFDP. It considered that this is dependent on securing a sustainable management resource with responsibility for coordination of WMO support for regional subprojects, and therefore requires a dedicated Office. The ICT concluded that a study is urgently required to scope the resource requirements of such Office, starting from an evaluation of the resources utilized by the Project thus far.

The ICT reviewed the outcomes of the meetings of the OPAG-DPFS Expert Teams (ETs) and Coordination Groups (CGs) and agreed on their future work programmes, which would be recommended to CBS-XV, in September 2012.

The ICT also reviewed the current version of the Manual on the GDPFS (WMO-No. 485) and proposed amendments as appropriate. It also reviewed the draft text for the Revised Manual. It noted that there were a number of parts of the new Manual that needed to be developed and therefore requested the Secretariat to contact the identified experts to prepare draft text for the new Manual by mid-June so that it could be presented for consideration by CBS-XV. The ICT noted that the new Manual introduces a number of changes to the current procedures. It therefore acknowledged that some GDPFS centres may report temporary non-compliance with regard to some of the requirements, mainly because of resource constraints during system development. In this context, the ICT noted that a transition plan for the implementation of the new Manual, which will replace the current version, needs to be developed to manage the technical changes and the initial designation of the GDPFS centres as defined in the new Manual, including WMCs and RSMCs. The ICT will develop such a plan for consideration by CBS.

Finally, the ICT investigated ways of changing the working structure to avoid overlaps and to address the difficulties, and also to make the overall structure lighter and easier to manage so that it could respond even more efficiently than at present to evolving requirements, priorities, key objectives etc. It worked out a structure comprised of an ICT and three standing Expert Groups (instead of five teams and two rapporteurs as at present), one on Forecasting Processes and Support (FPS), other on extended- and long-range forecasting, and the third on Emergency Response Activities (ERA). In addition dedicated Task Teams would be set up by the ICT for limited periods with specific targets and deliverables to be produced. The existing structure with revised ToR is presented in Annex IX and the alternative structure, including ToR for the Expert Groups and the indicative list of Task Teams that would be needed to address the present work programme of the OPAG, is given in Annex X. The ICT recommended that this alternative structure be considered for implementation by the forthcoming CBS session.

GENERAL SUMMARY OF THE WORK OF THE SESSION

1. OPENING

1.1 The Meeting of the CBS Implementation Coordination Team of the Open Programme Area Group (OPAG) on Data-Processing and Forecasting Systems (ICT-DPFS) was opened by its chairperson, Mr Bernard Strauss (Météo-France), at 09.30 hours on Monday, 21 May 2012, at the Headquarters of Météo-France, in Paris, France. Mr Strauss welcomed participants to the meeting. He introduced Mr Marc Gillet, Head of International Affairs Office of Météo-France, to address the meeting.

1.2 Mr Marc Gillet, on behalf of the Director-General of Météo-France Mr François Jacq, welcomed all participants to the meeting of the CBS/ICT-DPFS and to Météo-France headquarters, in its new building, in Saint Mandé near Paris. He noted that the headquarters of Météo-France is now collocated with the “Service Hydrographique et Océanographique de la Marine” (SHOM) and the “Institut National de l’Information Géographique et Forestière” (IGN), which are all part of a geophysics pole. He highlighted the importance to and the interest of Météo-France for all aspects of the data-processing and forecasting systems, from nowcasting to long-range forecasting, and the support to disaster risk reduction (DRR). In this context, he informed the meeting that Météo-France had recently extended its “Vigilance” system by adding storm surge aspects. He noted that Météo-France has been participating in the Severe Weather Forecasting Demonstration Project (SWFDP) in Southern Africa through its regional office in “La Réunion”, and anticipated that similar support could be provided to other SWFDP regional projects in areas such as Eastern and Western Africa and/or overseas departments (e.g. Caribbean and South Pacific). Mr Gillet noted that Météo-France takes part in the proposed RA VI RCC-network, being responsible for the long-range forecasting jointly with Roshydromet (Russian Federation). He concluded by wishing everyone a successful meeting.

1.3 Mr Peter Chen, on behalf of the Secretary-General of the WMO, Mr Michel Jarraud, welcomed participants to the meeting and expressed the gratitude and appreciation of WMO to Météo-France for hosting this meeting in Paris and for providing these excellent facilities. Mr Chen also thanked Mr Bernard Strauss of Météo-France for guiding the work of the OPAG-DPFS. Mr Chen expressed gratitude to the chairpersons of the OPAG’s Teams and Groups, and Rapporteurs for their dedication and efforts to the work that was assigned under their individual and collective leadership, which will continue to assist WMO to provide even better assistance to its Members in facing challenges of improving their forecasting systems and services.

2. ORGANIZATION OF THE MEETING

2.1 Adoption of the agenda

2.1.1 The ICT adopted the provisional agenda without changes, as provided in Annex I to this report.

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 website at:

http://www.wmo.int/pages/prog/www/DPFS/Meetings/ICT-DPFS_Paris2012/DocPlan.html

2.2.2 The ICT agreed its hours of work and other practical arrangements for the meeting. The meeting welcomed Mr Masami Sakamoto, who is attending the meeting on behalf of the chairperson of the Coordination Group on Nuclear Emergency Response Activities (CG-NERA), Mr René Servranckx. The list of participants in the meeting is provided in Annex II to this report.

3. INTRODUCTION AND BACKGROUND / REVIEW OF DECISIONS OF THE WMO GOVERNING BODIES AND STATEMENTS ADOPTED BY CBS RELATED TO THE OPAG on DPFS

3.1 The ICT was presented with background information related to the OPAG on DPFS, including recalling statements adopted by the 2010 extraordinary session of the Commission for Basic Systems (CBS-Ext.(10), November 2010), and relevant decisions of the sixteenth World Meteorological Congress (Cg-XVI, May 2011).

3.2 The ICT noted that CBS-Ext.(10) recognized progress and made a number of recommendations on DPFS activities, including on severe weather forecasting and the SWFDP, very-short-range forecasting, extended- and long-range forecasting, probabilistic forecasting and Ensemble Prediction Systems and applications, NWP forecast verification for deterministic NWP, emergency response activities – atmospheric transport modelling, revision of the Manual on the GDPFS (WMO-No. 485), the collaboration with CAS on operational aspects of the sand and dust storm system, capacity building and quality management framework. CBS-Ext.(10) recommended amendments to the Manual on the GDPFS, which were approved by Cg-XVI. The ICT noted that detailed information on progress made against these recommendations would be provided under the related agenda items.

3.3 The ICT noted that Cg-XVI concurred that the GDPFS should continue to develop under the responsibility of CBS, with a focus on operationalization of the following key areas: Severe Weather Forecasting, Very-Short-Range Forecasting, Probabilistic Forecasting and Ensemble Prediction Systems, Long-Range Forecasting, and NWP Verification. It also noted that Cg-XVI agreed that the GDPFS should continue to participate in coordinated training and capacity building activities and that the ERA should continue to provide high quality meteorological support to nuclear and non-nuclear environmental emergency response. In addition, the ICT noted the requests by Cg-XVI to (a) the Secretary-General and CBS to develop a strategy to assist Members in the implementation of improved high-resolution regional NWP including data assimilation; and (b) CBS to review the EER procedures in the Manual on the GDPFS, in order to strengthen aspects related to the provision of specialized meteorological information to the general public, in case of a nuclear emergency and volcanic ash events, and in the context of national disaster.

4. SEVERE WEATHER FORECASTING

4.1 The Rapporteur on the Application of NWP to Severe Weather Forecasting, Mr Jean-Marie Carrière (France), presented an overview of recent developments and advances on NWP/EPS to severe weather and high impact weather forecasting, being implemented by a number of WMO Members. These new techniques include: assimilation ensembles, the use of different physics in the model (perturbation of the physics) and/or perturbation of some parameters in the parameterization schemes. The ICT noted that EPS products (e.g. EFI, EPSgrams, probability of reaching or exceeding a given threshold, etc.) could be used by forecasters in the early detection of severe weather events and in the provision of information about the uncertainty or the probability that this event occurs. It further noted that EPS could also be used to provide information about the uncertainty of non-atmospheric hazards occurring by coupling EPS with other models (e.g. storm surges, atmospheric pollution transport and dispersion, floods, etc.). Realizing the availability and access to various EPS, the ICT noted that operational multi-ensemble approaches have also been developed and used. The ICT noted that these issues have been addressed by the CBS Expert Team on Ensemble Prediction Systems (ET-EPS) and agreed to further discuss them under agenda item 7.

4.2 The Secretariat briefed the ICT on (a) the Severe Weather Forecasting Demonstration Project (SWFDP), including the progress and major achievements of the regional subprojects in Southern Africa, South Pacific, Southeast Asia and Eastern Africa, and the recent development of a new subproject for the Bay of Bengal region; and (b) the outcomes of the fourth meeting of the Steering Group for the SWFDP (SG-SWFDP, Geneva, February-March 2012).

4.3 The ICT noted that the SG-SWFDP identified issues associated with the implementation of the regional subprojects, including sustainability, training aspects, and support for the full participation of NMHSs. In particular, the ICT recognized that SWFDP strategic issues include the limited effectiveness of the current project activities in addressing the needs of those NMHSs with very constrained technical capacity, due to limited or inadequate resources (human and financial). The ICT agreed that to address this issue, a number of activities might be targeted specifically to these NMHSs to address gaps and weaknesses, in order to bring them fully on board. Therefore, it agreed with the approach of developing national implementation plans (as the one taken in the SWFDP – Eastern Africa), resources permitting. The ICT endorsed a set of recommendations by the SG-SWFDP to support the full and sustainable participation of NMHSs, including those from LDCs, as presented in Annex III, and agreed to submit them for consideration by CBS-XV.

4.4 The ICT recalled that Cg-XVI approved a vision for the SWFDP as an end-to-end cross-programme collaborative activity led by the GDPFS. It noted that the SG-SWFDP discussed the integration of satellite information, testing GIFS-TIGGE developments, synergies with Flash Flood Forecasting, agricultural meteorology, etc. and developed a strategy for integrating new components into the SWFDP. The ICT endorsed this strategy, as presented in Annex IV, and agreed to recommend it for consideration by CBS-XV.

4.5 The ICT noted that the SG-SWFDP reviewed the *SWFDP Overall Project Plan* and *SWFDP Guidebook on Implementing Regional Subprojects*, and agreed on a number of issues that should be added and/or modified. Noting that these documents are very relevant for the development of new regional subprojects, as well as for resource mobilization, the ICT requested the WMO Secretariat to work with members of the SG-SWFDP in updating these two documents as soon as possible.

4.6 The ICT noted that SG-SWFDP developed draft text for the new Manual on a proposed specification of a network of regional and national centre(s) participating in severe weather forecasting, which is a new aspect to be incorporated into the Manual on the GDPFS. It agreed to review this draft text under agenda item 10.

4.7 The ICT noted that the SG-SWFDP discussed future directions for the SWFDP, including prospects for new regional subprojects. In view of the limited resources available, the ICT considered that, in the short term, any new project initiation should be delayed until at least one of the existing subprojects has reached Phase 4, i.e., continuing development phase, including full transfer of the project management to the regional level.

4.8 The ICT noted that the concern about resources necessary for setting up new subprojects extends to the continued success and further development of the entire SWFDP. It considered that this is dependent on securing a sustainable management resource with responsibility for coordination of WMO support for regional subprojects, including:

- Working with resource mobilization teams to secure long-term sustainable funding, and to manage the effective use of funds so as to ensure the sustainability of subprojects;
- Assisting where necessary the establishment of funding to enable the regional and global centres to transition their contributions from short-term demonstration to long-term sustainable services;
- Organizing central train-the-trainers workshops to support the regions in providing up-to-date training;
- Planning and implementing specific training and development activities in support of LDCs, such as the establishment of training desks in regional and global centres, organizing the exchange of staff, including forecasters, and developing appropriate mentoring schemes;
- Supporting the initiation of new subprojects and providing such support as is required to progress subprojects through to phase 4 (the continuing development phase) including full transfer of the subproject management to the regional level;

- Managing the cross-programme links of the SWFDP with other WMO programmes, including WWRP GIFS-TIGGE research, and application programmes such as the aviation, marine, hydrology, agriculture and health programmes.

4.9 The ICT considered that the sustainable provision of this support to the existing and new subprojects requires a dedicated Office, and that a study is urgently required to scope the resource requirements of such an Office, starting from an evaluation of the resources utilized by the Project thus far.

5. VERY SHORT-RANGE FORECASTING

5.1 The Rapporteur on the Application of NWP to Severe Weather Forecasting, Mr Jean-Marie Carrière (France), presented an overview of recent developments and advances on nowcasting and very short-range forecasting, being implemented by a number of WMO Members. These include: rapid refresh and high resolution modelling, and km-scale ensemble prediction. The ICT agreed that the implementation of rapid refresh suites has renewed the interest in using NWP models for nowcasting, while bringing new challenges on data assimilation, spin-up and cycling issues. At the same time, the ICT noted that as computer power increases and assimilation techniques improve, it becomes possible to run high resolution ensemble systems. A set of forecasts can be built either by using different lateral boundary conditions (coupling from global ensemble prediction systems), different initial states, different model error representation, or perturbations in the physics of the model (e.g. the cloud microphysics). The ICT noted that benefits of using km-scale or non-hydrostatic ensemble systems could be expected in the case of severe convective events, where present deterministic models often fail to adequately represent local extreme precipitations events.

5.2 The Secretariat briefed the ICT on the outcomes of the Expert Meeting on Very Short-Range Forecasting (EM-VSRF, Geneva, March 2011). The ICT noted that the EM-VSRF developed recommendations and guidelines on the way forward and future work on very short-range forecasting. In particular, the EM-VSRF agreed that very short-range forecasting should be considered/addressed as an end-to-end process, covering the following aspects: (i) in situ and remote-sensed observations; (ii) NWP, including verification aspects; (iii) post-processing, including blending approaches and extrapolation; and (iv) interactions with end-users. The EM-VSRF also agreed that education and training issues are relevant in all stages of the very short-range forecasting system, as well as visualization tools. The ICT recommended that more efforts be made on targeting sensitive areas/aspects of this end-to-end process.

5.3 Recognizing the importance of availability and timely (real-time) exchange of observational data including in situ meteorological observations and retrievals of observational data, and parameters (e.g. estimates of instability) computed from data acquired from satellite-based systems, aircraft (i.e. AMDAR), lightning and radar (where available), and noting that many required data sets are not exchanged on the WIS, the ICT encouraged the open exchange among NMHSs of such data for use in real-time severe weather forecasting and warning programmes. In addition to synoptic observational data, which are generally available through the WIS, the ICT recognized the importance of data from other observational systems (e.g. rain and river gauges) for various applications (e.g. tuning remote-sensed products, post-processing, and validation of NWP outputs). The ICT acknowledged the urgency to resolve the issues of data exchange at regional level, in order to make improvements on multi-hazard warning systems (e.g. flash flood guidance system), and therefore recommended that this exchange of observational data could follow the models developed within the SWFDP.

5.4 While noting that many NMHSs in developing countries do not have operating weather radars and/or national-wide radar coverage to support timely and accurately forecasts and warnings of severe convective in the very short-range forecasting period, the ICT agreed that satellite data processing systems and products represent new and powerful tools for forecasting in this forecast range. It therefore recommended that NMHSs in developing and Least Developed Countries (where weather radars are few or nonexistent) to make maximum use of satellite-based products. Recognizing that there are difficulties in the uptake of new products into weather forecasting daily routines of the forecasters, the ICT agreed that the SWFDP provides an appropriate model for introducing these new elements (as includes verification and reporting mechanisms, and training aspects), and recommended the development of guidelines on how to use and interpret these products at the regional level, taking into account regional and national requirements. These guidelines should be focused on practical use of such products by forecasters. In this context, the ICT was informed that the CGMS-WMO Virtual Laboratory for Satellite Meteorology has been effectively used in the 2011 SWFDP – Eastern Africa training workshop. It recommended that the SG-SWFDP further liaise with the WWRP/CAS Working Group on Nowcasting Research (WGNR) and the WMO Space Programme to address technologies and tools for nowcasting using satellite data processing systems and products, and develop such guidelines and e-learning modules.

5.5 The ICT agreed that high-resolution (10km resolution, or less) limited area models (LAMs) are very relevant to very short-range forecasting, however it noted the significant resources required to maintain such NWP systems in operational use and in optimal configuration (boundary conditions, local data assimilation, model tuning and adjustment, and verification). It therefore recommended that established RSMCs could provide NWP products to NMHSs in a region, following the model of the SWFDP. The ICT recommended that this approach should be included as part of the strategy to assist WMO Members in the implementation of improved high-resolution regional NWP, including data assimilation, in response to the Cg-XVI request. It also recommended to include this issue in the work programme for the GDPFS and the establishment of a Task Team to address this aspect.

5.6 Noting that SAF nowcasting (http://www.nwcsaf.org/HD/MainNS.jsp) makes its products and software available for implementation upon request, which can be used for early detection of potential development zones, the ICT recommended that these products be implemented at the global and regional levels, within the framework of the SWFDP. Recognizing that the algorithms may not apply from one satellite data acquisition system to another (i.e. different regions have different satellites, and different instrument and data systems), and the need for tuning products for a specific region, the ICT also recommended further engagement of the WMO Space Programme, and its Expert Team on Satellite Products and Utilization, in the SWFDP, at both the SG-SWFDP as well as at the Regional Subproject Management Team for each subproject, to advise on these aspects.

5.7 The ICT noted that there is a diversity of post-processing systems developed and implemented by WMO Members and agreed that there is a need to exchange such systems and share knowledge. In this context, the ICT recommended the use of an existing post-processing tool that NMHSs could adapt and implement, in whole or in part. In this context, it requested the Secretariat to work with those WMO Members that have developed and implemented such post-processing systems to facilitate the transfer of technology and knowledge among NMHSs. The ICT suggested that this could be done within the framework of the SWFDP.

6. EXTENDED- AND LONG-RANGE FORECASTING

6.1 The Chairperson of the Expert Team on Extended- and Long-Range Forecasting (ET-ELRF), Mr Richard Graham (UK), reported on the outcomes of the meeting of the Expert Team (Geneva, Switzerland, March 2012), highlighting emerging requirements on GPCs and associated Lead Centres (LCs) arising from activities in a number of areas, including: progress in implementation of the Climate Service Information System (CSIS) of the Global Framework for Climate Services (GFCS); accelerated progress towards designation of new Regional Climate Centres (RCCs) and developments with Regional Climate Outlook Forums (RCOFs); the developing Global Seasonal Climate Update (GSCU); the need for capacity building in the use of GPC products; recommendations from the ET on RCCs and lessons from the RCC development phase at ACMAD; and planning for a WWRP/THORPEX/WCRP research initiative on sub-seasonal to seasonal forecasting. The full report is available on the WMO website at http://www.wmo.int/pages/prog/www/DPFS/Meetings/ICT-DPFS_Paris2012/documents/Doc-6-ET-ELRF.doc.

6.2 Because of the growing requirements on GPCs and LCs, the ICT endorsed the ET-ELRF recommendation that a joint CBS/CCl workshop between GPCs/LCs and RCCs be organized to facilitate consolidation and prioritization of requirements. Proposed topics to be addressed include: review of the data requirements of RCCs and potential revision of the minimum list of variables to be supplied by GPCs; review and possible extension of the skill measures of the core SVSLRF; a Quality Management Framework for GPCs (dealing with, for example, protocol on informing of system changes); production of a standard naming convention for GPC products, to aid discovery on the GISC; development of guidelines for RCCs on the use of GPC products. The ICT noted that the ET-ELRF chairperson was tasked with scoping the workshop in close coordination with the joint CCl/CBS ET on RCCs and the WMO Secretariat.

6.3 The ICT took note of increasing demands on GPCs and LCs coming from their key roles in the CSIS of the GFCS and the need to ensure that these demands are considered in the GFCS implementation plan (including with regard to data storage and delivery technology). The ICT recommended that the ET-ELRF consider developing proposals for accessing the Trust Fund for the implementation of the GFCS to assist resourcing needed to respond to increasing demands.

6.4 The ICT noted that there are currently 12 GPCs (Beijing, CPTEC (Brazil), Exeter, Melbourne, Montreal, Moscow, Pretoria, Seoul, Tokyo, Toulouse, Washington and ECMWF) and since its previous meeting (Tokyo, September 2010) there have been no new applications for GPC status. The ICT noted with appreciation that a number of GPCs had made and were making significant enhancements to their prediction systems, which include: implementation of a coupled (1-tier) prediction system at GPC Montreal bringing the number of coupled systems in the network to eight; major upgrades to model physics and resolution at GPCs Exeter, ECMWF, Melbourne and Washington; upgraded hindcast datasets - 5 GPCs (Melbourne, Montreal, ECMWF, Washington and Seoul) now have hindcast periods that include the 1981-2010 period, the period recommended by the ET-ELRF (2010) meeting. Following the request by CBS-XIV regarding the review of GPC compliance with designation criteria, the ICT noted that GPCs have been providing minimum variables and some additional variables in a timely manner to the LC-LRFMME for at least 2 years; however, it acknowledged that some GPCs reported temporary non-compliance with regard to some of the verification requirements, mainly because of resource constraints during system development. GPCs Moscow, GPC Pretoria, GPC Tokyo and GPC Toulouse were congratulated on maintaining full compliance with GPC designation criteria. GPCs that were not currently fully compliant were encouraged to regain full compliance as soon as possible. The ICT was pleased to note that a paper describing the GPC network, its associated Lead Centres and its proposed role within the CSIS has been published in 2011 in the journal 'Climate Research' under the title 'Long-range forecasting and the Global Framework for Climate Services' (Graham et al., 2011).

6.5 The ICT noted with appreciation that a number of GPCs make available additional (non-mandatory) products including, grid-point value products, hindcast and forecast data required for downscaling, tropical cyclone products and experimental forecasts of rainy season onset and cessation.

6.6 The ICT noted with appreciation that the LC-LRFMME (operated by KMA and NOAA NCEP) has maintained operational services and its products have seen increasing use by RCCs and RCOFs. The LC-LRFMME has made substantial progress in developing new LC-LRFMME products from the GPC forecasts. In particular, probabilistic multi-model ensemble (MME) products for tercile categories have been developed and added, in June 2011, to the LC-LRFMME website, complementing the previously available deterministic (ensemble mean) products. Development of the probabilistic MME products has been accelerated to meet the schedule of the developing GSCU. Further developments include: new product formats, facilitating side-by-side display of forecasts from the GPCs; options to select different multi-model combining strategies and general improvement of the LC-LRFMME website framework.

6.7 The ICT noted with appreciation that the LC-SVSLRF has maintained and updated its website, a primary function of which is to display the SVSLRF skill scores supplied by GPCs in a standardized format. New verification data received from GPCs after upgrades to prediction systems has been uploaded as received. Monitoring of access to the LC-SVSLRF webpages indicates that the use of the verification information is at relatively low levels and this suggests that promoting use of the scores is more important than refining the SVSLRF. The most frequently accessed pages are those containing the skill maps.

6.8 The ICT noted that Cg-XVI requested the LC-LRFMME to extend its role to include the exchange of extended-range predictions and invited GPCs to provide data from their monthly forecast systems for display and generation of multi-model extended range products along the same lines as for seasonal range products. In order to allow coordination with the WWRP/THORPEX/WCRP research programme on subseasonal to seasonal prediction to inform this exchange, the ICT endorsed the ET-ELRF recommendation that a pilot exchange is first initiated, with GPCs supplying forecasts on a voluntary basis and the LC-LRFMME generating and displaying a range of products. While this pilot exchange is developing, and to accelerate the availability of extended-range products to WMO Members, it is recommended that GPCs running extended-range forecasts display an agreed set of products on their individual websites with coordination to achieve uniformity in display formats. The minimum variables to be exchanged are based on those of the seasonal exchange with additions to include the MJO diagnostics particularly relevant to the sub-seasonal range, as given in Annex V.

6.9 The ICT noted that standard procedures for verification of extended-range forecasts will be required to support the exchange of forecasts. Although the core skill measures of the SVSLRF may be used for verification of extended range forecasts, other aspects are not readily transferable (e.g. the hindcasts sets often do not have ensemble sizes large enough to allow robust probabilities of events of particular interest in the extended range (e.g. extremes) – and thus verification is often best achieved using accumulated real-time forecasts). The ICT therefore recommended waiting for results from the WWRP/THORPEX/WCRP research project on sub-seasonal to seasonal prediction – which will include verification activities – before finalizing standard verification guidelines for extended-range forecasts. In addition, noting the success of the SWFDP, particularly the established methodology of 'cascading forecasts' and the current implementation in East Africa, the Team suggested that a similar demonstration activity be scoped for extended-range forecasts – with scoping coordinated between GPCs, the implementation committee of the WWRP/THORPEX/WRCP sub-seasonal to seasonal research project and the steering group for the SWFDP.

6.10 The ICT noted that the further development of the seasonal-range exchange and verification and supported the recommendations by the ET-ELRF on:

(a) Hindcast exchange – noting that the provision of GPC hindcasts to the LC-LRFMME is strongly encouraged, but not mandatory, and acknowledging the importance of enhanced data exchange within the GFCS, it is recommended that the WMO secretariat contact the PRs of GPC countries urging all GPCs to participate in the hindcast exchange to the LC-LRFMME.

(b) Exchange of forecasts with longer lead time than 1 month – Noting that forecasts displayed on the LC-LRFMME website have so far been limited to a target period of the first 3 months after the month of issue (1-month lead from GPCs), and that lead times longer than 1 month have been identified as a requirement for the developing GSCU, and also for RCOFs in RA II, it is recommended that GPCs (particularly those with coupled systems) are urged to provide their forecast and hindcast data to lead times up to 3 months. Additionally the LC-LRFMME is requested to extend its display of GPC data and its multi-model products to include display of forecasts of greater than 1-month lead time.

(c) Provision of forecasts for higher order categories (e.g. outer quintiles), and exchange of additional variables and indices: It is recommended that GPCs provide forecasts of outer quintile categories (with accompanying skill information) to RCCs for their use at the regional level and that the following additional variables be included in the data exchange, for the time being on a non-mandatory basis: zonal and meridional components of the wind at 850 hPa and 200 hPa (U850, V850, U200, V200). Discussion of the formats for such products, other variables and large-scale climate indices, and whether they should be included in the minimum requirement for GPCs is proposed as a topic for the intended workshop between GPCs and RCCs.

(d) Verification of the LC-LRFMME multi-model products, GPC compliance with verification requirements of the SVSLRF, and real-time verification of LRF – it is recommended that verification of the LC-LRFMME multi-model products be completed by the LC-LRFMME following the SVSLRF and that the relevant scores and map information are passed to the LC-SVSLRF for display and to the TT-GSCU (to facilitate the pilot phase of the GSCU product). At the same time, all GPCs are urged to redouble their efforts to become fully compliant with the SVSLRF requirements (current Attachment II-8 of the Manual on the GDPFS). In addition, envisaging that the developing exchange of forecasts within GFCS will foster a requirement for more information on the real-time verification of forecasts, it is recommended that GPCs develop real-time verification products and make them available on their individual websites and that a link be provided to this information from the LC-SVSLRF website.

6.11 The ICT recalled that the WMO Executive Council requested CBS in collaboration with CCl to consider how multi-annual to decadal prediction systems being developed by some GPCs might be brought into the CSIS of the GFCS. It noted that GPC Exeter has (at the Exeter 2010 meeting) agreed to continue with an informal exchange of real-time decadal predictions. Real-time predictions to 10-year range, commencing 2011 and 2012 have so far been received from a number of prediction (research) centres. The ICT noted that first results of this exchange are promising and encouraged GPC Exeter to continue with the informal exchange and to prepare a written submission to CBS and CCl on results and recommendations on how such multi-annual/decadal predictions might be incorporated into the GFCS/CSIS.

6.12 The ICT noted that the ET-ELRF prepared an outline for a training curriculum, which the main objectives include increased understanding of (a) climate and its drivers; (b) climate models; (c) GPC products and services; (d) verification; and (e) communications (to convey the forecast in an efficient way to users). It also noted with appreciation that a number of GPCs have substantial capacity building commitments/programmes with RCCs, developing RCCs or RCOF communities. The ICT encouraged all GPCs to participate in capacity building and to provide guidance material, such as manuals, guides on the use of GPC products including scientific and technical aspects, guides on the skill of their forecasts etc., through their webpages, and to provide the website addresses to the WMO Secretariat, in order to develop a “pool” of training materials.

7. PROBABILISTIC FORECASTING AND ENSEMBLE PREDICTION SYSTEMS, AND APPLICATIONS

7.1 The Chairperson of the Expert Team on Ensemble Prediction Systems (ET-EPS), Mr Ken Mylne (UK), reported on the outcomes of the meeting of the Expert Team (Geneva, November 2011), highlighting progress made with respect to EPS-based products, probabilistic forecasting methods, and applications, coordination with THORPEX/GIFS-TIGGE especially related to implementation issues, and other aspects related to the ET’s Terms of Reference. The full report is available on the WMO website at http://www.wmo.int/pages/prog/www/DPFS/Meetings/ICT-DPFS_Paris2012/documents/Doc-7-ET-EPS.doc.

7.2 The ICT noted that Global Ensemble Prediction Systems have continued to improve in terms of horizontal and vertical resolution, and in diversification and advancement of the methods employed. For example, the generation of initial condition perturbations has advanced with the use of ensemble data assimilation and improved localization of perturbations at some centres, and the allowance for model uncertainty has advanced with the implementation of new methods of physics perturbations. One centre is now applying perturbations to sea-surface temperature (SST) fields to improve overall ensemble spread.

7.3 The ICT further noted that similar advances have also occurred in the implementation of limited area EPS (LAM-EPS). A large range of grid resolutions (typically between 7km and 33km) are employed, largely depending on the domain sizes of the countries running the systems. A wider range of methods is used than in the global systems. For example, use of multiple models or multiple physics schemes within ensembles is employed at several centres, and greater use of surface perturbations including SST and soil moisture perturbations.

7.4 The ICT was informed that the most significant advance in the last 2 years is the implementation of the first convective scale EPS's. The use of high-resolution convection-permitting models leads to a new level of uncertainty due to the rapid rate of error growth in such models, which means that a forecast of a few hours may be as uncertain in its resolved detail as a medium-range forecast of several days in the synoptic scales. The use of ensembles is therefore essential in order to fully specify the short-range forecast. However, due to the large dimensionality of the uncertainty it would be necessary to run much larger ensembles than are affordable (or are likely to be affordable for many years), in order to fully specify the uncertainty. As a result the forecast uncertainty is best represented using a combination of a convective-scale EPS with neighbourhood post-processing methods which take account of the possibility of convection happening at neighbouring grid-points.

7.5 The science of convective-scale EPS is still at a relatively early stage and some systems are simply downscaling lower resolution ensembles. Specific perturbation methods for the convective scale are still a research topic. The ICT noted that the only operational system in early 2012 is that operated by DWD in Germany, with Météo-France, the UK Met Office and some groups in the USA running systems in experimental mode. The emphasis of current systems is on prediction of heavy precipitation, but there is scope for much wider benefit, e.g. in improved forecasting of parameters such as fog and local winds which may both be forced by local topography.

7.6 The ICT realized that at most NMHSs operational forecast production on all timescales continues to be based on deterministic models, with the ensembles being used to provide peripheral and supplementary information. However, it noted that at a number of centres significant progress has been made in integrating EPS into core operational forecasting. At several centres medium-range forecast guidance is primarily based on EPS, for example throughout North America where the NAEFS multi-model ensemble produced by collaboration between CMC (Canada) and NCEP (USA) is used extensively by both these countries and also Mexico.

7.7 The ICT noted that in the UK the Met Office forecasters make extensive use of EPS for guidance in short and medium-range. The EPS is also now an important component of the NWP input to *Best-Data* systems being developed to provide a single-source of best forecast data for use in all automated and forecaster-generated product generation. The ensemble mean is used in creating the deterministic best-data beyond 48h ahead, and the ensemble distribution is used in probabilistic best-data. Ensemble and deterministic post-processing systems are close to being fully integrated, with both site-specific and gridded model output being post-processed in the same ways for EPS and deterministic NWP.

7.8 The ICT was pleased to note that the ET-EPS has completed a set of *Guidelines on EPS and Forecasting* (as given in Annex VI) to aid forecasters in effective application of EPS, and requested the Secretariat to publish these as a WMO publication and to distribute it to all WMO Members. The guidelines also include links to other sources of guidance e.g. from the ECMWF User Guide and the COMET on-line training materials.

7.9 The ICT noted that progress with statistical methods in post-processing has been relatively slow. Site-specific bias correction, for example using Kalman filter MOS methods, are quite widely applied. Reforecast datasets have been demonstrated to provide an effective resource for improved calibration, especially for forecasting of more extreme thresholds, but are only available operationally for the ECMWF EPS so are not yet widely used. The BMA (Bayesian Model

Averaging) method which has been widely recommended in the past is still used in a few centres, but its application has not grown significantly.

7.10 A major block to the publication and use of probabilistic forecasts has been the belief among many scientists and managers that people do not understand probabilistic information. There is now a considerable body of academic research which shows that the majority of people do understand this information, and make better decisions when presented with it. The UK Met Office has conducted several experiments in collaboration with university research groups. A mass-participation experiment conducted with the Universities of Bristol and Cambridge through an on-line game has shown that people presented with probabilistic information in a variety of formats make better decisions than those given simple deterministic forecasts.

7.11 The evidence shows that while not everyone may be able to make better decisions with uncertainty information, a very large number can. It would not make sense to withhold the useful extra information from those who can benefit from it because of a minority who are less able to exploit it.

7.12 The research provides useful guidance on the relative effectiveness of different presentations of uncertainty information in helping people make better decisions. Recalling CBS' request for GDPFS to work closely with PWS, the ICT recommended that the PWS programme review and update the guidelines on the presentation of probabilistic forecasts in the light of this new research and considered their requirements for probabilistic guidance products from GDPFS. The ICT also suggested that the PWS programme should consider wider provision of uncertainty information to both civil responder services and the general public. The ICT agreed that in addition to aiding better decision-making, providing uncertainty information has the following advantages:

- Scientific integrity through more honest representation of the capability and limitations of prediction systems;
- Allows public users of forecasts to decide their responses according to their personal sensitivities and vulnerabilities;
- Defensible position for the NMHS where accusations of wrong forecasts are made, since all available information is shared publicly.

7.13 The ICT recommended the use of EPS particularly for forecasting of severe and high-impact weather. It noted that a number of NMHSs are now issuing risk-based severe weather warnings (e.g. the France's Vigilance system and UK National Severe Weather Warning Service). Risk may be defined using a combination of probability (estimated from EPS) and impact. Assessment of impact is still largely subjective, based on weather thresholds (which may vary according to local climatology and societal vulnerability), but there is a growing amount of research on how to quantify the impact.

7.14 The ICT noted that EPS is increasingly used in combination with downstream models to predict aspects of societal impact, including:

- risk-based first-guess severe weather warnings, which provides guidance to forecasters related to the impact of severe weather;
- risk models combining hazard probability from EPS with models of societal impact (e.g. strong wind impact on transport networks);
- hydrology;
- Storm surge;
- Waves;
- Marine Pollution;
- Atmospheric Transport;
- Energy (wind, solar, etc.) and Trading;
- Forest fire;
- Aviation (i.e. icing, CAT, low visibility; routing; runway management).

7.15 The ICT noted that an expert on atmospheric dispersion modelling has participated in the ET-EPS meeting (Geneva, November 2011). It recognized that atmospheric dispersion can be subject to significant uncertainty, especially in long-range transport related to major nuclear and volcanic emergencies. The ICT noted that some centres have started experimenting with ATM models coupled with weather forecasts from EPS systems, and this is strongly encouraged.

7.16 The ICT agreed that another application of EPS for severe weather forecasting is its use in support of the SWFDP. A range of products are provided in the form of graphic images including probabilities of strong winds and heavy rain, and tracks and strike probabilities of tropical cyclones, and SWFDP is used as an effective means of providing training in the use of EPS.

7.17 The ICT noted that the GIFS-TIGGE WG is working to develop new severe weather forecasting products out of research using the TIGGE database. A researcher at MRI/JMA and now at University of Oxford has developed calibrated multi-model ensemble forecasts of extreme weather events, using the TIGGE archive to estimate the climate of the four models employed. These are currently produced 2 days delayed due to the restrictions on TIGGE data, but the UK Met Office is seeking to work with JMA and the researcher to implement the forecasts in real time in support of the SWFDP. The Met Office is also aiming to produce multi-model tropical cyclone track forecasts using funding from the EU project GEOWOW.

7.18 The ICT noted that the Lead Centre (LC) for EPS Verification provided by JMA collects verification results from an increasing number of global EPS production centres, and presents comparative results on its website (http://epsv.kishou.go.jp/EPSv/) which is no longer password protected. The LC has recently added the new CRPS score which is already being provided by a number of centres. Full instructions on provision of verification results and their calculation using a standard climatology are also provided on the LC website.

7.19 The ICT recalled that the EPS verification grid spacing used in calculation of the statistics has been 2.5°x2.5° (lat/lon). Noting that for deterministic NWP verification, Cg-XVI (May 2011) approved for inclusion in the existing version of the *Manual on the GDPFS* (WMO-No. 485) that all parameters shall be verified against the centre's own analysis on a regular 1.5° x 1.5° grid, the ICT realized that the same principle should be applied to the EPS verification, and stressed that this be incorporated in the new *Manual on the GDPFS*, which will replace the existing version and will be effective likely in 2015.

7.20 The ICT noted that in a few centres, the EPS is close to becoming a fully integrated part of the operational NWP system, and there is no longer a need for separate management of EPS applications. The ICT also noted the large overlap between the work of the ET-EPS and that of the Rapporteur on the Application of NWP to Severe Weather Forecasting, and agreed to address this issue under agenda item 11. While noting that the GDPFS may not yet have quite reached the same stage of integration, the ICT agreed that it should be aiming to do so within the next few years. At a certain point, the ICT would consider if and when it might be appropriate to replace the ET-EPS with a greater focus on severe weather forecasting using the best combination of both EPS and deterministic NWP.

8. FORECAST VERIFICATION

8.1 The Chairperson of the Coordination Group on Forecasting Verification (CG-FV), Mr David Richardson (ECMWF), reported on the outcomes of the meeting of the Coordination Group (Reading, May 2012), including the status of implementation of the new CBS procedures for upper-air verification, the results of a number of studies to evaluate the impact of the new procedures on values of verification scores, and the sensitivity to analysis differences on verification metrics and to differences in observation availability/usage, the Lead Centre for Deterministic NWP Verification (LC-DNV) website, the potential application of CBS standard verification procedures for Polar Regions, and the verification of surface fields. The full report is available on the WMO website at http://www.wmo.int/pages/prog/www/DPFS/Meetings/ICT-DPFS_Paris2012/documents/Doc-8-CG-FV.doc.

8.2 The ICT was pleased to note that significant advances have been made by most of the NWP centres in the implementation of the new CBS procedures for upper-air verification (as shown in the Table below). 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 standard climatology, which is provided by the LC-DNV through its ftp server (ftp.ecmwf.int).

Table – 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			

8.3 The ICT 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 noted that all these aspects and results from these impact studies related to the revised standard verification procedures would be addressed in a paper on updated verification procedures to be produced by members of the CG-FV. The ICT recommended that this 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.

8.4 The ICT was informed that a number of NWP centres carried out 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 requested the Lead Centre for Deterministic NWP Verification (LC-DNV) to make a summary of the results of these studies available on the LC-DNV website.

8.5 The ICT noted that a NWP centre carried out a study on the sensitivity to differences in observation availability/usage, and encouraged all NWP centres to participate in this research. The ICT noted that the CG-FV 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 CG-FV 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 LC-DNV ftp server would be used for exchanging the data.

8.6 The ICT expressed its appreciation to ECMWF for the development and maintenance of the LC-DNV website (http://apps.ecmwf.int/wmolcdnv/). The LC-DNV website shows a range of plots of the scores that are exchanged between NWP centres. It 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 website 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. The ICT noted that login accounts have been provided to CG-FV members and recommended that access to the LC-DNV website should be provided to all WMO Members through their WMO accounts. For further improvement, the ICT 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 ICT recommended that unrestricted access be given to the website, including the basic verification plots (without the personalization).

8.7 The ICT recommended that the LC-DNV website should be declared operational. In this context, the ICT requested the WMO Secretariat to announce the LC-DNV website by sending out a circular letter to WMO Members, and all NWP centres to present the LC-NDV website in various conferences, symposia and seminars.

8.8 The ICT noted that the CG-FV discussed the current status of verification of surface fields at NWP centres. 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 ICT 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. It recommended more research and studies to allow recommendations to be developed by the CG-FV.

8.9 The ICT noted that the CG-FV agreed to carry out 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. It also noted that other aspects require agreement, including on: (1) scores (ME, MAE, RMSE, contingency table based scores); (2) reference (climatology, persistence); (3) confidence intervals; (4) spatial aggregation; and (5) temporal aggregation. All NWP centres were encouraged to participate and share their studies on surface weather verification with members of the CG-FV. The ICT requested the CG-FV to prepare recommendations for standard verification procedures for surface weather parameters based on the results of these studies.

8.10 The ICT noted that the CG-FV 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. Noting 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, the ICT agreed to address this issue under agenda item 10.

9. EMERGENCY RESPONSE ACTIVITIES (ERA)

9.1 Nuclear ERA

9.1.1 Mr Masami Sakamoto (Japan), on behalf of the Chairperson of the Coordination Group on Nuclear Emergency Response Activities (CG-NERA), Mr René Servranckx (Canada), reported on (1) the outcomes of the meeting of the Coordination Group (Vienna, November 2011), which was focused on the responses and experiences in relation to the Fukushima Daiichi NPP emergency; and (2) progress made with respect to Nuclear ERA, including the WMO response to the Fukushima Daiichi NPP accident, the status of implementation of the operational Regional and Global Arrangements, improved product distribution and access methods, the RSMC products and services for nuclear emergencies, cooperation between WMO and IAEA, CTBTO, ICAO, and WHO, the ERA webpages, the ensemble atmospheric transport modelling, and the status of review of the WMO Technical Note 170, entitled: "Meteorological and Hydrological Aspects of Siting and Operations of Nuclear Power Plants". The full report is available on the WMO website at http://www.wmo.int/pages/prog/www/DPFS/Meetings/ICT-DPFS_Paris2012/documents/Doc-9-1-NERA.doc.

9.1.2 The ICT note that at the CG-NERA meeting (Vienna, November 2011), the representatives of NMHSs, including those of RSMCs with activity specialization in Atmospheric Transport Modelling (RSMC-ATM), and RTH Offenbach briefed the meeting on their respective responses and experiences, including the roles they played as WMO regional centres, as well as within or in support of their national nuclear emergency response organizations and operations. The representatives of relevant international organizations (IAEA, WHO, ICAO and CTBTO) briefed the meeting on their respective roles and the relevance of meteorological information made available by WMO RSMCs in relation to their respective decision making processes during the Fukushima Daiichi NPP accident and emergency, with the view of identifying issues and possible enhancements to the present system of meteorological support. Based on these reports, and the lessons learnt from the Fukushima Daiichi NPP accident and emergency, the CG-NERA identified issues, and agreed on actions and improvements to the operational procedures, including those in response to the requests by the WMO Governing Bodies, as presented in Annex VII (excerpt of the CG-NERA 2011 Vienna meeting report on some of the WMO response to the Fukushima Daiichi NPP accident).

9.1.3 The ICT noted that the operational availability of radiological monitoring data for use in RSMC operational environment continues to be difficult to attain. These data may be available to some NMHSs, depending on the national arrangements with their radiological monitoring authorities. However, these are generally not passed on to or available at RSMCs. NMHS should be encouraged to strengthen their contacts with radiological monitoring authorities and explore the possibility of making radiological data available to the RSMCs during an incident. The ICT noted that discussions are also underway with the CTBTO regarding possible access to their data.

9.1.4 The ICT noted that all RMSCs use web-based technologies to exchange information and products. The RMSCs with the designation for the environmental emergency response now have a common-look-and-feel mirrored (seven servers in total) but independent password protected webpage to post standard products and exchange information. All RSMCs also post their information by ftp or by SCP to the common-look-and-fell webpages of the other RSMCs. The key advantage is that the RSMCs websites have identical content while being completely independent from one another. The ICT agreed that there are benefits associated with this approach that allows accessibility to the RSMC products even when one server is down. The ICT also noted that some of the RSMC mirrored websites have seen the addition of a link to "meta-data" for each RSMC via an "All Products" button. The concept was to create a clickable link that would take the user to a listing of additional RSMC model products that could include, as examples, higher resolution images, Google Earth output, and GRIB products. This concept would allow the RSMCs to post additional products that would not fit in the standard mirrored webpages. The contents of the meta-data link are dynamic such that a directory listing link is created for each event, allowing the display of data and products from past exercises or responses (archive).

9.1.5 The ICT recalled that the implementation plan for the migration of RSMC products from fax distribution to e-mail/Internet distribution is progressing. While noting that it is highly desirable to only use official NMHSs' operational e-mail addresses, the ICT recognized that many NMHSs only have less secure commercial or freeware, and personal webmail accounts, and that this is a problem with no suitable solution. The ICT agreed with the next phases of the implementation plan, which include the following steps: (a) the RSMCs that have not yet done so will commence testing e-mail distribution within their respective Regions of responsibility, and contact those Members that have not replied to the circular letter; RSMCs will provide updated lists to WMO; and (b) WMO and RSMCs, in consultation with IAEA decide additional measures to obtain additional replies from Members; WMO to provide updated lists to RSMCs and to update all contact information on the WMO ERA webpages.

9.1.6 The ICT was pleased to note that the relationship of the WMO and the designated Centres with the IAEA is solid and also strongly recognized by other relevant International Organizations. It noted that monthly communications tests are conducted between the IAEA Incident and Emergency Centre (IEC) and RTH Offenbach. Quarterly exercises are conducted between the IEC and lead RSMCs. In addition, many RSMCs exercise on a monthly basis as well. Since 2009, every quarterly test includes the GTS message distribution and distribution of products by the lead RSMCs to the NMHSs in their Regions of responsibility.

9.1.7 The ICT noted that RSMCs continue to experiment with different parameters and formats for such charts, including for the forecast time-range of the standard products, and for longer time ranges up to 10 days as well as geo-referenced information. Parameters have been defined to experiment with ''Plume Time of Arrival'' products and tests will be conducted to evaluate their usefulness. Some RSMCs provide such products to the IAEA on an experimental, non-official basis during the Fukushima event. Uncertainty in dispersion calculations and inclusion of precipitation data in deposition calculations continue to be of interest. The ICT noted that the current agreement between the WMO and the IAEA is based on the fact that a link between the Competent Authorities concerning the Conventions and the National Meteorological and Hydrological Services was developed to help with the interpretation of the atmospheric dispersion products. While this might not be needed for a few advanced Member States, this is still valid for the majority. The ICT strongly recommended improving and promoting contacts, coordination and liaison between NMHSs, who receive RSMC products, and their counterpart National Competent Authorities for nuclear emergencies.

9.1.8 The ICT noted that the successful and CTBTO-WMO collaboration of the last decade continues. It recalled that the arrangement between CTBTO and WMO allows the CTBTO Provisional Technical Secretariat (PTS) to request and obtain, automated or semi-automated and in near-real-time, atmospheric transport modelling (ATM) results from RSMCs in case of Treaty-relevant detections at radionuclide (RN) sampling stations of the International Monitoring System (IMS) to supplement its own computations. The backtracking modelling capacities of the RSMCs can also be used for other, non-CTBTO applications and are available to all WMO Members upon request. The ICT noted that a significant number of notifications were issued to the RSMCs is support of detections (measurements) of interest to CTBTO after the Fukushima Daiichi accident. The ICT noted that NMC Vienna represented WMO at the briefings of the CTBTO to the states signatories during the Fukushima Daiichi event. The ICT also noted that discussions are underway between CTBTO and WMO to evaluate possible modifications to existing arrangements. These include new protocols for ftp transfer of the backtracking results and calculations on higher resolutions.

9.1.9 The ICT recalled that WMO Members continue to show a great interest in the meteorological data from the CTBTO International Monitoring System Radionuclide stations (IMS/RN). Data from over 60 stations are now being transmitted by the Canadian Meteorological

Centre (CMC) on the WMO GTS. The system however relies on emails from CTBTO and does not have operational status. Problems occur from time to time. NMC Vienna is in the process of taking over this task from the Canadian Meteorological Centre. WMO stations identifiers are being assigned to all CTBTO stations and the meteorological data will be encoded in the proper WMO format for fixed stations. This will also facilitate quality control of the data.

9.1.10 The ICT noted that the measures taken by the International Civil Aviation Organization (ICAO) with regards to the accident at the Fukushima Nuclear Power Plant. With respect to the meteorological aspects, area control centres were immediately informed aircraft in flight about the release and provided advice on possible alternative routes, upon receiving information on the accidental release of radiation to the atmosphere from the IAEA via the WMO RSMC Exeter through VAAC London. In addition, Japan issued weather advisories relevant to the safety of aircraft and alerted pilots of hazards en route. The ICT noted that the need for guidance related to the issuance of warnings (SIGMET messages) designed for aviation was again clearly identified during the Fukushima Daiichi NPP accident. Canada, a member of ICAO's International Airways Volcano watch Operations Group, submitted a paper on issues regarding the provision of information to aviation on radioactive material in the atmosphere at the 6th Meeting of ICAO's International Airways Volcano Watch Operations Group (IAVWOPSG, Dakar, Septeber 2011), where issues related to the scientific and practical aspects of radiation exposure and health impacts, led to the development of a draft concept of operations for the provision of guidance for radioactive cloud SIGMET and the identification of possible products that could be generated as guidance for the Meteorological Watch Offices. The IAVWOPSG meeting concurred with the need for the referred guidance and products. However, due to some concerns on what the criteria for triggering the SIGMET should be (the dose criteria for the passengers' health or the contamination of the aircraft itself), further work is underway. A conjoint paper by IAEA, ICAO and WMO members was submitted to the IAEA Inter-Agency Committee on Radiological and Nuclear Emergencies Meeting (Paris, December 2011) to seek expert advice on the best criteria to be used to develop the referred guidance.

9.1.11 The ICT noted that throughout the Fukushima event, MeteoSwiss (Switzerland), on behalf of WMO, has provided support and technical assistance to WHO in relation to weather forecast and atmospheric dispersion, and on visualization and interpretation for planning appropriate public protection measures for the surrounding regions. Noting that the basis for the relations between WMO and WHO is defined by the working arrangements concluded by WMO with WHO dated 1952 (WMO-No. 60, entitled "Agreements and Working Arrangements with Other International Organizations"), the ICT recommended further discussions between WMO and WHO on identifying the nature and the scope of the cooperation between the two agencies in the event of a nuclear emergency, in order to develop a joint Concept-of-Operations or Memorandum of Understanding between relevant departments of WMO and WHO.

9.1.12 The ICT noted that a detailed review/redesign/updating of the WMO Technical Note No. 778 (documentation on RSMC support for EER targeted for meteorologists at NMHSs) and of the WMO ERA webpages was completed in October 2011. Noting that there are such technical documents that indicate the arrangements and provides great detail of scientific and technical information related to ERA, the ICT recommended promoting the ERA to the NMHSs through the Regional Associations by making use of this documentation.

9.1.13 The ICT noted that possible future ensemble modelling products of RSMCs during a nuclear emergency continue to be of interest. The ENSEMBLE system developed by European Commission's Joint Research Centre in Ispra, Italy provides a possible platform to host and test such calculations, and to present the results. A "private" RSMC NERA session using the ENSEMBLE system has been created. The ICT noted that a first exercise is now underway.

9.1.14 The ICT noted that following the request by Cg-XV (May 2007) with regards to the outdated WMO Technical Note 170, entitled: "Meteorological and Hydrological Aspects of Siting and Operations of Nuclear Power Plants", the CG-NERA review this publication and noted that only a few sections concern CBS, and several WMO programmes and technical commissions should be involved in updating the Technical Note. Following a throughout review of the CBS relevant sections (Chapter 2, entitled Practical guidance for meteorologists in charge of the meteorological assessments and continuing services; section 2.2.4 – normal NPP operation, and 2.2.5 – NPP emergency situations), the CG-NERA developed a proposed expanded outline for updating these sections base on the contribution by the representative of RSMC Washington.

9.2 Non-nuclear ERA

9.2.1 The Chairperson of the Expert Team on Applications of Atmospheric Transport Modelling (ATM) for Non-nuclear ERA (ET-nNERA), Mr Christopher Ryan (Australia), reported on the development of atmospheric transport modelling technologies for use in support of environmental emergency response, including for volcanic ash and sand and dust storm, the ATM-backtracking experiment, mechanisms for capacity building, working arrangements with relevant International Organizations, and development of operational procedures. The full report is available on the WMO website at http://www.wmo.int/pages/prog/www/DPFS/Meetings/ICT-DPFS_Paris2012/documents/Doc-9-2-NNERA.doc.

9.2.2 The ICT recalled that a number of major ERA events with significant impacts have occurred since the last meeting of the ET-nNERA (Toulouse, December 2009), including volcanic eruptions in Iceland, Chile and Indonesia, and the Fukushima Daiichi NPP accident. The operational impact of these events and the follow-up activities have fully occupied many of the ET-nNERA members, slowing progress on the work plan decided in 2009, and forcing the ET-nNERA meeting planned to 2011 to be postponed to late 2012.

9.2.3 The ICT was informed that the WMO Commission for Aeronautical Meteorology (CAeM) Management Group (October 2011) noted that widespread and prolonged disruption to international air navigation caused by the recent eruptions of volcanoes in Iceland, Chile and Indonesia have resulted in significant pressure being placed by the aviation industry on the aeronautical meteorology community and particularly the nine Volcanic Ash Advisory Centres (VAAC) to provide enhanced levels of volcanic ash service delivery. Inconsistency of VAAC forecast process and output have also been exposed while previously existing and recognized global variations in capacity to undertake the necessary geophysical and observational monitoring of volcanoes, volcanic ash and other volcanic gases have been further highlighted. The ICT agreed that this is especially important given the fact that the eruptive source term initialization of all transport/dispersion models represents the largest source of error in model-based forecasts.

9.2.4 In addition, the ICT was informed that following the second ICAO International Volcanic Ash Task Force (IVATF) meeting (Montreal, July 2011), the WMO Volcanic Ash Scientific Advisory Group (VASAG) was charged with a number of actions relating mainly to dispersion/transport model initialization, volcanic ash observational technologies and a continued leading involvement in developing a universally accepted definition of 'visible ash'. At its recent meeting (January 2012) the VASAG summarized recent developments in volcanic ash science and technology, including:

- data assimilation in transport and dispersion models was starting, often using WRF-type models;
- an inverse modelling scheme for detecting source parameters involving the Austrian Met Institute (ZAMG);
- The UK Met Office is involved in the UK Natural Environment Research Council (NERC) consortium that is looking at improving the atmospheric representation of volcanic plumes. Components of this project involve integrating numerical models of eruption column physics with dispersion models;
- USGS is working on bent-plume experiments in a wind tunnel and on modifying a 1D volcanic plume model to refine relationships between plume height and eruption rate. Progress is also being made on the USGS Eulerian ash model Ash3d, including development of a GUI that will allow users outside the USGS to use the model;
- A wide range of relevant papers is available at the link: http://vhub.org.

9.2.5 While recognizing that the ET-nNERA has not been directly involved in these activities, the ICT was pleased to note that ET-nNERA members have been participating in these developments.

9.2.6 The ICT noted that chairperson of the ET-nNERA and Mr Yuki Honda (Japan, co-chairperson of the OPAG on DPFS) have continued to represent CBS in the ad hoc CAS-CBS task team, which was established to ensure that operational aspects of the proposed Sand and Dust Storm Warning Assessment and Advisory System (SDS-WAS) be developed in accordance with the GDPFS purpose and principles. The ICT agreed to further address this issue under agenda item 12.

9.2.7 The ICT recalled that the ET-nNERA coordinated an ATM-backtracking experiment by four RSMCs in 2008 with the goals of (1) demonstrating to WMO Members and relevant international organizations the new operational backtracking capabilities and products that the RSMCs can provide; and (2) exploring the concept of operations for the requesting and the provision of backtracking products and services. Information on the demonstration, including its results, is available on a website at http://ensembles-eu.metoffice.com/adg/wmo/Welcome.html. The experiment results were not calculated in real-time so operational procedures were not exercised. CBS-XIV encouraged the ET-nNERA to undertake a second demonstration experiment with increased participation of GDPFS centres and to use the demonstration to assist in the development of procedures for requesting and provision of emergency response services. The ICT also recalled that the ET-nNERA, at its 2009 meeting, agreed that the backtracking capability demonstrated in its first experiment is not presently appropriate for a chemical incident or non-nuclear events that are of a very local or short-fused nature, or where there are no real-time monitoring networks for the hazardous substance.

9.2.8 In this context, the ET-nNERA agreed that the next demonstration experiment should be developed with the objectives: (1) to test and develop possible operational procedures for request-reply for regional centre ATM support for a significant chemical incident; (2) to demonstrate and illustrate to NMHSs the use of ATM in a significant incident for supporting decision-making; (3) to demonstrate to CBS that this programme area continues to make progress; and (4) to examine and explore how to integrate results from a few RSMCs and to provide guidance to NMHSs. The ICT noted that the ET-nNERA plans to carry out this experiment after developing a chemical incident scenario with the following features: (1) approximately 3-day duration; (2) vertical extent of the release sufficient to ensure impacts at regional-range, transboundary, over a water body and populated area; and (3) all RSMCs, and other NMCs, to participate in the demonstration. An appropriate location for the simulated chemical fire has been selected: the Campana-Zarate petrochemical plant in Argentina, which is located close to the Uruguay border. In the event of a major fire, transboundary impacts and effects on large population centres such as Buenos Aires and Rosario City could be expected.

9.2.9 The ICT requested the ET-nNERA to continue to work on capability building in NMHSs with regard to atmospheric transport modelling. In the same context, the ICT was informed that a welcome announcement was made in 2011 by the COMET Program, regarding the publication of “HYSPLIT Applications for Emergency Decision Support”. This is a 3-hour module which is intended to help forecasters understand their role in providing decision support services to emergency managers who are dealing with the air dispersion of hazardous materials. In addition the module explains inputs for the HYSPLIT dispersion model and gives forecasters hands-on experience with running the model. The module can be viewed at http://www.meted.ucar.edu/dispersion/hysplit/index.htm.

9.2.10 The ICT reaffirmed that cooperation with relevant International Organizations is important, as learned from collaborating with the IAEA on nuclear emergencies, with CTBTO to develop new applications, and with ICAO on the airborne volcanic ash advisory service. These collaborations are seen as an effective, mutually supportive strategy for disaster risk reduction. At the same time, the ICT noted that it has continued to prove difficult to establish practical arrangements or plans with agencies such as UN-OCHA and WHO, despite several direct approaches by the WMO

Secretariat. The ICT endorsed the activities in the ET-nNERA work programme aimed at improving cooperation with and awareness of these International Organizations.

9.2.11 The ICT agreed that the future work programme for the ET-nNERA should focus on: (1) operational arrangements; (2) detection and verification; (3) capacity building; and (4) role of International Organizations. Regarding the operational arrangements, the first priority is to complete the drafting of operational procedures for significant non-nuclear incidents, where a NMHS could request and receive ATM support from a RSMC or another regional centre, followed by the proposed experiment which will exercise the procedures.

10. MANUAL ON THE GDPFS (WMO-No. 485)

10.1 The ICT noted that all expert teams and coordination groups had reviewed their relevant parts of the Manual on the GDPFS (WMO-No. 485) – Volume I and proposed amendments, as appropriate. These are detailed in Annex VIII, and relate to the aspects below:

- Mandatory functions of and criteria to be recognized as an RSMC for Atmospheric Sand and Dust Storm Forecasts (RSMC-ASDF): amendments to Part I, paragraph 4.1.2.2; Part I, Appendix I-1; Part II, paragraph 1.4.1.2; and new Appendix II-12;

- Standard verification of deterministic NWP products: amendments to Part II, Attachment II.7, Table F.

10.2 The ICT anticipated the designation of RCC/RCC-Networks and RSMC-ASDFs at CBS-XV (September 2012).

10.3 The ICT noted the outcomes of the CBS Expert Meeting on the Review of the Manual on the GDPFS (Geneva, October 2011) and that all expert teams and coordination groups had reviewed their respective draft texts for the new Manual on the GDPFS. The ICT agreed that any proposed amendments to the Manual on the GDPFS, with the exception of those identified in item 10.1 and 10.2), should be reflected in the new Manual. With this in mind, and taking into account that the new Manual will most likely be in force by 2015, the ICT reviewed the draft text for the revised Manual and developed new text, as given in a working document available on the WMO website at ftp://ftp.wmo.int/Documents/PublicWeb/www/gdpfs/Manual-on-the-GDPFS/Manual-on-the-GDPFS-May2012.doc. It noted that there were a number of parts of the new Manual that needed to be developed and therefore requested the Secretariat to contact the identified experts to prepare draft text for the new Manual by mid-June so that it could be presented for consideration by CBS-XV.

10.4 The ICT noted that the new Manual introduces a number of changes to the current procedures. It therefore acknowledged that some GDPFS centres may report temporary non-compliance with regard to some of the requirements, mainly because of resource constraints during system development. In this context, the ICT noted that a transition plan for the implementation of the new Manual, which will replace the current version, needs to be developed to manage the technical changes and the initial designation of the GDPFS centres as defined in the new Manual, including WMCs and RSMCs. The ICT will develop such a plan for consideration by CBS.

11. FUTURE WORK PROGRAMME, INCLUDING STRATEGIC DIRECTION, STRUCTURE, TERMS OF REFERENCE, ETC.

11.1 The ICT reviewed the structure of the OPAG on DPFS, including its coordination groups, expert teams and rapporteurs, and their respective Terms of Reference (ToR). In this context, the ICT noted the potential overlaps and commonalities between the work programme for (1) the ET-ELRF and ET-EPS, especially on aspects related to extended-range forecasting (ERF); and (b) the ET-EPS and the Rapporteur on the Application of NWP to Severe Weather Forecasting.

11.2 In addition, the ICT noted the CCl proposal for converting the CBS ET-ELRF to a joint CBS-CCl Expert Team, whose membership would include two CCl representatives, to facilitate stronger collaboration between the two Technical Commissions. It stressed that the ToR should retain the existing focus on operational aspects (which already reflect a significant thrust on CBS-CCl collaboration), and that the ET-ELRF shall report and propose amendments to the procedures and guidelines in the GDPFS to CBS through the ICT-DPFS. Reporting to the CCl management group will be through the co-chair of OPACE-3. The ICT noted that a formal proposal for converting the CBS ET-ELRF to a joint CBS-CCl Expert Team has been made for consideration by the WMO Executive Council, at its upcoming session (June 2012).

11.3 The ICT investigated ways of changing the working structure to address the difficulties mentioned in 11.1, and also to make the overall structure lighter and easier to manage so that it could respond even more efficiently than at present to evolving requirements, priorities, key objectives etc. It worked out a structure comprised of an ICT and three standing Expert Groups (instead of five teams and two rapporteurs as at present), one on Forecasting Processes and Support (FPS), other on extended- and long-range forecasting, and the third on Emergency Response Activities (ERA). In addition dedicated Task Teams would be set up by the ICT for limited periods with specific targets and deliverables to be produced. The existing structure with revised ToR is presented in Annex IX and the alternative structure, including ToR for the Expert Groups and the indicative list of Task Teams that would be needed to address the present work programme of the OPAG, is given in Annex X. The ICT recommended that this alternative structure be considered for implementation by the forthcoming CBS session.

12. ANY OTHER BUSINESS (AOB)

12.1 RCC Designation

12.1.1 The ICT noted the completion of demonstration phases of the RA VI RCC-Network and the RA II North Eurasian Climate Centre (NEACC): It recommended their designation be formalized for consideration at CBS-XV (September 2012), and proposed amendments to the Manual on the GDPFS, as given in Annex VIII.

12.2 Sand and Dust Storm

12.2.1 The ICT noted that draft text on the mandatory functions and criteria for the designation of an RSMC with activity specialization in Atmospheric Sand ad Dust storm Forecasts (RSMC-ASDF) had been developed by a small ad-hoc CAS/CBS joint task team (that consists of Dr Michael Schultz (Chairperson of the SDS-WAS Northern Africa-Middle East-Europe (NA-ME-E) Node), Prof Soon-Ung Park (Chairperson of the Asia Node), Mr Christopher Ryan (Chairperson of ET-nNERA, CBS) and Mr Yuki Honda (Co-chairperson of OPAG-DPFS, CBS)), based on a proposal from the SDS-WAS NA-ME-E Node. The ICT noted that this draft text was reviewed by the Regional Steering Group of SDS-WAS Asia Node, at its third meeting (Tsukuba, Japan, March 2012) and endorsed by CAS, at the fifth meeting of the Joint Science Committee (JSC) of the World Weather Research Programme (WWRP) (Geneva, April 2012). In this context, the ICT reviewed the draft text on the mandatory functions and criteria for the designation of an RSMC–ASDF, and proposed amendments to the current version of the Manual on the GDPFS as presented in Annex VIII.

12.2.2 Considering the maturity of the activities performed at each regional node, the ICT anticipated that the SDS-WAS NA-ME-E Regional Centre (AEMET, Spain) is a possible candidate for designation as RSMC-ASDF at CBS-XV. The AEMET would need to demonstrate their abilities to fulfill the mandatory functions of RSMC-ASDF at CBS-XV.

12.3 Other Business

12.3.1 No other issues were considered under this agenda item.

13. CLOSING

13.1 The Meeting of the CBS Implementation Coordination Team of the Open Programme Area Group (OPAG) on Data-Processing and Forecasting Systems (ICT-DPFS) closed at 15:30 on Friday, 25 May 2012.

AGENDA

1. OPENING

2. ORGANIZATION OF THE MEETING

2.1 Adoption of the agenda
2.2 Working arrangements

3. INTRODUCTION AND BACKGROUND / REVIEW OF DECISIONS OF THE WMO GOVERNING BODIES AND STATEMENTS ADOPTED BY CBS RELATED TO THE OPAG on DPFS

4. SEVERE WEATHER FORECASTING

5. VERY SHORT-RANGE FORECASTING

6. EXTENDED- AND LONG-RANGE FORECASTING

7. PROBABILISTIC FORECASTING AND ENSEMBLE PREDICTION SYSTEMS, AND APPLICATIONS

8. FORECAST VERIFICATION

9. EMERGENCY RESPONSE ACTIVITIES (ERA)

9.1 Nuclear ERA
9.2 Non-nuclear ERA

10. MANUAL ON THE GDPFS (WMO-No. 485)

11. FUTURE WORK PROGRAMME, INCLUDING STRATEGIC DIRECTION, STRUCTURE, TERMS OF REFERENCE, ETC.

12. ANY OTHER BUSINESS (AOB)

13. CLOSING

Annex II

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Annex III

RECOMMENDATIONS TO SUPPORT THE FULL AND SUSTAINABLE PARTICIPATION OF NMHSs, INCLUDING THOSE FROM LDCS

The SG-SWFDP explored the issues around LDC participation in the SWFDP, and suggested and recommended possible solutions to the issues identified, as follows:

a. Capacity

i. Observations

1. The SG-SWFDP emphasized the importance of establishing a realistic inventory of observing capacity within each LDC, and of generating a commitment to the timely provision of observations from the LDC to the Regional Centre.
2. There was a need to properly establish the regional requirements for the exploitation of satellite data to assist short-term forecasting e.g. flash flood forecasting.
3. Those NMHSs which had access to radar resources should be encouraged to work with neighbours to establish radar composites for the benefit of all.

ii. Forecasting

1. The SG-SWFDP recommended the design and definition of a forecast process which mirrored forecast office workflow, and to further develop the current SWFDP websites following the concept of a dashboard, as an aid to better decision-making. Recognizing the potential for information overload in many forecast offices, including in LDCs, the SG-SWFDP felt that a formalized forecast checklist would help to focus forecasters' attention on the most important weather issues of the day. The SG-SWFDP emphasized that this dashboard would need to be tailored to the needs of each specific NMHS and should be considered in conjunction with the development of the National Implementation Plans.
2. The SG-SWFDP also emphasized that the development of a competencies framework was necessary to ensure that forecasters had attained the required levels to properly perform their tasks.

iii. Visualization

1. To facilitate the engagement of LDCs at a minimal entry level, the SG-SWFDP recommended that visualisation systems be web-browser based with content optimized for the available bandwidth.
2. The SG-SWFDP emphasized the importance of enhancing the interpretation of satellite imagery through the use of existing web-based visualisation systems.

b. Leadership and organizational culture

1. The SG-SWFDP emphasized the importance of reinforcing and building on existing practices.
2. To encourage a better user-focus, the SG-SWFDP suggested the development of exercises that were scenario-based and that engaged users as well as forecasters, to assist in the mutual understanding that underpins good communication.
3. Recognizing that forecasters needed to be fully aware of hazards and their implications, NMHS management should develop strategies to ensure that forecast staff members were fully aware of the potential impact of their work on the community which they serve.
4. The SG-SWFDP acknowledged the importance of mentoring and training to empower forecasters and to help all NMHS staff develop and maintain the complementary skills, such as communications, team and relationship building, user focus and situational awareness, that optimize the impact of their technical work.

c. Resourcing

i. The SG-SWFDP had concerns for the long-standing sustainability of the SWFDP and the systems that support it at global, regional and national level.

ii. The SG-SWFDP recognized the need for defining the long-term ownership of each subproject to ensure sustainability and identified some issues that would need to be addressed in this context:

1. Establishment and implementation of SWFDP training desks at global and regional centres.
2. Utilization and creation of regular weather briefings from the regional centres.
3. Involvement of regional training centres for ongoing regional and national training support.
4. Developing key players' engagement management plan.
5. Develop country-specific implementation plans.
6. Establish and run a recruitment, training, succession, and development plan for in-country individuals who will act as focal points / champions / team leaders that can take ownership for the SWFDP activities in that country.

iii. The SG-SWFDP recognized the benefits to be gained from better coordination with and facilitation from other WMO activities.

iv. The SG-SWFDP recognized that sustainability implied that ownership of the subprojects would ultimately need to move from the Technical Commission level to EC/Cg and to appropriate regional structures (e.g. MASA).

Annex IV

STRATEGY FOR INTEGRATING NEW COMPONENTS INTO SWFDP

The SWFDP framework has been successful in providing support to NMHSs and enhancing their capability to provide effective warnings of severe weather to DMCPAs and to the public for the protection of life and property. Cg-XVI (Geneva, Switzerland, May 2011) approved a vision for the SWFDP as a cross-programme collaborative activity and requested that the SWFDP should engage all WMO Programmes that concern the real-time prediction of hydrometeorological hazards. This strategy considers how that may best be achieved.

Principles

Recognizing the success of the SWFDP development framework, the development of future regional subprojects should be based on the experience of the more advanced subprojects. The scope and evolution of each subproject should be decided by the Regional Subproject Management Team (RSMT) according to the needs of the NMHSs and the capabilities of the designated Regional Centres. However, it is recommended that the following principles of success from previous subprojects should provide guidance:

- Start small with focus on most important severe weather identified by the participating countries for protection of life and property.
- Keep scope of project manageable.
- Measure success through metrics compared to an initial baseline.
- In the final phase expand scope including cross-programme activities as required, to meet the needs for additional services identified by the region.

Phased structure for the development of subprojects

Each subproject should develop in several phases as outlined below. It should be noted that the boundaries between phases are not precise, and may vary according to the needs of the region, but in general should follow this pattern:

<u>Phase 1</u> – Set up of basic cascading structure of forecast data and information from global centres through regional centres to a small group of NMHSs. Initial planning of PWS structures within the countries to ensure warnings are acted upon to protect life and property.

<u>Phase 2</u> – Demonstration of benefits of the cascading system and of PWS structures within the countries, within the confines of the limited scope set up under Phase 1. Collect feedback and verification to measure benefits relative to the initial baseline (Figure 1 below).

<u>Phase 3</u> – Inclusion of additional countries/NMHSs in the region and the extension to additional severe weather hazards as required. Possible trialling of new severe weather products, for example from GIFS-TIGGE. Planning of structures and mechanisms to ensure sustainability in the region (Figure 2 below).

<u>Phase 4</u> – Sustainability and development of SWFDP activities including the exploring of synergies with other WMO programmes in order to respond to the needs of other user sectors (e.g. aviation, marine, hydrology, agriculture, etc) (Figure 3 below).

Important considerations from Phase 3 onwards:

- Management of sustainable operations within the region.
- Requirements for cascading of additional information in support of new services.
- Long-term funding structures in support of contributions to the SWFDP from global centres, regional centres and training centres.

- Testing of new guidance materials developed under WWRP research activities such as GIFS-TIGGE products.

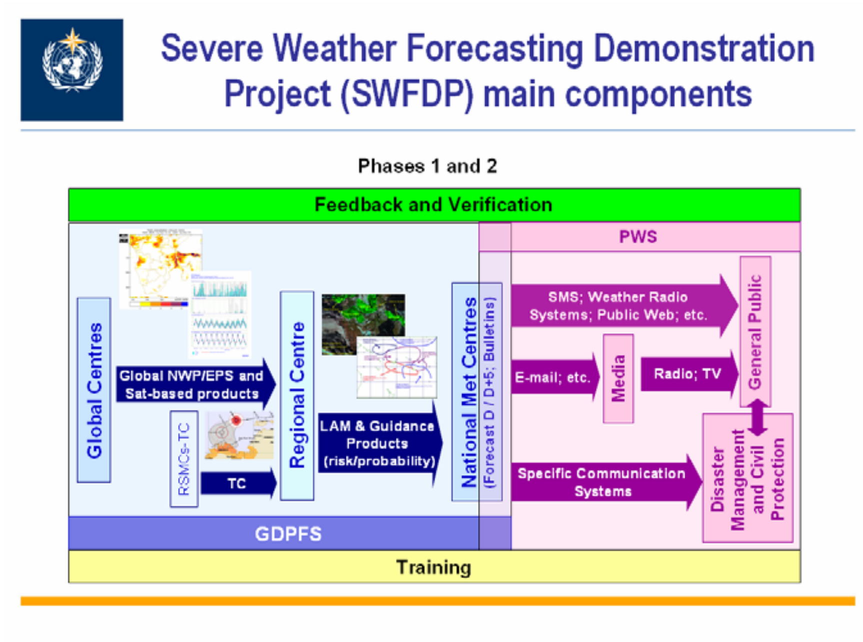


Figure 1 – Phases 1 and 2 of the SWFDP.

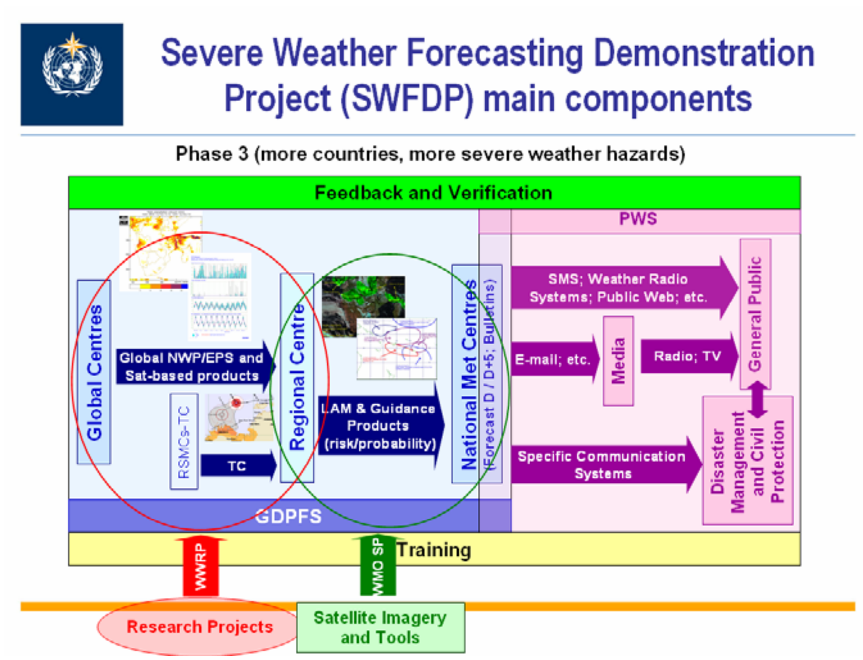


Figure 2 – Phase 3 of the SWFDP.

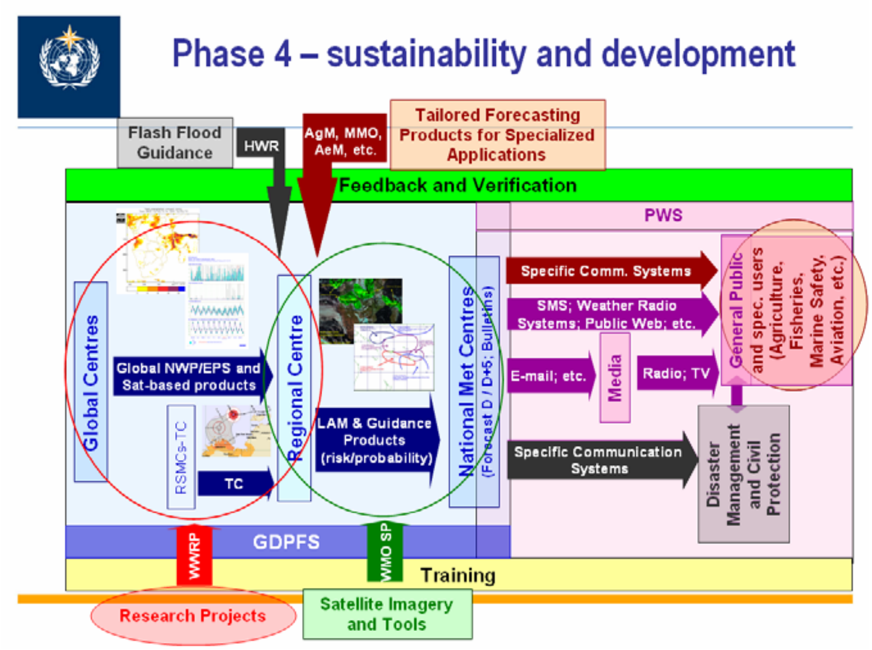


Figure 3 – Phase 4 of the SWFDP.

SCOPING AN OPERATIONAL EXCHANGE OF ERF

The data exchange, and development of products for the extended-range, is envisioned to key on the operational monthly prediction systems at GPCs. Table 1 shows the list of proposed products (plots) to be displayed on the individual GPC websites.

Table – List of proposed products (plots) to be displayed on the individual GPC websites

Products/variables	Covering periods	Charts	Verification scores
• Accumulated precipitation • Average 2m temp	Weeks 1,2,3,4, 3-4,1-4	Probabilistic maps • terciles • outer quintiles (optionally)	Reliability diagrams / ROC
MJO Need: • OLR • U850 • U200	32 days	• Hendon and Wheeler diagram • Hovmoller	Temporal correlation and RMSE -----
Velocity Potential	Weeks 1,2,3,4, 3-4,1-4	Velocity potential anomaly (Ensemble mean for each period)	correlation

Proposed data exchange among GPCs for an extended-range prediction pilot is described below. This lays down some broad guidance and several issues will have to be resolved in near future. It is recommended that some members of the ET-ELRF attend the technical workshop proposed under the WWRP/WCRP initiative on the “Sub-seasonal and Seasonal Prediction” which would be held to resolve data exchange issues. Such a meeting will provide a common ground for research and operational efforts in resolving the data exchange issues.

<u>Variables to exchange</u>: The recommendation for minimum variables is SST, T2m, precipitation, u200, v200, u850, OLR. This list may be augmented following the need to developing specific products.

<u>Frequency of model output to exchange</u>: Exchange of daily model output is recommended. Exchange of daily data will provide the freedom to develop products for different time-averages, for example, weekly means, monthly mean, average over week 3-4. Data should also be exchanged for the individual members in the ensemble so that probability forecasts can be developed.

<u>Exchange frequency</u>: Initially it is recommended that exchange of data will be once a week. Operational schedule of various monthly prediction systems at GPCs need to be considered in deciding on the best day of the week to exchange the data among GPCs.

<u>Forecast length</u>: Forecast length will be determined by the longest common period over which operational monthly prediction systems at different GPCs are run.

Data format: As for the data exchange policy in place for the LC-LRFMME, use of grib format is recommended.

Exchange of full fields: It is recommended that exchange of data should be for full fields. This exchange then needs to be accompanied by the exchange of relevant hindcast data such that forecast anomalies and tercile (or quintile) boundaries for probabilistic forecasts can be computed.

How to exchange the data: Similar to the exchange of seasonal forecast data, i.e., via ftp.

GUIDELINES ON EPS AND FORECASTING

1. Introduction

Ensemble Prediction Systems (EPS) are Numerical Weather Prediction (NWP) systems which allow us to estimate the uncertainty in a weather forecast as well as the most likely outcome. Instead of running the NWP model once (a deterministic forecast), the model is run many times from very slightly different initial conditions. Often the model physics is also slightly perturbed, and some ensembles use more than one model within the ensemble (multi-model EPS) or the same model but with different combinations of physical parameterization schemes (multi-physics EPS). Due to the cost of running an NWP model many times, the EPS is normally run at around half the horizontal resolution of the equivalent deterministic NWP model. The EPS normally includes a control forecast which uses the ensemble resolution model but without any perturbations to the analysis or model. The individual NWP solutions which make up the ensemble are often referred to as the ensemble *members*. The range of different solutions in the forecast allows us to assess the uncertainty in the forecast, and how confident we should be in a deterministic forecast. The uncertainty in a weather forecast can vary a lot from day to day according to the synoptic situation, and the EPS approach provides an estimate of this day-to-day uncertainty. The EPS is designed to sample the probability distribution function (pdf) of the forecast, and they are often used to produce probability forecasts – to assess the probability that certain outcomes will occur.

These guidelines are intended to provide some general advice to forecasters and forecast providers on the effective use of EPS, and on what EPS can and cannot be expected to provide. A general working knowledge of the principles and use of NWP is assumed. For those requiring more detailed information, the ECMWF User Guide (http://www.ecmwf.int/products/forecasts/guide/) provides comprehensive guidance on the use of ECMWF systems including detailed advice on the use of EPS; the COMET training materials (http://deved.meted.ucar.edu/nwp/pcu1/ensemble/) also provide training on the use of EPS.

In general, it is strongly recommended that uncertainty should be communicated as part of every forecast. Guidance on the communication of uncertainty is given in the PWS Guidance (WMO TD-1422).

Examples shown in these guidelines are mostly taken from the UK Met Office's MOGREPS EPS systems, or the ECMWF EPS, but the principles described apply to any EPS.

2. Why should we use EPS?

NWP systems using the latest numerical models of the atmosphere are very powerful systems to aid the forecaster in producing weather forecasts. Many models now provide a good enough representation of the weather that they can also be used to provide basic automated weather forecasts from Direct Model Output (DMO), although in general it is recommended that some post-processing should be used to calibrate automated forecasts. DMO provides a better representation of some weather elements than others, for example surface temperature is often quite well-resolved (at least away from steep surface orography) whereas precipitation is often much less well resolved.

However, despite these advances, it is well-known that forecasts from even the very best models can often go badly wrong. This is most obvious in forecasts several days ahead and is due to the *chaotic* nature of the atmosphere. We forecast the weather by starting the model from an analysis of the state of the atmosphere based on the latest observations which are taken all around the world. The model then calculates how the atmosphere will change and evolve from this initial analysis state over the coming days. Chaos theory means that the way the atmosphere evolves is very sensitive to small errors in that initial analysis, so that a tiny error (often too small for the forecaster to even notice) can grow into a large error in the forecast. Even with the best observations we can never make a perfect analysis, so we cannot make perfect forecasts. This is why we run EPS (ensembles).

In an ensemble forecast we make very small changes (perturbations) to the analysis, and then re-run the model from these slightly perturbed starting conditions. If the different forecasts in the ensemble are all very similar to each other then we can be confident of our forecast, but if they all develop differently, and for example some develop a major storm while others develop a much weaker depression, then we will be much less confident. However, by looking at the proportion of the ensemble members which predict a storm, we can make an estimate of how likely the storm is.

When we look at shorter-range forecasts of 1 or 2 days ahead, the general pattern of the weather is usually much more predictable, but we can still find important differences between ensemble members when we look at the local detail of the weather which may be important to many forecast users. Also, occasionally the larger-scale evolution can be uncertain even at short-range – this is most likely to happen during the development of major storms, so it is important to take account of the EPS even in short-range forecasts.

3. Types of EPS

Ensemble Prediction Systems for use in weather forecasting come in three main types, global, regional and convective-scale, and as with deterministic NWP models, they address different time-scales in the forecast. These will be outlined briefly below. Within each of these categories there are many variations, such as the way in which perturbations are created and the variations in the models used within the models – however the principles of how the ensembles are used remains the same, and these details are not covered here. (It may be noted that ensembles are also used for long-range forecasting and climate prediction. The principles are very similar, but these will not be considered in these guidelines which focus on forecasts of up to 15 days, which is the period over which it is often possible to forecast daily weather).

3.1 Global EPS

Global EPSs are normally designed and used for medium-range forecasting of 3-15 days ahead. They use global NWP models and are run at relatively low resolutions with typical grid-lengths of between 30 and 70km. Although they are primarily designed for use in the medium-range, their global coverage means that they can also be used to provide short-range EPS forecasts in regions of the globe where no other EPS are available, and may be the only available option for many WMO members. In this context they are used extensively to provide products to support the WMO SWFDP (Severe Weather Forecasting Demonstration Project) projects.

Forecasters using global EPS should always remember that the relatively low grid resolutions will limit the detail they can expect in the forecasts. Global EPS will often not be able to resolve details such as the full strength of wind speed in a storm.

3.2 Regional EPS

Regional or LAM (Limited Area Model) EPSs use regional models over smaller areas and are focussed more on the short-range forecast of 1-3 days ahead. They use higher grid length resolution than the global EPS, typically between 7 and 30km, which allows them to forecast more local detail in the weather and also to better resolve intense weather systems. Nevertheless the forecaster should still remember the limitations of resolution, so for example a regional EPS should not be expected to predict details of small-scale systems like thunderstorms.

A regional EPS has to take its lateral boundary conditions (the weather systems moving into the area from outside the domain) from a global EPS. Some regional EPS systems use a high-resolution regional analysis and calculate corresponding high-resolution perturbations, but others simply take the initial conditions and perturbations from the same global EPS which provides the boundary conditions – this is normally referred to as *downscaling*. In a downscaling EPS the forecast needs to run for a number of hours before the model can “spin up” the higher resolution detail.

3.3 Convective-scale EPS

Convective-scale NWP, with model grid-lengths of 1-4km run over relatively small domains, is now available in a number of more advanced NWP centres. These models, sometimes referred to as *convection-permitting* are able to resolve some of the detail of large convective systems, and thus can attempt to predict details such as the location and intensity of thunderstorms. While this offers great potential for improved forecasts, convective systems evolve very rapidly and have short predictability timescales, so the forecasts can rapidly be affected by chaos. EPS is therefore highly relevant to convective-scale NWP because convective instability adds a new scale of forecast uncertainty not resolved by the lower resolution models, and with much shorter timescales.

In addition to convection itself, models on this resolution have greatly enhanced capability for forecasting other aspects of local weather, such as low cloud and visibility of interest to aviation. Many of these phenomena are significantly affected by topographic forcing which may give enhanced predictability when that forcing (e.g. slopes, coastlines, vegetation, albedo) can be resolved by the models (e.g. convective initiation or valley fog). Convective scale EPS has the potential to provide information on the predictability of all these weather elements.

At the time of writing in 2011 convective scale EPSs are under development at various centres. DWD runs the COSMO-DE-EPS with a resolution of 2.8 km in preoperational mode since December 2010. The UK Met Office and Météo-France have plans to introduce such systems in the near future, and research is being conducted in other countries.

Due to the very high cost of running convective-scale EPS they are unlikely to be available outside the producing nations for many years, and experience of them is still very limited. They are discussed only briefly in these guidelines.

The much higher resolution of convective-scale EPS is expected to allow better resolution of many weather phenomena than is possible with global and regional EPS, for example local winds forced by topography and possibly elements like low cloud and visibility, especially where such phenomena are forced by local details of the topography or land surface.

For precipitation the models are likely to better resolve the intensity and spatial scales of local precipitation, especially in convective precipitation. However to sample the full range of uncertainty in convective precipitation would require very large ensembles with hundreds or thousands of members, which will not be affordable in the foreseeable future. It is therefore strongly recommended that convective-scale EPS is post-processed using techniques such as neighbourhood processing (where it is assumed that a feature such as a convective shower may be realistic but may be misplaced and occur anywhere around the neighbourhood within, say, 10 grid-lengths of where it appears in the model) to provide a more realistic spatial distribution of probabilities. Similar techniques may also be appropriate for other variables, to take account of the small size of the ensembles.

4. Standard EPS Products

This section describes some of the standard EPS products which are generated from most EPS systems, and briefly how they may be used.

4.1 Basic Direct Model Output Product Generation

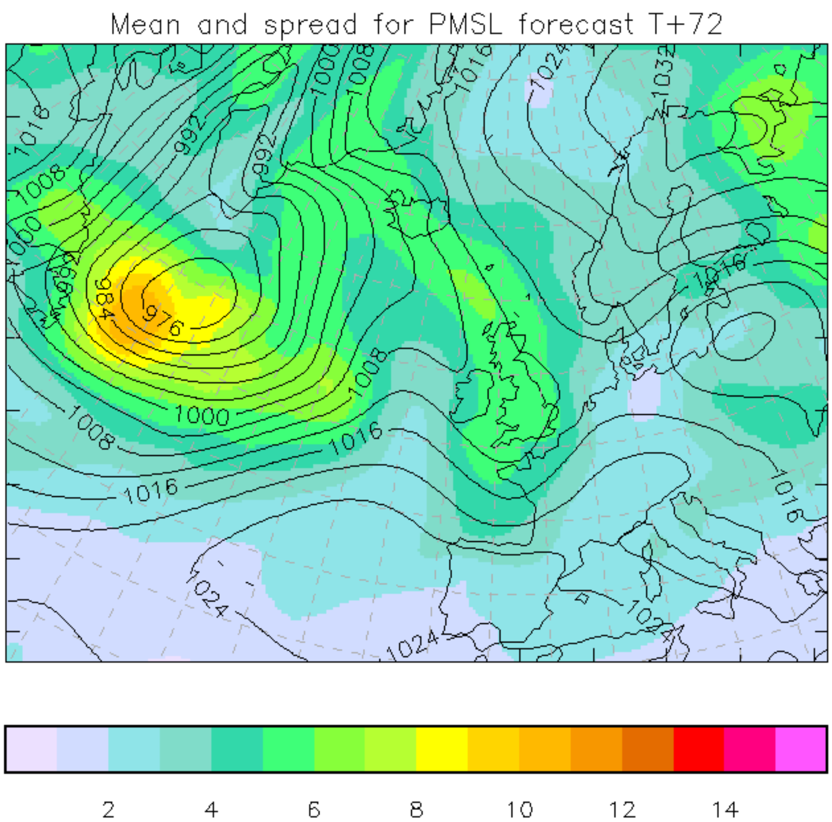
A range of basic products are produced from most EPS systems directly from model output fields. These typically include:

4.1.1 Ensemble Mean

This is a simple mean of the parameter value between all ensemble members. The ensemble mean normally verifies better than the control forecast by most standard verification scores (RMSE, MAE, ACC, etc) because it smoothes out unpredictable detail and simply presents the more predictable elements of the forecast. It can provide a good guide to the element of the forecast which can be predicted with confidence, but must not be relied on its own as it will rarely capture the risk of extreme events.

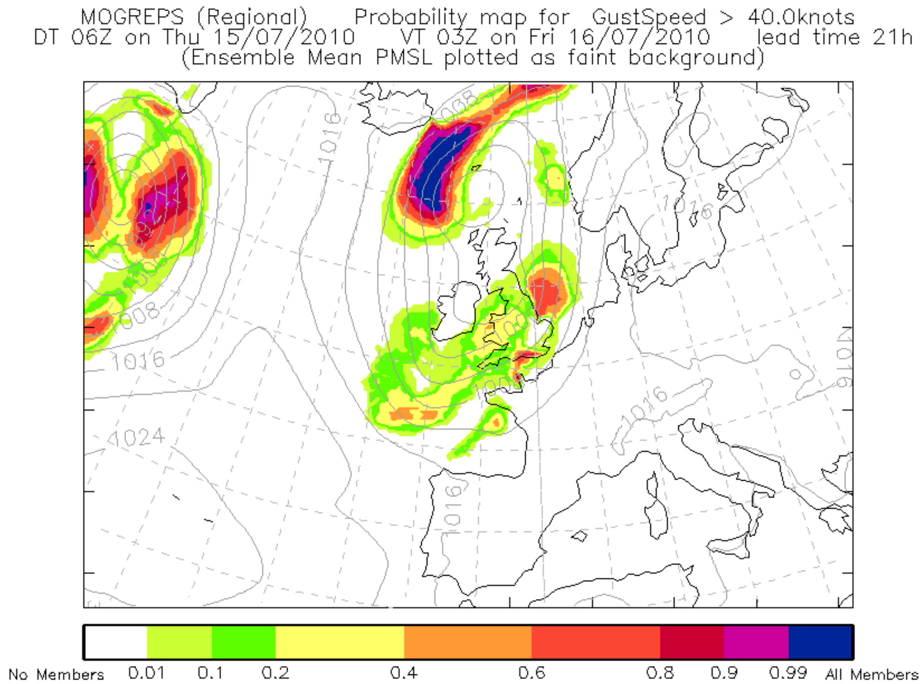
4.1.2 Ensemble Spread

This is calculated as the (non-biased) standard deviation of a model output variable, and provides a measure of the level of uncertainty in a parameter in the forecast. It is often plotted on charts overlaid with the ensemble mean. The example below shows both ensemble mean PMSL as black contours and spread of PMSL as colour shading. The areas of strong colours indicate larger spread and therefore lower predictability.



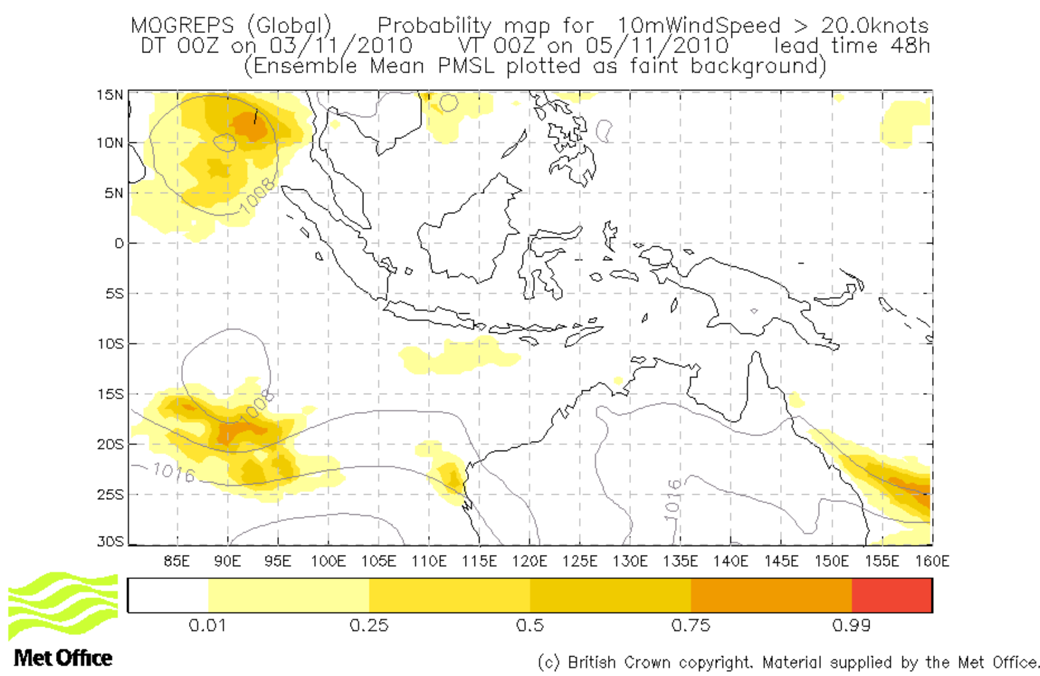
4.1.3 Basic Probability

Probability is frequently estimated as a simple proportion of the ensemble members which predict an event to occur at a particular location or grid-point (e.g. 2m Temperature less than 0 Celsius, or more than one standard deviation below normal). The example shown below shows the contoured probability of wind gusts exceeding 40kt. The ensemble mean pressure at mean sea-level (PMSL) is also included as grey contours.



It should be noted that this definition of probability is not a true Bayesian probability as would be defined by a statistician, but provides a useful estimate for practical purposes. It makes an assumption that the model accurately reflects the climate distribution of occurrence of an event. Probability forecasts produced in this way should always be verified over large samples of cases to determine the extent to which forecast probabilities relate to observed frequencies.

The second example shown below is one of those produced for the SWFDP project in the South Pacific.

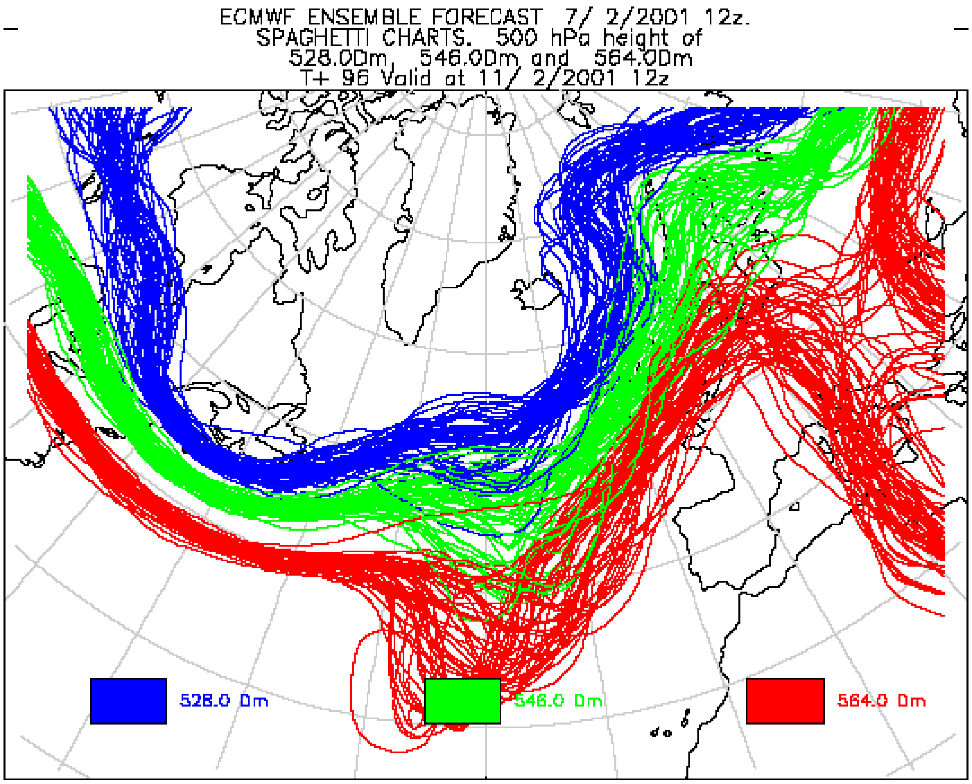


4.1.4 Quantiles

A set of quantiles of the ensemble distribution can provide a short summary of the uncertainty. Commonly used quantiles are the Maximum and Minimum of the ensemble distribution, and the 25th, 50th (median) and 75th percentiles. Others often used include the 5th, 10th, 90th and 95th percentiles.

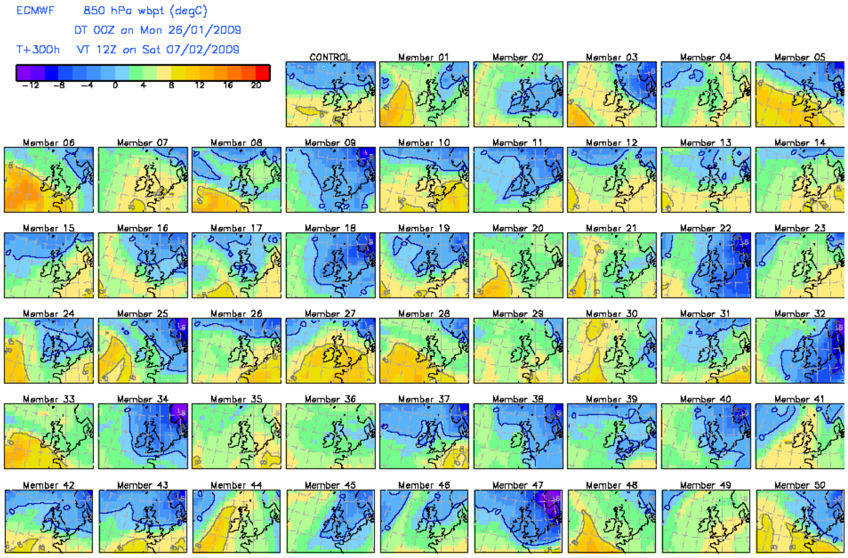
4.1.5 Spaghetti Maps

Charts showing a few selected contours of variables (e.g. 528, 546 and 564Dm contours of 500hPa geopotential height) from all ensemble members can provide a useful image of the predictability of the field. Where all ensemble member contours lie close together the predictability is higher; where they look lie spaghetti on a plate, there is less predictability.



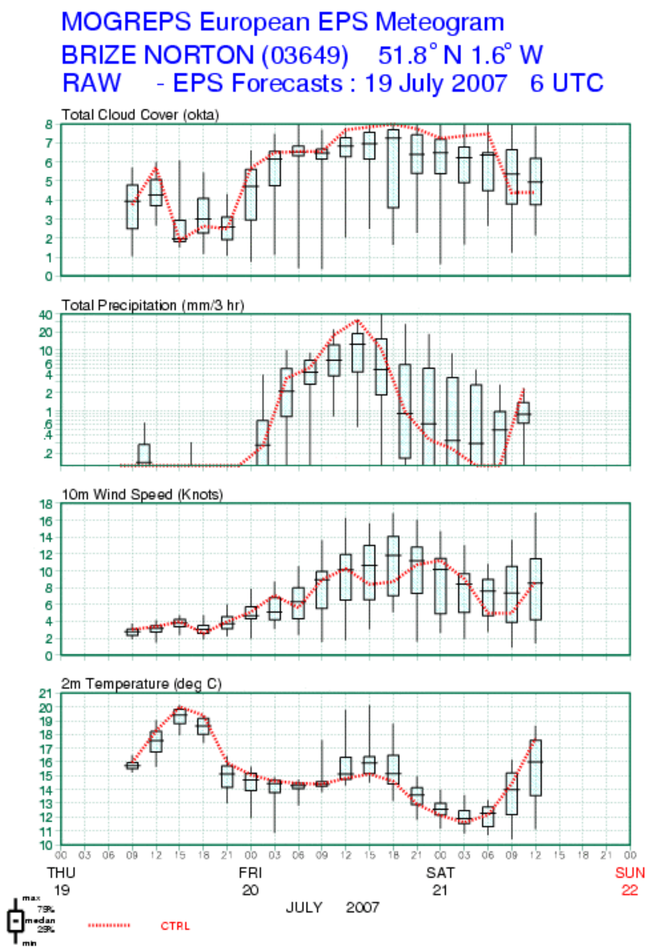
4.1.6 Postage Stamp Maps

A set of small maps showing contoured plots of each ensemble individual member allows the forecaster to view the scenarios in each member forecast, and assess the possible risks of extreme events. However this presents a lot of information which can be difficult to assimilate.



4.1.7 Site-specific Meteograms

Model output variables can be extracted from the grid for specific locations. There are many presentations which can be used to represent the forecast at locations, such as plume charts, Probability of Precipitation etc. One of the most commonly used is the Ensemble Meteogram (or EPSgram) which uses a box and whisker plot to illustrate the main percentile points of the forecast distribution for one or more variables.



5. General Comments Applying to all use of EPS

This section presents a number of general principles which apply to all use of EPS. Following sections provide more detail on the specific use of EPS for particular types of forecast production.

- An EPS best represents the uncertainty in resolved variables
  - Upper-air usually more skilful than surface
    - Surface parameters are affected by sub-grid scale uncertainty not resolved by the model
  - As resolution and model performance increases, the ability to predict surface weather parameters is continually improving
- An EPS is only as good as the model(s) it uses.
  - If a model is unable to represent certain phenomena, the EPS will also be unable to represent it.
    - A good example is that most ensembles cannot resolve convective storms, which is one of the reasons why some centres are developing ensembles at convective scale.
  - An EPS will share any systematic biases of the model used.
- How to combine deterministic forecast with ensemble/probabilistic?
  - Relative capabilities of ensemble members compared to hi-res/control
  - See the "Guidelines on using information from EPS in combination with single higher resolution NWP forecasts (February 2006)"
- A common question is whether a forecaster can improve the distribution by re-weighting members (e.g. the high-resolution control forecast if included) or by rejecting some members?
  - Forecasters may think that some members are unrealistic
  - Can we eliminate some members on the basis of recent observations or pick a "best member"?
    - PERHAPS, for certain aspects of the forecast over very short-period forecasts and for local forecasts over a small area
      - Over a large area or the full model domain, the control forecast will always be the most skilful.
    - NOT for longer period forecasts
  - This type of approach is subjective and difficult.
  - **It is strongly recommended that forecasters should use the whole EPS distribution in a probabilistic approach.**

- Strengths and weaknesses of the models/ensembles available to the forecaster should be known. Documentation should be easily available to the forecaster.
  - **Verification** of multiple thresholds to be available
  - Summary doc of strengths and weaknesses by season
- Be careful with "end of chain" diagnostic parameters (e.g. precipitation, cloudiness,…). For instance look at distributions of indices in convective situations.
- Forecasters should not always rely on direct model output of weather variables, but should also consider analysis of better resolved diagnostics which may aid interpretation of the EPS forecast (e.g. synoptic features,, environment/precursors/potential for high-impact weather developments such as moisture convergence, low level jets, development regions, convective diagnostics etc).

The use of EPS (and other probabilistic tools) opens the possibility of issuing two different types of forecast, fully probabilistic, or deterministic with supplementary uncertainty information (for instance confidence). Which type we use affects who makes decisions from the forecast. In general the use of fully probabilistic forecasts allows each user to tailor their decision to their specific needs (e.g. using cost-loss estimation), and is therefore strongly encouraged.

6. Use of EPS in Deterministic Forecasting

In general it is strongly recommended that probabilistic forecasts provide the best and most complete weather forecast for customers, and should be encouraged, especially at longer lead-times. However it is recognised that many customers demand a simple deterministic forecast, and where a deterministic forecast is to be produced, the use of an EPS can often provide a more reliable forecast than a single deterministic NWP run. This is particularly true for forecasts more than 1-3 days ahead, and can help reduce jumpiness from run-to-run of the forecast system at any time range.

Several indicators from the EPS can be used to optimise the deterministic forecast. The ensemble mean will on average score the best by many standard verification scores, but it must be remembered that it will tend to smooth out the smaller scale unpredictable detail, and will rarely capture the intensity of important high-impact weather systems. The ensemble mean should not therefore be used on its own if the use of the forecast is concerned about potential severe weather impacts. Other useful guides to the most likely forecast can be the median (central point in the pdf) or mode (most likely value in the pdf) – these are easier to identify for single weather parameters than for the complete forecast picture.

If a deterministic forecast is to be issued, it may sometimes be augmented by a statement of the confidence of this forecast to take some advantage of the uncertainty information available. The confidence will not always be the same for all elements of the same forecast. Confidence indices, if used, are best provided separately for each variable. The confidence level should be based on the spread of the ensemble, but also considering the known forecast skill limitations.

The best approach to issuing a deterministic forecast will depend on the predictability as indicated by the ensemble spread. The spread could be analyzed using various products such as, spaghetti plots, and map depicting variance at the synoptic scale and then, at the lower scales, using meteograms, quantiles, cluster analysis, etc. :

- Small spread in the ensemble (good predictability)
  - In this case it may be reasonable to offer more detail in the forecast.
  - Take the control, the high resolution control, the ensemble mean or the median as a guide (with due regard for the need for calibration or bias correction).
  - Spread may often differ between model variables so small spread in one parameter does not guarantee confidence in all aspects of the forecast.
    - Good synoptic scale predictability does not always mean predictability in surface weather variables such as temperature or convective precipitation.
    - Forecaster should still take account of uncertainty in parameters not resolved by the model.
- Large spread in the ensemble (poor predictability)
  - Avoid giving too much detail in the forecast
  - Ensemble mean should be considered but if the ensemble covers a range of scenarios the ensemble mean will not provide a realistic scenario
  - So in that situation, take most representative member of the ensemble (e.g. most populated cluster or mode of pdf) as a guide to the most probable outcome
    - Note that the most representative ensemble member may not give the most probable value for each weather element (e.g. most probable temperature at a location may not be correlated with the most probable precipitation amount.)
  - The uncertainty assessment
    - Encourage users to follow forecast updates.
  - Take into account extremes of the EPS and of the high resolution control
    - Make a careful evaluation of the possible evolutions of the synoptic situation and their potential impacts.
    - Take into account the behavior of models.
      - The high-resolution control may be better able to represent certain high-impact events.

- In the short range (12 - 18 hours), it may be possible to take into account the latest observations (3-6 hours into the forecast) in order to choose a scenario or a member of the ensemble
    - For example, a rapidly evolving cyclone may be best predicted by the member with the best position after a few hours *but ONLY* in the very short-range!
    - Be aware that future evolution will be influenced by features coming from upstream. This makes member selection for forecasts beyond ~24h impossible.
    - Also the consistency of the latest runs with respect to the previous is a factor to take into account.
- In the longer range, while probabilistic forecast are best suited, if a deterministic forecast is to be produced, the use of the ensemble mean or median could yield more reliable forecasts, with less jumpiness between runs of the forecast.

6.1 Decision Making from deterministic forecasts

Weather forecasts are only useful when people make decisions from them. It is often argued that it is easier to make a decision from a deterministic forecast than a probabilistic one. However when the forecaster issues a deterministic forecast the underlying uncertainty is still there, and the forecaster has to make his/her best guess at the likely outcome. Unless they fully understand the decision that the user is going to make based on the forecast, and the impact of different outcomes, then the forecaster's "best-guess" may not be well-tuned to the real needs of the user.

- The choice of making a deterministic forecast for a specific event to occur should not be taken without some knowledge of the needs of the end user. An optimal decision cannot be made without the cost-lost ratio of the user. This ratio can be assessed by a survey or a direct discussion with the end user.
- When appropriate the forecasters should convey the risks and impacts associated with worst-case scenarios alongside the most likely outcome

7. Scenarios

A useful way to summarise the uncertainty in a weather forecast can be to describe a small number of possible outcomes, or scenarios, rather than giving the full detail of a probabilistic forecast. For some customers used to receiving deterministic forecasts, this may be more acceptable. Ideally the EPS can be used to estimate the relative likelihood of the different scenarios presented. In most cases, to avoid confusion, the best approach may be to issue a most-likely scenario based on the advice above on issuing deterministic forecasts, plus a single alternative scenario – this may often be a *worst-case* scenario, perhaps reflecting a low probability but high-impact possibility suggested by the most extreme ensemble members. However care should be taken not to give the impression that either scenario will be correct – the truth could easily lie somewhere in between (or even be different again!)

Useful tools to aid in issues alternative scenarios are postage-stamp maps (4.1.6) which show the forecaster all the individual forecasts in the ensemble, or clustering (9.3) which automatically groups the ensemble members and provides the forecaster with an objective assessment of the possible scenarios.

8. Full Probabilistic Forecasts

Wherever possible, the use of a full probabilistic approach is recommended in issuing forecasts. This provides a full representation of the uncertainty information provided by an EPS, and also allows users to tune their decision-making to take account of their particular applications.

Probabilistic forecasts can be expressed in a number of ways, and need not always use the word *probability*:

- A forecast of a weather variable provided with error bars which vary according to the ensemble spread.
- A fuller representation of the ensemble distribution showing a number of percentile values, as used in the standard meteogram product.
- Probabilities of specific (well-defined) events occurring, expressed as numbers or as contoured shading on a map.

When a forecast is presented as a probability, it is very important to express very clearly *what* the probability is for, so that both the forecaster and the user is clear and understands. We often talk about the probability of an *event* occurring, and it is this event which must be defined. Often the event will be for a threshold value to be exceeded (e.g. more than 50mm of rain, or temperature below 0 Celsius). Ideally it will be something which has an important impact for which someone will have to take a decision (e.g. the probability that ice will form on roads so that road treatment will be required). It is also important to define when and where the event is forecast for:

- Exact time, or time period which the forecast refers to.
- Exact location or area which the forecast applies to.
    - If it is an area, does it mean a forecast that the threshold will ne exceeded somewhere in the area, or everywhere in the area?

A good test of whether an event is well-defined is to ask yourself whether you could easily measure whether the event does happen or not (in other words, could you verify the forecast). If you cannot easily say, then you may need to define the event better.

The following bullets provide a number of issues which should be considered when basing probabilistic forecasts on EPS outputs:

- Calibrated, bias corrected forecast can be directly issued to the end user (low cost).
    - This approach allows for the possibility of issuing automated forecasts for many locations and users.
    - Methods for bias correction and calibration are discussed in section 9.
- Direct model output (DMO) from ensembles should be used with care, as it may not provide reliable probabilistic forecasts, but will often nevertheless provide valuable information. In some cases use of DMO may be essential where there is no calibration system in place – calibration is difficult for certain variables such as precipitation, or where adequate observations are not available.
- To generate probabilistic forecasts of outcomes dependent on more than one weather element, it is important to calculate this outcome for each ensemble member and then combine members to create the probabilities. This retains consistent correlations between different weather variables and also different locations (e.g. the correlation in temperature between two locations). Calibration or post-processing may spoil this consistency.
    - This principal also applies when using the ensemble to drive downstream impact models (e.g. hydrological models) where the downstream model should be run for each ensemble member and then the probability of the downstream impact calculated.
- In “usual” situations, forecasters should not try to change the probabilistic forecasts issued by the EPS (DMO or post-processed). The forecasts can be issued directly to the public. Forecasters should target their attention to “unusual” situations.
- In “unusual” situations, probabilistic forecasts can be adapted by the forecasters using experience, analogues, conceptual models,…. Forecasters may be able to correct for some known system biases or model weaknesses. The corrections should be made by using the guidelines mentioned in section I.
- Studies have shown that the general public is able to make better decisions, when presented with uncertainty information in forecasts than with a deterministic forecast. When uncertainty information is not provided people make their own assumptions.
- Probabilities have to be presented in a comprehensive graphical form. Examples and guidelines are given in the PWS document PWS-18, WMO/TD No. 1422.

- Probabilities of events relevant to specific applications should be defined. This includes, for example, application in agriculture in which the occurrence of dry spells or rainy periods influences irrigation, seeding, harvest…
- Risk is a combination of impact and likelihood of a phenomenon which can be produced by the EPS. It gives an objective and valuable decision basis to the forecasters in order to assess different warning levels. Impact has to be agreed with the relevant authorities (PWS customers). Climatology usually provides a good reference to establish the thresholds of phenomena which produce impact. The thresholds can be adapted taking into account the recent evolution of the various environmental parameters (recent rainfall accumulations affect soil saturation, leaf-cover on vegetation, snow cover etc.).
- It is recommended that where probabilities are indicated for significant high-impact weather, a forecaster-written comment or warning should be added.

9. Post-Processing

The aim of this guidance is to provide explanation and advice for post-processing using statistical dynamical and other approaches to improve EPS outputs. There are numerous approaches and the paragraphs below capture some of the most common. Some methods are quite generic and may be best applied by EPS producers at source, while others are quite specific to applications and may be better applied specifically for individual users.

9.1 Statistical post-processing

Generally speaking statistical post-processing is needed in order to correct systematic errors in models and thereby add value to direct NWP model output. These errors are particularly important for surface parameters (e.g. 2m temperature, 2m humidity, 10m wind speed, precipitation, total cloudiness, …) and are linked to local conditions.

More precisely, statistical post-processing can be used to:

- Remove systematic biases
- Adjust ensemble spread
- Quantify uncertainty not represented directly by the EPS
- Predict what model does not represent explicitly (e.g. low visibility)

In general statistical methods are easier to apply to some types of model output variable than others. Temperature is often relatively easy, for example, as it is a continuous variable and varies relatively smoothly in model fields, and most importantly temperature errors are often approximately normally distributed. Precipitation, by contrast, is particularly difficult because precipitation fields often have much multi-scale structure which is poorly represented by models, especially on the small scales. Its climatological distribution, and hence the distribution of forecast errors is bounded at zero at one end and often highly skewed, making it much more difficult to represent statistically. The problem can sometimes be reduced by transforming the distribution to make it more quasi-normal, but in general post-processing methods for precipitation are much less effective than for other variables.

9.1.1 Bias correction of the First Moment of the PDF (Probability Density Function)

This post-processing is similar to MOS (Model Output Statistics) methods applied for single models, but with some important differences. For ensembles, it is well known that a traditional MOS which is trained specifically for each forecast lead-time will lead to a significant decrease of the ensemble spread at longer lead times. Instead, it is recommended to use a pseudo-perfect prognosis approach. This method is based on the use of MOS statistical models computed over the first 24h of the forecast and then applied to the corresponding steps during at all forecast lead-times.

Adaptive methods such as the Kalman-filter are recommended to allow the corrections to be automatically updated to account for model changes (upgrades) and changes in the season.

In the case of single-model ensembles (i.e. the same model is used for all of the members, even where model perturbations are implemented) the same statistical model should be trained using the control forecast and applied to all members of the ensemble.

In the case of multi-model or multi-physics ensembles (i.e. where different models are used to build the pdf, or systematically different model versions are applied, e.g. different parameterization schemes) specific statistical models should be trained and applied for each model version.

In either case the development of these statistical models need a training set of model outputs (predictors) and observations (predictands). In the case of adaptive methods such as the Kalman filter this training set is updated continuously from the daily forecasts.

The “observations” can be either site-specific observations or may be the best available set of analyses. In the case of site observations the statistical post-processing will lead to local forecasts (i.e. at each site specific point where observations are available). When analyses are used the end product is a bias-corrected and downscaled gridded forecast.

It should be noted that when different weather variables are independently bias-corrected, some of the correlation between variables represented by the different ensemble members may be lost. For this reason forecasters may prefer to view direct model outputs.

9.1.2 Calibration of higher moments of the PDF

Bias removal for the second moment of the pdf is often known as “calibration”. It aims to improve the reliability of the probabilistic forecast. Therefore this kind of post-processing is specific to ensemble prediction systems and is particularly important to optimize probability forecasts. As for the first moment bias correction, calibration is based on local conditions and requires high quality observations or analyses as a reference.

A number of methods are under development which attempt to calibrate both the first and second moments of the pdf to optimize the complete distribution.

- A method developed at the University of Washington is now considered as one of the best to deal with this issue. This method, called “Bayesian Model Averaging” is based on specific statistical assumptions (e.g. normal distribution for temperature).
- EKDMOS (Ensemble Kernel Distribution Model Output Statistics) is another technique which has been implemented in the USA.

The above methods are commonly applied to variables such as temperature and wind-speed. Variables such as precipitation are more difficult to correct due to the nature of the pdf and the local variability of observations. Some specific approaches are under development, but post-processing methods are at present less successful and may not improve significantly over raw model outputs.

It must be noted that there are limitations to the potential of statistical post-processing especially in the case of severe events. Commonly calibration will improve the statistical reliability of probabilistic forecasts (the match of forecast probabilities to frequency of observations of the event) but reduce the resolution of the forecasts (the ability to discriminate whether an event will occur or not). Sometimes it is found that calibration will improve forecasts of common events, but degrade the probabilities of more extreme events. The main reason for this is that observations of these kinds of events are rare, and the statistical distributions are trained to the more common events. Therefore calibration cannot be expected to provide significant improvement over the raw forecasts in this case.

Some attempts have been made to develop post-processing explicitly for prediction of more extreme events, for example first-guess severe weather warning systems. In these cases the systems can be calibrated specifically to optimize the reliability for extreme thresholds. Nevertheless, human expert interpretation remains particularly important for assessment of the risk of extreme events.

9.2 Downscaling

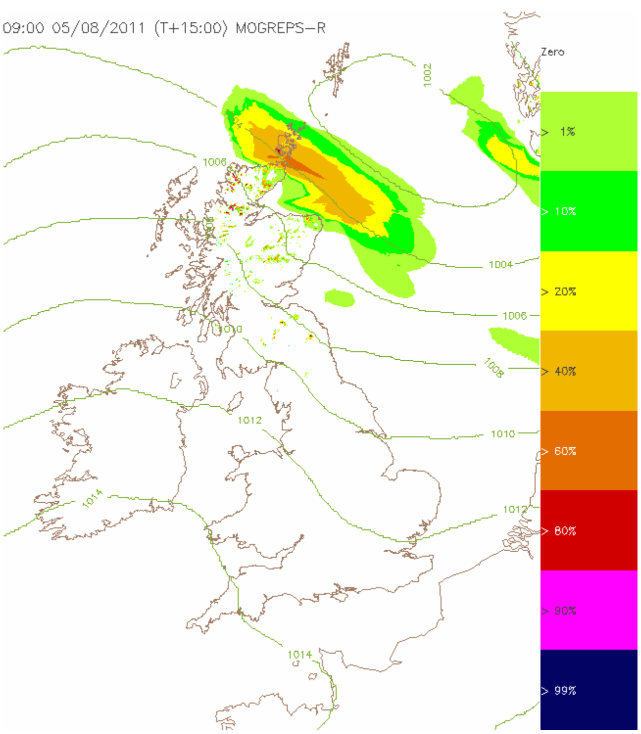
A number of methods may be used to add some local detail to forecasts generated with lower resolution models, and these techniques may be applied to EPS forecasts just as with deterministic NWP.

9.2.1 Dynamical Downscaling

Dynamical downscaling may be defined as the use of a higher resolution limited-area NWP model to add detail forced by topographic detail and to resolve fine-scale processes such as convection. Ideally all ensemble members will be downscaled, but where cost constraints prevent this, a selected set of members may be downscaled. In dynamical downscaling, the initial conditions, boundary conditions and perturbations are taken directly from the lower resolution EPS members. Care must be taken to ensure that the downscaling is appropriate to ensure good performance of the high-resolution model, e.g. appropriate ratios of grid sizes, rate of updating of boundary conditions etc. The model performance should be carefully tested over the domain. Many LAM and convective-scale EPSs are dynamical downscaling systems from global ensembles.

9.2.2 Topographic downscaling using simple physical models

For some parameters such as 2m temperature and 10m wind speed a simple downscaling can be applied using a relationship to the surface topography. For example in surface temperature forecasts the lapse rate may be used to downscale the low resolution EPS field to a higher resolution grid using a gridded topography. The example below shows probabilities of strong wind downscaled from a regional EPS using a high-resolution orography field, and shows how probabilities of winds over the mountains in Scotland can be detected which were missed in the DMO version of the chart.



9.2.3 Site-specific extractions

Forecasts for specific locations may be generated by extracting data from model grids. In the simplest implementations data are simply taken from the nearest model grid-point, or are interpolated between the nearest grid-points by linear interpolation. Various methods are used to improve on these approaches, using similar techniques to the downscaling methods. In particular corrections to surface temperature and wind speed should be made to account for the difference between model orography and the true altitude of the site. An intelligent grid-point selection system which chooses the most representative grid-point can also be better than a simple interpolation, especially near coastlines where it may be better to choose the nearest land-point to represent a land-location, rather than for example the nearest grid-point which may be over the sea. This approach may also be beneficial near steep orography.

A one-dimensional model could also be used for specific forecast applications (e.g. 1D fog models for airports).

9.2.4 Statistical Downscaling

Downscaling of surface fields may also be done by building a statistical relationship between low-resolution model fields and high-resolution analyses. There are two approaches which may be followed:

9.2.4.1 Using Analysis Differences

The statistical relationship may be developed by comparing high-resolution gridded analyses with the corresponding analysis fields on the EPS model grid. This provides a downscaling vector which may then be applied to EPS forecast fields to provide bias-corrected and downscaled forecast fields on the high-resolution grid.

9.2.4.2 Kalman Filter

A Kalman filter approach may be applied at each grid-point of the high-resolution grid to build a statistical relationship with the lower-resolution EPS analysis fields. This Kalman filter may then be applied to the EPS forecast fields to provide bias-corrected and downscaled forecast fields on the high-resolution grid.

9.2.5 High Impact Weather Diagnostics

A number of methods are available to diagnose specific high-impact weather phenomena from NWP models, and these can be applied equally to EPS. A good example is Severe Convection diagnostics. These often use a number of model multi-level model outputs to diagnose the instability and potential for severe convection, and provide probabilities for phenomena such as large hail, tornadoes and convective wind gusts.

9.2.6 Downscaling by combination of low-resolution EPS and high-resolution control forecast

Low resolution ensemble perturbation fields (difference between the perturbed member forecast and the control forecast) can be added to a high resolution control forecast fields to provide a high-resolution probabilistic forecast.

9.3 Clustering techniques

Classification processes can be used to synthesize the huge amount of information contained in ensembles. Different kinds of classifications can be implemented:

- Clustering attempts to group together members which are most similar in their evolution over a defined geographical region of interest. Several standard clustering algorithms are available and may produce different groupings under. The clustering outcome also depends on the variables chosen.

- The "tubing" classification identifies a central cluster of the members closest to the ensemble mean and those members most significantly different from the ensemble mean (tube extremes). Tubing is useful to identify the most likely outcome and also the possible scenarios most different from that solution.
- Classification of forecasts by matching ensemble members to a defined set of flow regimes, for example the Grosswetterlagen types defined for central Europe. This method may provide the clustering which best matches a synoptic forecaster's expectations.

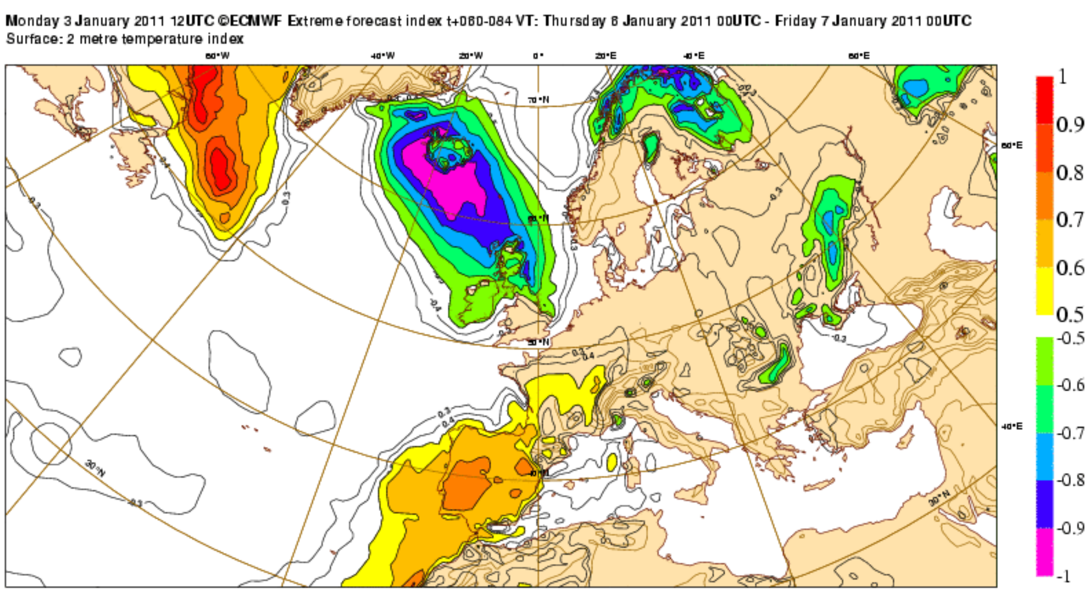
9.4 Use of Reforecasts

Research has shown that calibration of ensemble forecasts using historical sets of "reforecasts" – forecasts run with the same model or EPS from sets of historical cases, initiated from reanalyses – can be very effective in improving the quality and reliability of probabilistic forecasts. Such reforecasts provide a better dataset for training of statistical post-processing methods compared to using recent forecasts, as they provide a better sampling of different weather regimes and types. This can be particularly useful for optimizing the calibration of forecasts for rare or extreme events. However the running of reforecasts adds substantially to the computing cost of running an EPS, and depends also on the availability of a suitable reanalysis dataset to provide the initial conditions. As a result very few EPSs currently have reforecast datasets available, but their use is recommended where possible. Where a full reforecast dataset is not available, an alternative may be to use a recent archive of EPS forecasts from the same system, although is likely to provide a less reliable sampling of the full model climate.

9.4.1 Extreme Forecast Index (EFI)

One application of reforecasts is the computation of an Extreme Forecast Index.

NWP models and EPS systems do not represent accurately the climate of the real atmosphere, and identification of extreme events may be best done in relation to model climatology. The Extreme Forecast Index developed by ECMWF allows identification of forecasts which are extreme relative to the model climate, providing an alert to a risk of severe weather. The EFI does not provide explicit probabilities of severe events.



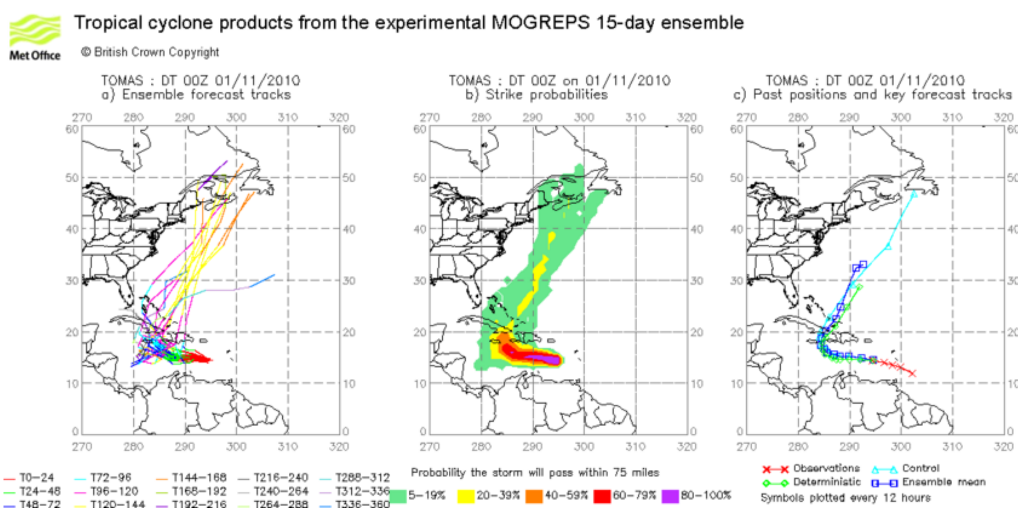
Reforecasts can also be used to assess forecast severity in relation to climatological return periods, which can be a useful way to communicate the severity of an event.

9.4.2 Quantile-Quantile Matching

Another approach to forecast calibration which can be used where an estimate of the model climate is available is Quantile Matching. For example the value corresponding to the 90th percentile of the model climate may be interpreted to represent the 90th percentile of the real observed climate distribution for a particular location. In general this method requires the use of a reforecast dataset to provide the model climate.

9.5 Feature Tracking

A useful technique for lower resolution EPS such as global EPS is to track meteorological features in each member of the ensemble. A good example is Tropical Cyclones (TC) which are not well-resolved in the model, but the global models can nevertheless predict the movement of the storms quite well. A global EPS could not be expected to predict the intensity of strong winds or heavy rain in a TC but could track its position. The forecaster can interpret the probabilities of severe weather by knowing the characteristics of tropical cyclones, combined with the ensemble information on where it is likely to go. The example below shows tracks of Hurricane Tomas in the members of the ensemble, probabilities that the storm will pass close to locations on the map, and summary tracks such as the ensemble mean track. These types of charts are often made available to the Tropical Cyclone RSMCs.



10. Use of EPS in Prediction of Severe Weather and issue of Warnings

Severe or high-impact weather events occur on a wide range of scales in space and time, from Tropical cyclone, extra-tropical cyclone, monsoon, winter storms and other large scale systems, to smaller scale systems such as local severe storms, orographic precipitation, thunderstorms and tornados. Forecasters must take account of the different predictabilities of different types of events (e.g. do not try to predict a thunderstorm 3 days in advance).

A well structured NMHS severe weather warning system should have appropriate thresholds, lead-times and level of service agreed with users. Thresholds should normally reflect the level of impact the weather is expected to have on society, including danger to life and property, and disruption to everyday life. Features which should be considered in a warning system include:

- Types of warnings; regions; thresholds (severity/impact and probability)
    - o Risk = Probability x Impact
- A good warning system is one that will be easily understood by users, with standard thresholds adhered to by forecasters.

    - Many countries now use a 4-colour *traffic light* system (Green, Yellow, Amber and Red) indicating different levels of risk and corresponding levels of action which users should take.
- A good warning system will require feedback from users to NMHSs. The NMHSs in turn should give feedback to producers enabling them to design appropriate products.

EPS are a powerful tool in predicting severe weather events. For impact-based warnings systems the EPS may be used to help estimate the probability of weather hazards for use in the estimate of Risk = Probability x Impact. However, EPS can only predict severe weather which the model(s) can resolve:

- Numerical Weather Prediction has limitations in explicitly resolving smaller scale phenomena, which leads to under-estimation of extreme events likelihood within EPS.
- Sometimes can identify pre-cursor conditions for severe developments or favorable large scale environment such as convective indices
- Lower resolution EPS (Global) is less likely to be able to resolve details of an extreme event
- Regional EPS, which usually has higher resolution, should provide more detailed uncertainty estimates at the smaller scales.

Hazard thresholds used in the EPS may need to be calibrated to take account of the above limitations.

Early indications of some *extreme* events will be predicted in the tail of the ensemble distribution.

- Therefore forecasters and users should not ignore low probability events, especially when those events are very rare.
    - For example, ignoring probabilities below 20% or even 10% could result in missing the most important events signaled by the EPS.
    - To be able to use low probabilities, forecasters need verification information
    - "false alarms" are actually correct features of low probabilities. However low probabilities may be required in potential high-impact situations
    - It is expected that the probability will increase closer to the event – usually but not always

An extreme event may also be forecast essentially correctly, but with errors or uncertainties in location or timing.

Synoptic interpretation (e.g. weather feature tracking, use of analogues) or statistical downscaling tools are ways to add skill to the basic EPS.

- Note that some statistical methods require large data samples for training, and may not be well-suited to rare or extreme events.
- Cyclone tracking products (for both tropical and extra-tropical cyclones) can provide a useful summary of the development of high-impact storms.
- There is potential for development of more feature-based diagnostics for poorly resolved severe weather systems.

The Extreme Forecast Index (EFI) can be a useful tool in alerting forecasters to a potential severe event.

- EFI does not provide explicit probabilities of specific events, and should be interpreted in conjunction with other tools.
- Currently only a small number of systems can provide an EFI due to the need for a model climatology.

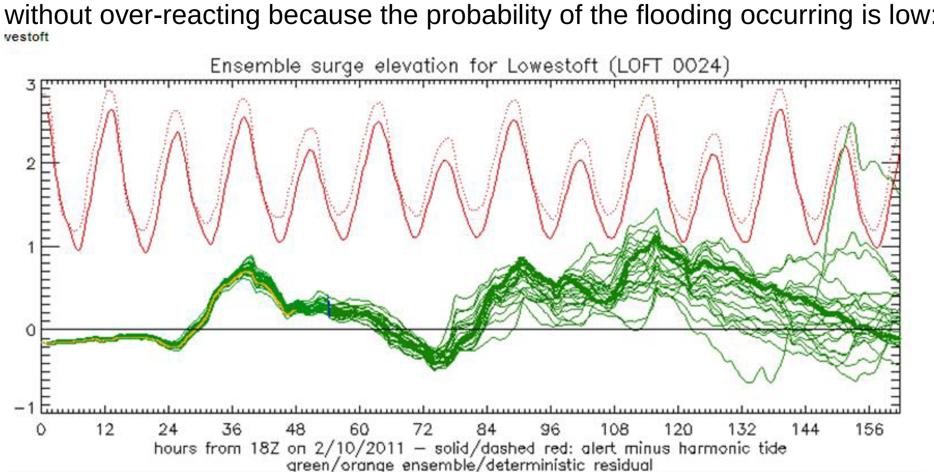
Consideration of input from multiple forecasting systems (EPS and deterministic) may give additional information on the probability of extreme events

- Production of verification highlighting the skill and limitations of EPS is important.
    - Users of EPS should be aware of those limitations and strengths.

- o However, due to the rarity of most extreme events it is often impossible to provide reliable (or statistically valid) verification of probabilistic performance. It may be possible to gain some estimate of skill for extreme events by extrapolating from the verification of less-severe events.
- Given the diminishing of the EPS skill with increasing lead time, latest available products are generally given higher credibility. However, previous runs of an EPS may still provide useful information about a rare event because of the lack of spread (limitation in the sample size).

11. Severe Weather Impact Modeling

The uncertainty in the weather forecast can be propagated through to uncertainty in impact by coupling ensemble members to impact models and generating a distribution of impact predictions. Examples include hydrological models for probabilistic flood forecasting, coastal storm surge models, heat health models etc. This is an advanced application which is being increasingly applied in the more advanced centres. The example below shows an ensemble forecast of storm surge at a coastal port, where the weather forecasting EPS has been used to force an ensemble with a storm surge model. The red lines at the top of the graph show the flood danger level oscillating up and down with the tide, and a flood risk is indicated where the ensemble forecast surge lines cross above the red lines. This is an interesting example as one member of the ensemble produces an extreme surge at day 7, indicating a low probability of severe coastal flooding. In this situation the user needs to be able to take some early preparedness action but without over-reacting because the probability of the flooding occurring is low:



12. Verification

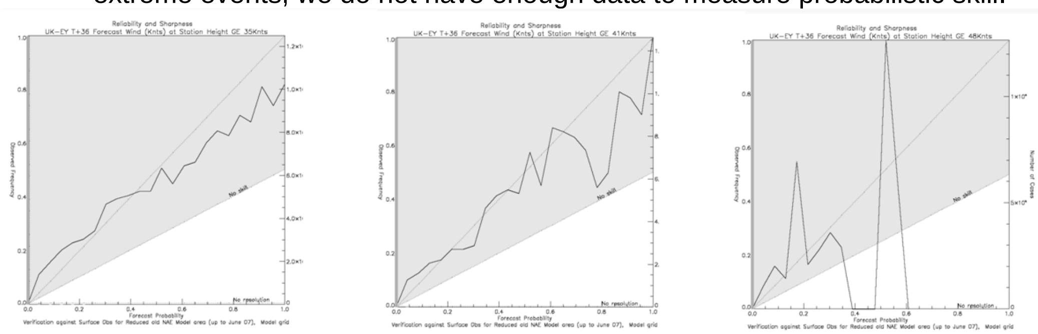
Verification is a very important part of everything we do in forecasting. If we do not verify our forecasts – measure how good they are by looking back afterwards and seeing how well the forecast matched what actually happened – then we have no way of learning and improving our forecasts in the future. This is just as true with probabilistic forecasts. You will often find people say that a probability forecast can never be wrong (unless we say 0% or 100%). Some people will also say that it is just a way for the forecaster to avoid making a decision. The way to challenge these views is to demonstrate that we do verify the forecasts, and that they have useful skill.

We do not provide here a detailed guide on verification of forecasts, but we describe a few important points:

- A *single* probability forecast cannot be right or wrong.
    - o If we predict something with a high probability and it happens, it is often tempting to say "Look, we got it right!" We should avoid doing this, because when we forecast something with a low probability and it happens we will want to say to the user "We did say it was a possibility even though it was a low probability".
- If we say there is a 30% probability that we will get more than 10mm of rain, and the observation shows that we get only 1mm, the forecast is not right or wrong. We have to

measure the actual observed amount for many occasions when we make such a forecast – out of every 100 times that we say this, we should get over 10mm on 30 occasions. This is what the forecast means. Out of 100 times that we predict 80% probability, we should get it 80 times.

- The simplest way to present verification is using a reliability diagram, which plots a graph of the observed frequency against the forecast frequencies – so it plots exactly the test described above. Below are three examples of reliability diagrams for probabilities of wind speeds exceeding Beaufort Force 8, 9 and 10. The ideal is that the line should lie up the main diagonal, from (0,0) to (1,1). The first diagram on the left for Force 8 is quite good and shows that forecasts of high probability do mean the event is much more likely – the slope of the graph is slightly less than ideal, but good. The second is similar but not quite so good for the highest probabilities at the top right of the graph. The third on the right, for Force 10, shows useful skill for probabilities up to 30%, but at probabilities above that there is no useful information. In fact this is a rare event and there are not enough samples in the dataset to measure whether there is useful skill – this is a common problem with verifying extreme events, we do not have enough data to measure probabilistic skill.



- There are many other measure of probabilistic forecast. We list some other common ones here – much more information is easily available from an internet search for these terms, or from standard guides to forecast verification:
    - Brier Score – a root mean square error for probability forecasts of a particular event threshold.
    - Brier Skill Score – compares the Brier Score of the forecasts with the Brier Score of some reference forecast system.
    - Reliability – measures how well forecast probabilities match observed frequencies.
    - Resolution – measures how good the system is at predicting probabilities which are different from “normal”.
    - ROC (Relative Operating Characteristic) – measure how good the forecasts are for decision-making – similar to resolution.
    - CRPS and RPS – (Continuous) Ranked Probability Score – like a Brier Score for multiple thresholds of the weather variable.

WMO CBS has defined a standard set of verification scores for comparison of EPSs, and these are displayed for a number of global EPSs at the Lead Centre website at http://epsv.kishou.go.jp/EPSv/ .

13. Forecaster Training

In general, forecaster training should include components on predictability and ensemble forecasting:

- Motivation for probabilistic forecasts – chaos theory and its impact.
- Statistical background theory and approaches.
- Aims of initial condition and model perturbations.
- Standard ensemble verification tools and their meaning.
- Explanation of basic meaning of products (e.g. lines on chart).
- Methods of post-processing and their impacts.

Learning Through Doing – The training of forecasters in the use of EPS guidance should be a practical experience using tools which are as close as possible to those used in operations. The optimal benefit from practical training on EPS is only obtained when an NMHS has access to operational EPS data, the operational time to use it and the products and tools to make direct use of it.

  - Benefits of training which is not reinforced by operational practice are rapidly lost.
  - Provision of training in conjunction with a demonstration project such as the SWFDP can help to ensure that the training is reinforced and consolidated by the provision of relevant operational EPS data.

  - During training, case studies should be worked through showing the appropriate use of EPS guidance, both in routine and severe weather scenarios.
  - Web-based tools can be valuable in training, as they can be used on any workstation system through a standard browser to ensure continued access afterwards.

- In the relatively new area of EPS, periodic training is expected to generate the best benefit. Forecasters require time to build experience in using this guidance followed by further training to reinforce key concepts. It would also be of benefit if various NMHSs could share their experience with EPS.
- Training resources
  - ECMWF Users' guide http://www.ecmwf.int/products/forecasts/guide/
  - COMET ensemble modules: http://deved.meted.ucar.edu/nwp/pcu1/ensemble/

WMO RESPONSE TO THE FUKUSHIMA DAIICHI NPP ACCIDENT
(excerpt of the CG-NERA Vienna 2011 meeting report, which is available on the WMO website at http://www.wmo.int/pages/prog/www/CBS-Reports/DPFSERA-index.html)

5. WMO RESPONSE TO THE FUKUSHIMA DAIICHI NPP ACCIDENT, TRIGGERED BY THE GREAT EAST-JAPAN EARTHQUAKE AND TSUNAMI OF 11 MARCH 2011

5.1 The representatives of National Meteorological and Hydrological Services (NMHSs), including those of Regional Specialized Meteorological Centres (RSMCs) with activity specialization in Atmospheric Transport Modelling (RSMC-ATM) and RTH Offenbach briefed the meeting on their respective responses and experiences in relation to the Fukushima Daiichi NPP accident and emergency, including the roles they played as WMO regional centres, as well as within their national nuclear emergency response organizations and operations. Their full written reports are available on the WMO website at http://www.wmo.int/pages/prog/www/DPFSERA/Meetings/CG-NERA_Vienna2011/DocPlan.html. Based on these reports, and the lessons learnt from the Fukushima Daiichi NPP accident and emergency, the meeting identified issues, and agreed on actions and improvements to the operational procedures.

Provision of specialized meteorological information for the general public

5.2 The meeting recalled the request by the World Meteorological Congress, in its sixteenth session (May 2011), to the Commission for Basic Systems (CBS) to review the EER procedure to strengthen the aspects related to the provision of specialized meteorological information for the general public in the *Manual on the Global Data-Processing and Forecasting System* (GDPFS) (WMO-No. 485). The meeting noted that the current version of the *Manual* states in Appendix I-3: "RSMCs... shall provide, on request, support and advice to the IAEA and WMO Secretariats in the preparation of public and media statements". The meeting also noted that throughout the Fukushima event, the WMO Secretariat posted an excerpt of the joint statements by the lead-RSMCs on the meteorological situation on the WMO website; and JMA has prepared and maintained a webpage (http://www.jma.go.jp/jma/en/2011_Earthquake.html) with meteorological information for the disaster struck region (in Japanese and in English).

5.3 While recognizing that there were issues associated with public information and that there is a need for the provision of specialized meteorological information to the general public, the meeting agreed that public information is primarily the responsibility of national authorities. Noting that, within the existing arrangements, the main role of the RSMCs is to assist NMHSs within their regions, the meeting recommended that guidelines on the interpretation of the products from the RSMCs should be developed and included in the WMO/TD-No. 778. At the same time, the meeting requested RSMCs to explore the feasibility of developing a regional product(s) that could support and assist NMHSs, and the WMO and IAEA Secretariats, in the preparation of public information; and present their proposals in the next CG-NERA meeting. In addition, the meeting recommended the organization of teleconferences with the participation of all RSMCs, and WMO and IAEA Secretariats, in order to help developing a coordinated response.

5.4 The meeting discussed the possibility of distributing RSMC products to the general public, and agreed that, in accordance with the existing procedures, RSMCs are not allowed to do it, and that the dissemination of such products to the general public is entirely within of the responsibility of the national authorities.

Notification by IAEA

5.5 The meeting noted that these were issues associated with the timely issuance of the notification by IAEA (WNXX01) on the GTS, and that some NMHSs do not know what kind of actions they should perform upon receipt of this notification. The meeting recommended that documentation on the content of the WNXX01 notification, including examples, should be prepared and included in the WMO/TD-No. 778.

5.6 The meeting also recommended that IAEA issue the WNXX01 notification as early as feasible, before the event reaches the class of general emergency (e.g. for situations where there is a likelihood of an atmospheric release), in accordance with the existing procedures stated in Appendix I-3 of the *Manual on the GDPFS*. The meeting requested IAEA to send the notification to RTH Offenbach by e-mail (using fax as a back-up).

Source Term

5.7 The meeting noted that a number of RSMCs and NMCs have worked on the estimation of the source term, either by themselves or in collaboration with other national institutions within their countries. Noting that CTBTO radiological monitoring data was useful for estimating the source term, the meeting agreed to address the issue of accessibility to such data under agenda item 6.4.

5.8 The meeting recalled that the World Meteorological Congress, at its sixteenth session (May 2011), noted that the prediction maps should take into account the actual and accumulated emissions into the atmosphere, and requested CBS to work with the IAEA and CTBTO to enhance the usefulness of these products, which should assist NMHSs in fulfilling their respective national responsibilities. Therefore, the meeting requested RSMCs to explore possibilities for the determination of a realistic source term. In the same context, the meeting noted that the IAEA Member States have tasked the IAEA in the Action Plan on Nuclear Safety to provide Member States, international organizations, and the general public with timely, clear, factually correct and easily understandable information during a nuclear emergency on its potential consequences, including analysis of available information and prognosis of possible scenarios based on evidence, scientific knowledge and the capabilities of Member States. The development of default source terms falls well within this task.

5.9 The meeting recommended that, whenever possible, RSMCs should use a realistic source term instead of a unit release in their calculations. The meeting also noted that in the case a realistic source term is not available, the possibility for users of the RSMC products to scale the results (isotope specific) might be useful for example to estimate the impact of a worse case scenario or that of variations in the amount of Becquerel released. This could be done for example with an interactive / dynamic webpage. An action to explore this possibility is identified in Annex III.

Requests by NMHSs, IAEA and Delegated Authorities for RSMCs' products

5.10 The meeting recalled that during the Fukushima event, a number of special/private requests were made by NMHSs and IAEA to RSMCs for atmospheric dispersion products outside of the operational agreement at the current stage, for a factual presentation of the situation. These products, namely atmospheric dispersion calculations for the local/regional range, have used sometimes higher resolution grids and / or better estimate of the source term, to produce a more detailed deposition pattern or air concentrations. In addition, the meeting noted that a number of NMHSs of neighbour countries of the accident State have also requested such products to the RSMCs within their WMO Regions. In this context, the meeting also recalled that the World Meteorological Congress, at its sixteenth session (May 2011), noted the need for information on the interpretation of the prediction, and therefore requested CBS to work with the IAEA and CTBTO to enhance the usefulness of these products, which should assist NMHSs in fulfilling their respective national responsibilities. Noting that the provision of such products by the RSMCs to NMHSs was made on a volunteer basis, and taking into account the usefulness of these products to NMHSs, the meeting encouraged all RSMCs to accommodate requests from other WMO Members whenever possible, making use of the best resolution possible.

5.11 In the same context, the meeting noted that the IAEA requests were made on ad-hoc arrangements between some RSMCs and the IEC. However, considering the tasks given to the

IAEA by the Ministerial Conference (June 2011) and consequently in the Action Plan on Nuclear Safety developed by its Members States, requirements for such high resolution products were also expressed by IAEA (in support of its Member States). The meeting stressed that coordination arrangements for the operational request, production and release of such products may need to be defined. To this end, the meeting requested the RSMCs to explore the feasibility of producing such products in a more regular and systematic way. Noting that such requests can increase significantly to the workload of RSMCs and that there are resource issues associated with these requests, the meeting encouraged the WMO and IAEA Secretariats to consider convening a workshop to define users' requirements, which could be used for supporting the development of such arrangements.

5.12 The meeting discussed the possibility of distributing RSMC products to all NMHSs in their regions upon receipt a request by a Delegated Authority in a situation of a declared general emergency (i.e. IAEA's notification already issued). The meeting agreed that those RSMCs receiving these requests, can post their products on the RSMC mirrored websites, and can notify all NMHSs within their regions depending of the circumstances and if the RSMC feels that it is appropriate.

New Products and Formats

5.13 The meeting noted that the Fukushima event helped to identify the need for new products, and some special users required data in GIS-compatible format, in addition to the product formats already defined in the *Manual on the GDPFS*. The meeting requested RSMCs and the IAEA to identify suitable products and formats that could be developed to meet the requirements of users. The meeting noted that both IAEA and WHO would welcome products in a geo-referenced format, preferably shape files, KML, or other file formats (with suitable viewer).

Other issues

5.14 The meeting also identified issues related to WMO-IAEA and WMO-CTBTO arrangements and products, and WMO documentation, which are reported under agenda items 6 and 7, respectively (NOT INCLUDED HERE).

PROPOSED AMENDMENTS TO THE CURRENT VERSION OF THE MANUAL ON THE GDPFS
(Updates to the Manual on GDPFS are in shaded text and deleted parts are crossed out)

Mandatory functions of, criteria to be recognized as, and designation of an RSMC for Atmospheric Sand and Dust Storm Forecasts (RSMC-ASDF): amendments to Volume I, Part I, paragraph 4.1.2.2; Part I, Appendix I-1; Part II, paragraph 1.4.1.2; and new Appendix II-12

PART I
4.1.2.2 *Centres with activity specialization*
The functions of RSMCs with activity specialization shall include, inter alia:
(a) Providing long-, extended- and/or medium-range forecasting products;
(b) Providing advisories for tropical cyclones, severe storms and other dangerous weather phenomena;
(c) Providing tailored specialized products to service users in a particular area, including atmospheric sand and dust storm forecasts;
(d) Providing trajectories and atmospheric transport modelling products, including backtracking, in case of environmental emergencies ~~or other incidents~~;
(e) Providing information on prolonged adverse weather conditions, including drought monitoring;
(f) Undertaking activities related to the WCP and other WMO international programmes. This includes providing climate diagnostic, climate analysis and prediction products to assist in climate monitoring

PART I, APPENDIX I-1
3. The RSMCs with activity specialization are the following:
[...]

RSMC European Centre for Medium-Range Weather Forecasts (RSMC ECMWF)

Provision of Atmospheric Sand and Dust storm Forecasts:
RSMC-ASDF 'CITYNAME'

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

PART II
1.4.1.2 *Regional Specialized Meteorological Centres (RSMCs) with activity specialization*
A Regional Specialized Meteorological Centre (RSMC) with activity specialization shall be designated, subject to the formal commitment by a Member or group of cooperating Members, to fulfil the required functions of the centre and meet the requirements for the provision of WWW products and services initiated and endorsed by the relevant WMO constituent body or bodies concerned. The centre should be capable of preparing independently or with the support of WMCs, and where appropriate, other GDPFS centres and disseminating to Members concerned:
(a) Global medium-range forecasts and related analyses;
(b) Global extended- and long-range forecasts and related mean analysed values and anomalies;
NOTE: Centres producing global long-range forecasts, and recognized as such by CBS, are called Global Producing Centres for Long-range Forecasts (GPCs). The criteria to be recognized as a GPC and the list of designated GPCs is given in Appendix II-8.
(c) Tropical cyclone warnings and advisories, storm position, intensity and track forecasts for their areas;

(d) Three-dimensional atmospheric modelling products including trajectories, integrated pollutant concentration, and total deposition for environmental emergency response, atmospheric backtracking modelling procedures;

(e) Atmospheric sand and dust storm forecasts in a particular geographical region;

NOTE: Centres producing regional atmospheric sand and dust storm forecasts and services, which are recognized as such by CBS following the guidance by CAS and at the request of the Regional Association(s) concerned, are called RSMC for Atmospheric Sand and Dust storm Forecasts (RSMC-ASDF). The definition and the list of designated RSMC-ASDF, mandatory functions of and criteria to be recognized as an RSMC-ASDF are given in Appendix II-12.

(~~e~~f) Regional LRF products, climate monitoring products, climate watches, drought monitoring products, climate data services, and tailored climate products.

NOTE: Centres producing regional long-range forecasts and other regional climate services or groups of centres that collectively provide these forecasts and services in a distributed network, and are recognized as such by CBS and CCl at the request of regional associations, are called Regional Climate Centres (RCCs) or RCC-Networks, respectively. Definitions of RCCs and RCC-Networks, the list of designated RCCs and RCC-Networks, and mandatory functions of RCCs and RCC-Networks can be found in Appendix II-10. The criteria to be recognized as an RCC or RCC-Network are given in Appendix II-11.

APPENDIX II-12

DESIGNATION AND MANDATORY FUNCTIONS OF REGIONAL SPECIALIZED METEOROLOGICAL CENTRES WITH ACTIVITY SPECIALIZATION IN ATMOSPHERIC SAND AND DUST STORM FORECASTS

The mandatory function of the Regional Specialized Meteorological Centre(s) with activity specialization in Atmospheric Sand and Dust storm Forecasts (RSMC-ASDF) include creating, developing and maintaining a webportal to display forecast products as well as additional information, including a system to collect users' feedback. The goal is to provide guidance on the risk of sand and dust storm occurrence within an identified geographical domain of responsibility, and help the NMHSs-concerned improve their warning services to the national authorities.

RSMC-ASDF are recognized as such by CBS following the guidance by CAS and at the request of the Regional Association(s) concerned, including for sensitive areas whose boundaries extend beyond or are outside those of a single Regional Association.

Designated RSMCs for the provision of Sand and Dust storm Forecasts, including their geographical region of responsibility, are:
RSMC-ASDF 'CITYNAME' (geographical area)

The RSMC-ASDF shall:

Real-time functions

- Prepare regional forecast fields using a dust forecast model continuously throughout the year on a daily basis. The model shall consist of a numerical weather prediction model incorporating on-line parameterizations of all the major phases of the atmospheric dust cycle.
- Generate forecasts of the following minimum set of variables:
  - o Dust load (kg•m^{-2})
  - o Dust concentration at the surface (µg•m^{-3})
  - o Dust optical depth at 550 nm (-)
  - o 3-hour accumulated dry and wet deposition (kg•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 about 0.5x0.5 degrees.

- Disseminate through the GTS/WIS and provide on its webportal the forecast products in pictorial form not later than 12 hours after the starting forecast time.
- Issue an explanatory note on the webportal when operations are stopped due to technical problems.

Non-real-time functions

- Store the generated products in WMO GRIB format.
- Maintain the webportal built to display forecast products as well as additional information.
- Perform seasonal and annual forecast evaluation based on available observational data.
- Issue annual activity reports.
- Support user training courses.
- Provide information on methodologies and product specifications and the guidance on their use.

Standard verification of deterministic NWP products: amendments to Volume I, Part II, Attachment II.7, Table F

I – STANDARDIZED VERIFICATION OF DETERMINISTIC NWP PRODUCTS

[...]

3. Parameters

Extra-tropics

Mandatory

- Mean sea-level pressure (verification against analysis only)
- [...]

[...]

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 ~~listed~~ 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.

[...]

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

[…]

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)

[…]

EXISTING STRUCTURE WITH REVISED TORs

Implementation Coordination Team on Data-Processing and Forecasting System

(a) Identify new emerging requirements (input required from RAs and other bodies);
(b) Determine how GDPFS Centres can best contribute to fulfil emerging requirements;
(c) Participate in THORPEX planning groups as appropriate to advise on conditions and requirements for practical implementations in operational systems;
(d) Identify needs for training through workshops and other means of delivery;
(e) Coordinate the implementation of decisions by CBS related to GDPFS;
(f) Review of Expert Teams and rapporteurs and make recommendations to CBS concerning future work.

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.

Expert Team on Ensemble Prediction Systems

(a) Provide advice on EPS in relation to probabilistic forecasts in the context of short- and medium-range EPS products, focusing on applications concerned with all aspects of the EPS systems which forecast the weather on a daily basis;
(b) Review progress on EPS and its application to severe weather forecasting including progress on multi-centre ensembles and on regional model based EPS, and prepare ways to make best operational usage of these developments;
(c) Propose guidance for the generation of EPS products (e.g. EPS-grams, presentation of cyclone tracks and strike probabilities, hazard maps, calculation of probability, calibration methodologies, etc.) to ensure compatibility of EPS products supplied to WMO Members by different centres;
(d) Develop education and training material for forecasters including rationale of concepts and strategies of EPS, and on the nature, interpretation and application of EPS products;
(e) In consultation with the Coordination Group on verification, review verification system for EPS products and provide guidance on the interpretation of verification;
(f) Support the further development of the Lead Centre on Verification of EPS by reporting on verification measures and determining the best way of presenting skill of ensemble forecasting systems. Provide relevant software to NMHSs through the Lead Centre website;
(g) To review the Manual on the GDPFS (WMO-No. 485) and propose updates as necessary concerning EPS;
(h) Develop specifications for the introduction of probabilistic information into products from RSMCs with geographical specialization;
(i) Participate in THORPEX Working Groups:
    (i) To ensure that the proposed GIFS (Global Interactive Forecast System) is suitable for operational implementation and application;
    (ii) To review progress on the use of EPS for targeting of observations.

Joint CBS-CCl Expert Team on Extended- and Long-range Forecasting

(a) On the basis of requirements from Regional Climate Centres (RCCs), Regional Climate Outlook Forums (RCOFs) and NMHSs, and in the context of Climate Services Information System (CSIS) of the Global Framework for Climate Services (GFCS), guide future development, outputs and coordination of components in the production of LRF. The components include Global Producing Centres (GPCs), Lead Centres for Long-range Forecast Multi-model Ensembles (LC-LRFMME), the Lead Centre for the Standardized Verification System for Long-range Forecasts (LC-SVSLRF) and other relevant bodies generating and providing LRF products;

(b) In coordination with CCl, promote the use of GPC and LC forecast and verification products by RCCs, RCOFs and NMHSs, develop interpretation guidance to facilitate their use, and encourage feedback on usefulness and application;

(c) Report on production, access, dissemination and exchange of LRF products and provide recommendations for future consideration and adoption by CAS, CCl, CBS, WCRP and other appropriate bodies;

(d) In consultation with relevant experts in CAS and CCl and with the CBS Coordination Group on Forecast Verification, review developments in verification scores and practices with a view to updating the Standardized Verification System for Long-range Forecasts (SVSLRF);

(e) Assess applications for GPC status against the designation criteria and make recommendations on designation to CBS;

(f) Review the rules regarding user access to GPC and LC-LRFMME forecasts products;

(g) Review the status of extended-range forecasting activities, and promote the availability and exchange of extended-range forecasts and verification products;

(h) In close collaboration with WCRP, promote international cooperation and research on initialized predictions for timescales longer than seasonal and report on potential for operational predictions to CBS and CCl;

(i) Review the *Manual on the GDPFS* (WMO-No. 485) and propose updates as necessary concerning extended and long-range forecasts.

The Expert Team shall comprise representatives from CBS and CCl to facilitate the necessary interactions and dataflows between components of the CSIS. Team membership shall comprise representatives from GPCs and two CCl experts, one of which shall be the co-chair of CCl OPACE-3. In order to retain the existing focus on operational aspects this team will report and propose amendments to the procedures and guidelines in the GDPFS to CBS through the ICT DPFS. Reporting to the CCl management group will be through the co-chair of OPACE-3.

Coordination Group on Nuclear Emergency Response Activities (ERA)

(a) Test and improve the collective ability of all RSMCs, the IAEA, the RTH Offenbach and NMHSs in the ERA to fulfil the operational requirements specified in global and regional arrangements, according to adopted standards and procedures;
(b) Implement and explore further improved distribution/access methods for specialized products to NMHSs, and the IAEA in collaboration with the IAEA and other relevant organizations;
(c) Collate the individual capabilities of RSMCs to produce enhanced products in support of nuclear emergencies, including ensemble techniques;
(d) Explore the operational availability of radiological monitoring data for use in the RSMC operational environment;
(e) Develop concepts of operational arrangements for atmospheric transport modelling backtracking products;

(f) Continue testing and evaluating the operational arrangements with CTBTO.

Expert Team on Modelling of Atmospheric Transport for Non-nuclear ERA

(a) Monitor the needs of the NMHSs for atmospheric transport modelling and identify those areas in which RSMCs can be of assistance;

(b) Identify and promote technical resources which can assist NMHSs in developing their atmospheric transport modelling capabilities, particularly for limited area non-nuclear emergencies such as chemical releases to the atmosphere;

(c) Monitor the atmospheric transport modelling capabilities of RSMCs and other centres for support to transboundary non-nuclear emergencies, related to emissions from various sources such as volcanic eruptions, dust storms, large fires, and biological incidents, with the goal of improving operational arrangements;

(d) Develop strategies to strengthen operational links with international organizations relevant to non-nuclear ERA, and between NMHSs and relevant national authorities.

Annex X

ALTERNATIVE STRUCTURE AND RECOMMENDED TOR

Implementation Coordination Team on Data-processing and Forecasting Systems (ICT-DPFS)

(a) Consider the requests and WMO priorities from Cg/EC;
(b) Identify new emerging requirements (input required from RAs and other bodies);
(c) Determine how GDPFS Centres can best contribute to fulfill emerging requirements;
(d) Coordinate the implementation of decisions by CBS related to GDPFS and ERA;
(e) Make recommendations to CBS concerning future work;
(f) Review requirements and decide the establishment and activities of Task Teams, including Joint Task Teams.

Expert Group on Forecasting Process and Support (EG-FPS)

(a) Review the Manual on the GDPFS (WMO-No. 485) to ensure that procedures for forecasting systems and verification are adequate and meet CBS needs; Propose updates as necessary;
(b) Review GDPFS and Lead Centres' activities, support their developments and provide guidance as stated in Manual;
(c) Assess applications for GDPFS status against the designation criteria and make recommendations on designation to CBS;
(d) Liaise with relevant WMO programmes, Technical Commissions and international organizations as required to advise on requirements for practical implementations in operational systems;
(e) Review new developments and advances in NWP and related systems, particularly with regard to severe and high impact weather forecasting;
(f) Provide advice to NMHSs on NWP, including EPS, products for all forecast ranges, particularly with regard to severe and high impact weather forecasting;
(g) Liaise with the PWS programme to promote and support the use and communication of NWP, especially probabilistic, information available from the GDPFS Centres; develop interpretation guidance to facilitate their use, and encourage feedback on usefulness and application;
(h) Promote and support the education and training of forecasters on the use and interpretation of NWP, including EPS, products, and their strengths and weaknesses;
(i) Provide guidance on capacity building concerning the implementation of operational NWP systems, including verification systems, and/or the use of NWP products.

Joint CBS-CCl Expert Group on Extended- and Long-range Forecasting

(a) On the basis of requirements from Regional Climate Centres (RCCs), Regional Climate Outlook Forums (RCOFs) and NMHSs, and in the context of Climate Services Information System (CSIS) of the Global Framework for Climate Services (GFCS), guide future development, outputs and coordination of components in the production of LRF. The components include Global Producing Centres (GPCs), Lead Centres for Long-range Forecast Multi-model Ensembles (LC-LRFMME), the Lead Centre for the Standardized Verification System for Long-range Forecasts (LC-SVSLRF) and other relevant bodies generating and providing LRF products;
(b) In coordination with CCl, promote the use of GPC and LC forecast and verification products by RCCs, RCOFs and NMHSs, develop interpretation guidance to facilitate their use, and encourage feedback on usefulness and application;
(c) Report on production, access, dissemination and exchange of LRF products and provide recommendations for future consideration and adoption by CAS, CCl, CBS, WCRP and other appropriate bodies;

(d) In consultation with relevant experts in CAS and CCl and with the CBS Coordination Group on Forecast Verification, review developments in verification scores and practices with a view to updating the Standardized Verification System for Long-range Forecasts (SVSLRF);
(e) Assess applications for GPC status against the designation criteria and make recommendations on designation to CBS;
(f) Review the rules regarding user access to GPC and LC-LRFMME forecasts products;
(g) Review the status of extended-range forecasting activities, and promote the availability and exchange of extended-range forecasts and verification products;
(h) In close collaboration with WCRP, promote international cooperation and research on initialized predictions for timescales longer than seasonal and report on potential for operational predictions to CBS and CCl;
(i) Review the *Manual on the GDPFS* (WMO-No. 485) and propose updates as necessary concerning extended and long-range forecasts.

The Expert Group shall comprise representatives from CBS and CCl to facilitate the necessary interactions and data flows between components of the CSIS. Group membership shall comprise representatives from GPCs and two CCl experts, one of which shall be the co-chair of CCl OPACE-3. In order to retain the existing focus on operational aspects this team will report and propose amendments to the procedures and guidelines in the GDPFS to CBS through the ICT-DPFS. Reporting to the CCl management group will be through the co-chair of OPACE-3.

Expert Group on Emergency Response Activities

(a) Review the Manual on the GDPFS (WMO-No. 485) to ensure that procedures for Environmental ERA are adequate and meet CBS needs; Propose updates as necessary;
(b) Test and improve the collective ability of all RSMCs, the IAEA, CTBTO, the RTH Offenbach and NMHSs in the ERA to fulfill the operational requirements according to adopted standards and procedures stated in the Manual;
(c) Review RSMC Environmental ERAs' activities for various sources such as volcanic eruptions, dust storms, large fires, and nuclear and biological incidents, and provide guidance as stated in Manual;
(d) Promote and support the education and training of users on the use and interpretation of atmospheric transport modeling products, and their strengths and weaknesses;
(e) Identify the focal point of and liaise with relevant international organizations to advise on requirements for practical implementations in operational systems relevant to Environmental ERA;
(f) Explore the availability of atmospheric ash, dust, chemical, biological and radiological monitoring data and etc. for use in the RSMC operational environment;
(g) Identify and promote technical resources which can assist NMHSs in developing their atmospheric transport modelling capabilities, particularly for limited area non-nuclear emergencies such as chemical releases to the atmosphere.

Task Teams on (for example):

(1) Development surface verification;
(2) Collaboration with GIFS-TIGGE on new products for SWFDP;
(3) Development of products for and verification of extended range forecasts;
(4) Development of time of arrival charts;
(5) Development concepts of operational arrangements for atmospheric transport modelling products;
(6) Development of strategy to assist WMO Members in implementation of high resolution.

Joint Task Teams on (for example):

(1) New Manual, incl. updated definition of WMCs and RSMCs (Relevant TCs and International Organizations);
(2) Development of contribution to GSCU and CSIS (with CCl);

(3) Revision of Technical note 170 (with CCl and CHy);
(4) Communication of forecast uncertainty (with PWS);
(5) Updating the Guidebook and Plan for the SWFDP and providing guidance on the strategic development of SWFDP towards long-term sustainability (with PWS and other WMO programmes).