WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

IMPLEMENTATION COORDINATION TEAM ON DATA PROCESSING AND FORECASTING SYSTEM (DPFS)

MONTREAL, CANADA
29 SEPTEMBER – 3 OCTOBER 2008

FINAL REPORT

1 Opening of the Meeting

1.1 The Meeting of the CBS Implementation Coordination Team of the Open Programme Activity Group (OPAG) on Data-Processing and Forecasting Systems (ICT DPFS) was opened at 9:30 a.m. on Monday 29 September 2008 at Environment Canada, Québec Region of Meteorological Service of Canada (MSC), Montreal, Canada. On behalf of the MSC, Mr Michel Jean, Director of MSC Operations for Environment Canada, Québec Region welcomed the ICT meeting. Mr Bernard Strauss (France), Chairperson of the ICT DPFS added his welcome.

1.2 On behalf of the Secretary General of WMO, Mr Peter Chen explained the context of the work of the OPAG in WMO's Commission for Basic Systems (CBS) that addresses the numerical weather prediction (NWP) systems and forecasting processes that are implemented by WMO Members, as part of the Global Data-Processing and Forecasting System (GDPFS) of the World Weather Watch (WWW) Programme, including the Emergency Response Activities (ERA) programme. The GDPFS and ERA programmes are both operational and contribute to Disaster Risk Reduction. The fifteenth WMO Congress (2007) adopted a Results Based Management Framework, aligned to its Strategic Plan. The activities of the OPAG contribute directly to the framework's Expected Results (ER): ER 1 (production of forecasts and warnings), ER 2 (climate information and prediction), ER 6 (disaster risk reduction), ER 7 (Services), ER 9 (capacity building).

1.3 CBS-XIII (2005) in St. Petersburg, followed by CBS-Ext.(06) in Seoul, noted significant progress made in many areas such as Severe Weather Forecasting, including the Severe Weather Forecasting Demonstration Project (SWFDP), Extended- and Long-Range Forecasting, Emergency Response Activities. The CBS-Ext.(06) agreed to maintain the organizational structure of the OPAG DPFS with some adjustments and with revised work programme.

1.4 In advance of CBS-XIV, planned for March 2009, this meeting will review the work of the OPAG and develop appropriate recommendations to the coming session, including on its future structure and work programme, paying special attention to how it will contribute to the Expected Results, and to disaster risk reduction goals, e.g., role of RSMCs to assist NMHSs to provide early warnings, through more effective use of NWP in severe weather forecasting, seasonal forecasting for adapting to climate variability and change, with improved linkages with research outputs and technology transfer, such as in ensemble prediction methods through THORPEX (TIGGE/GIFS), and NWP verification.

1.5 On behalf of the Secretary General, Mr Chen thanked the chairpersons of the OPAG's Teams and Rapporteur for their dedication and effort to the work that was assigned under their leadership. He expressed appreciation to the representatives of the Regional Associations and encouraged effective interactions between the OPAG with the Regional Rapporteurs for DPFS, in the aspects of the implementation of the GDPFS.

2 Organization of the Meeting

2.1 Adoption of the Agenda

The agenda was adopted and is found in Annex I.

2.2 Working arrangements

The meeting agreed to the hours of work and tentative timetable for the meeting. The list of participants is found in Annex II.

3 Introduction and Background

3.1 The Chairperson of the ICT, Mr Bernard Strauss, provided introductory remarks regarding the work of the OPAG. He noted to the ICT that the GDPFS programme is a core element of the operational infrastructure of the World Weather Watch System, and as well underpins the services that WMO Members provide, including public weather services and also services in many socio-economic sectors.

3.2 The Secretariat briefed the meeting on the major relevant outcomes from the fifteenth WMO Congress (2007) and Executive Council (EC-LIX (2007), EC-LX (2008)), highlighting in particular the very favourable support of the Severe Weather Forecasting Demonstration Project, as well as the very significant achievement of the collaboration of WMO with the Comprehensive Nuclear Test-Ban Treaty Organization in atmospheric transport modelling in backtracking for Treaty Verification.

3.3 The Chair noted that the meeting will review the Terms of Reference, last revised at CBS-Ext.(06), with the view to update the OPAG's structure and direction of work and activities and recommend them to CBS-XIV, planned for March 2009. These aspects were discussed in detail under agenda item 12.

4 Severe Weather Forecasting

4.1 The Rapporteur on Applications of NWP to Severe Weather Forecasting, Mr Jean-Marie Carrière provided input to the meeting on the use of ensemble forecasting systems to severe weather forecasting. The meeting discussed the paper under agenda item 7, on Probabilistic Forecasting and Ensemble Prediction Systems and Applications.

Severe Weather Forecasting Demonstration Project (SWFDP)

4.2 The Secretariat briefed the meeting on the progress of the Severe Weather Forecasting Demonstration Project (SWFDP), including the major result of the first regional subproject in Southeast Africa, and the outcomes of the second meeting of the Steering Group for the Project.

4.3 The SWFDP is an initiative to further explore and enhance the use of outputs of existing NWP systems of the GDPFS, including ensemble prediction systems (EPS). Its aim is to contribute to capacity-building and to help developing countries to have available and implement the best possible use of existing NWP, including EPS products for improving forecasts and warnings of hazardous weather conditions. Global-scale products, as well as data, other products and information provided by other regional centres (e.g. limited-area NWP) are integrated and synthesized by a designated Regional Specialized Meteorological Centre (RSMC), which, in turn, provides daily guidance for short-range (days 1 and 2) and medium-range (out to day-5) on heavy rain and strong winds to participating National Meteorological Centres of the region. This is a "Cascading" concept of the forecasting process.

4.4 The SWFDP in its first implementation in Southeast Africa completed its one-year field phase in November 2007. It focused on improving weather forecasting and warning services for heavy rain and strong winds and involved global and regional centres to build the capacity of the NMHSs of Botswana, Madagascar, Mozambique, Tanzania, and Zimbabwe. The participating global centres included ECMWF, NCEP (U.S.A.), and Met Office (UK). The participating regional centres included RSMC Pretoria, RSMC La Réunion (Tropical Cyclone forecasting) and ACMAD. A final report has been drafted.

4.5 The meeting agreed with the conclusion of the Project Steering Group that a key element of the success of the first project is the very important role and very significant operational tasks performed at RSMC Pretoria, including operations of the RSMC's dedicated Web site and portal,

as part of the “Cascading forecasting process” concept, for increasing the efficiency of access and use of all available products and information by the NMHSs. It was also noted that the RSMC Daily Guidance Product plays a very important role in the cascading process and will continue to improve over time, as forecasters, in NMCs and RSMC alike, increase their forecasting knowledge and skills with experience and ever increasing use of existing NWP/EPS products. Continued cooperation among global, regional, and national meteorological centres under the established SWFDP framework is necessary to sustain and increase the benefits already realized, in this continuous regionalized capacity-building approach.

4.6 The project was able to demonstrate: an accelerated implementation into operational use of outputs of advanced NWP/EPS systems; continuous learning by forecasters as an effective way of capacity building; a sustained “tight” cycle of demonstration, adapting to regional needs, evaluation, and operational implementation; contributed to adopting probabilistic forecasting methods; and an increase in the visibility, credibility, and value of meteorological services in public and economic sectors.

4.7 The project also demonstrated the possible new role of RSMCs of the GDPFS to synthesize and to provide forecasting guidance on severe weather forecasting to regional groups of NMCs, and in this case saw the strengthening of RSMC Pretoria for the geographical region of Southern Africa.

4.8 The five NMHSs that participated in the SWFDP in Southeast Africa requested the demonstration project be established operationally following its successful one-year demonstration. The Meteorological Association of Southern Africa (MASA) has proposed on behalf of its members that the SWFDP be sustained and expanded to include the NMHSs of its members. Executive Council (EC-LX, 2008) suggested a transition of the demonstration project to an operational state and the inclusion of the NMHSs of the MASA members.

4.9 As a result of the decision of EC-LX to allocate surplus budget, a joint GDPFS/PWS training workshop is now planned for forecasters of NMHSs of Southern Africa, in particular to facilitate the implementation of the expansion of the SWFDP. The training will include subjects on NWP/EPS, probabilistic forecasting techniques, use of advanced satellite-based products for Nowcasting, and PWS aspects, as well as the SWFDP operational framework. Representatives of disaster management and civil protection authorities (DMCPA) will be invited to participate in the PWS part of the workshop, to use this opportunity to improve organizational linkages for mulit-hazard early warnings for disaster risk reduction. The expansion of the project into Southern Africa will require the establishment of a new Regional Subproject Management Team whose first task will be to develop a new Regional Subproject Implementation Plan; this activity is envisioned for 2009.

4.10 In RA III, a joint GDPFS/PWS training workshop took place in Curitiba, Brazil (10-21 September 2008), to train forecasters of central South American NMHSs (Argentina, Brazil, Paraguay, Uruguay, Chile, Bolivia, Peru), to prepare the ground for the implementation of a SWFDP regional subproject. A Regional Subproject Implementation Plan is being developed.

4.11 In RA V, following expression of interest at Congress, discussions took place during EC-LX and at other regional meetings to formulate a proposal on using the SWFDP as a mechanism to improve weather forecasting and warning services for the South Pacific Islands. A Regional Subproject Implementation Plan is being developed.

4.12 In recognition of the importance of the services provided by NMHSs to end-users for the overall benefit of the public at large, the Steering Group noted the effective communication of forecasts and warnings services represented a critical step in realizing the full value of the investment in improving the forecasting process. The meeting agreed the following four aspects of public weather service delivery were of high priority:

- Ensuring that forecasters are fully aware of the needs of each user group;
- Ensuring that users are fully aware of the limitations of the forecasting process;
- Development of improved communication skills within the forecaster community;
- Assessments of user satisfaction with the forecast and warning services provided by the NMHS (including the establishment of appropriate baselines where possible).

4.13 Two particular user groups were identified by the Steering Group as being of greatest importance: Disaster Management and Civil Protection Authorities (DMCPA), and the Media.

4.14 The Steering Group noted that a comprehensive multi-hazard end-to-end systems approach to planning of SWFDP is desirable, and recognized that in the implementation there is a practical advantage to use a building-block evolutionary approach, as was used in the first SWFDP regional subproject, i.e., that the GDPFS "engine" (of the Cascading forecasting process) was first implemented (November 2006). With a well-functioning forecasting "engine" in place, other blocks are added, such was the case for introducing PWS aspects, in February 2007.

4.15 The "SWFDP Overall Project Plan" and "SWFDP Guidebook on Implementing Regional Subprojects" have been updated to reflect the experience of the first Regional Subproject, as well as input from Public Weather Services and Disaster Risk Reduction goals.

4.16 The meeting emphasized the need to continue to address training needs, and adopting a strategy of training-trainers for increasing the capacity of regional trainers to maintain the skill levels and benefits achieved from the SWFDP. The joint GDPFS/PWS training events have been effective for preparing and maintaining skills of forecasters in SWFDP. The meeting also noted that the use of Web-based training approach could be cost-effective and should be explored as part of the project.

5 Very Short-Range Forecasting

5.1 The CBS/DPFS Rapporteur on Applications of NWP to Severe Weather Forecasting, Mr Jean-Marie Carrière, provided input to the meeting on the conclusions and recommendations of the Expert Meeting on Very Short-Range Forecasting (November 2007).

5.2 The meeting agreed that for the first 12 hours of the forecast period, a suitable blending of observational data and high-resolution NWP outputs is possible, while recognizing that data assimilation would be a major technical challenge, and costly. Nevertheless, investment in additional observations could both support statistical post-processing to improve forecasts, as well as improve verification of forecasts.

5.3 The meeting was informed by Mr André Méthot, Regional Rapporteur for RA IV, that the Meteorological Service of Canada is exploring blending methodologies for the Very Short-Range forecast period, where the routine forecasts would eventually be entirely automated, and where forecasters would only intervene in the forecasting of severe weather events.

5.4 The meeting suggested that the: "Table of possible blending approaches with model and observational data combinations for very short-range forecasting" developed by the experts should be finalized, and made available to Members. The table is found in the annex to this paragraph. While an expert team could be established to develop a project proposal on one of the higher priority tools, with a specific application in mind, it was felt that possible applications should come from a clearly identified need(s) in a specific regional context of the problem, for example possibly identified from a SWFDP project. With clearer requirements, a project could be developed to include Nowcasting and high resolution Limited-area NWP to cover the entire forecast period out to t+12 hours.

6 Extended and Long-range Forecasting

Summary of key areas of progress

6.1 Dr Richard Graham, chairperson of the Expert Team on Extended and Long-Range Forecasting (ET-ELRF), informed the ICT of recent activities of the ET in developing coordinated global provision of long-range forecasts to members, including future RCCs, Regional Climate Outlook Forums (RCOFs) and NMHSs. The ICT congratulated the ET on the considerable progress achieved, and noted in particular:

- the designation of 9 Global Producing Centres of Long-Range Forecasts (GPCs) at CBS-Ext.(06), following development of designation criteria by the ET;
- development of a functioning Lead Centre for the Standard Verification System for Long-range Forecasts (LC-SVSLRF), co-hosted by GPCs Montreal and Melbourne, and including a Web site display of skill maps and diagnostics from the GPCs, using standard visualization formats;
- development of the capabilities of a Lead Centre for Long-range Multi-model Ensemble forecasts (LC-LRFMME) jointly by GPCs Seoul and Washington, following endorsement of the concept by Cg-XV. The developing LC-LRFMME provides much of the recommended functionality including collection of forecast data from GPCs and provision of a website from which GPCs' forecasts can be downloaded or visualized in common graphical formats. Multi-model ensemble products are also in development.

GPC designations

6.2 At its April 2008 meeting, the ET agreed that the Russia Hydromet Centre, Moscow, be recommended for designation as a GPC at CBS-XIV, having achieved the required criteria. The ICT also welcomed applications for GPC designation from two additional centres, CPTEC (Sao Paulo, Brazil) and the South African Weather Service (SAWS, Pretoria), which had been reviewed by the ET ahead of the ICT meeting. The chair of the ET informed the ICT that these two centres were compliant with the required criteria for GPC designation, apart for mainly minor items which should be corrected in the near future. Therefore the ICT decided that CPTEC and SAWS be recommended for GPC designation at the next CBS meeting, provided that they produce a timetable for achieving compliance. Related amendments proposed for the Manual on the GDPFS are in the annex to paragraph 6.14.

Review of GPC capabilities

6.3 The ICT acknowledged that development and maintenance of GPC capability is a substantial undertaking and that it was likely that not all existing GPCs were fully compliant with the designation criteria. It was also recognized that temporary periods of minor non-compliance will be acceptable when GPCs' prediction systems are in transition. The ICT therefore requested that all existing GPC identify any areas of non-compliance, and provide the ET-ELRF with dates by which full compliance will be re-established. The ICT asked the ET-ELRF to develop a procedure for reporting areas of non-compliance.

Data provision by GPCs

6.4 At its April 2008 meeting, the ET agreed a list of products and services, in addition to the minimum requirement, that GPCs may supply on request to further assist RCCs or NMHSs in carrying out their duties. The ICT recommended the list, after minor amendments, be included as a new Attachment II-11 of the Manual on the GDPFS. The ICT also approved minor changes to the definition of the minimum criteria of Appendix II-6. These proposed amendments are detailed in the annex to paragraph 6.14.

Feedback from RCCs and NMHSs on experience with using products supplied by GPCs.

6.5 At its April 2008 meeting, with assistance from representatives from the centres at Tokyo, Beijing, Pune and Moscow, the ET developed guidelines to assist and encourage RCCs and NMHSs to provide feedback to GPCs on their products and services. The ICT endorsed the guidelines after minor amendments and recommended inclusion as a new Attachment II-13 of the manual on the GDPFS, detailed in the annex to paragraph 6.14.

Proposed functions of LC-LRFMME and designation Seoul/Washington Lead Centre

6.6 The ICT endorsed the list of functions of LC-LRFMME developed by the ET after making some amendments, and noted that more than one such Lead Centre might exist, each with different regional or activity specializations. The ICT agreed GPC Seoul and GPC Washington had jointly developed capacity for an LC-LRFMME with responsibility for a Web portal of GPC and MME products with global coverage, and recommended designation at CBS-XIV (2009). Corresponding recommended amendments to the Manual on the GDPFS are detailed in the annex to paragraph 6.14.

6.7 Detailed specification of the data to be supplied by GPCs to LC-LRFMMEs will be listed on the Lead Centre Web sites. The content and format for the supply of data to the Seoul/Washington LC-LRFMME and the terms of the exchange are provided in the annex to this paragraph.

Collaboration with CCl regarding designations of Regional Climate Centres in the GDPFS

6.8 The close collaboration between CBS and CCl , has resulted in proposed designation criteria for RCCs and possible proposals for RCC designation at CBS-XIV. The ICT reviewed the revised definitions and function of RCCs (mandatory and highly recommended) and made small revisions. The resulting set of proposed amendments to the Manual on the GDPFS are detailed in the annex to paragraph 6.14.

6.9 The meeting suggested that the CCl consider including the additional text for the Manual of the GDPFS to express its guidance on regional RCC structures: "….RCC functions for a region may be undertaken within one or more single (multifunctional) centre(s). Alternatively, a region may establish a RCC-Network in which the mandatory (and possibly other) RCC functions are distributed amongst various centres, or nodes. It is strongly advised that a region select one structure or another, and not mix the two types in the same region." The meeting also suggested that a list of GPC and RCC contact points be exchanged to facilitate exchange of information and increased cooperation.

6.10 The meeting suggested that consideration be given to the participation of a representative of CCl at CBS-XIV to support inclusion of the designation criteria, and possible RCC nominations.

Extended-range forecasting

6.11 The meeting agreed that extended-range matters should be maintained in the work of the ET, and that the Terms of Reference for the ET should include aspects related to the infrastructure and verification aspects for this range. It was agreed that these activities are in general of lower priority than progressing the development of GPC, LC-LRFMME and LC-SVSLRF long-range services that meet the needs of Climate Information and Prediction.

Future plans

6.12 The ICT reviewed the future plans of the ET detailed in the Chairpersons report. It was agreed that key priorities were to:

- increase the functionality and coordination of the LC-SVSLRF and developing LC-LRFMME;

- promote the developing services to users and to gather and act on user feedback. A number of options to achieve this were recognized. In particular, the ICT encouraged the ET to participate in the World Climate Conference-3 in 2009.
- It was also noted that participation in the 10-year review of RCOFs would be an opportunity to introduce and better integrate the GPC and Lead Centre outputs into the seasonal forecast consensus process under CCl/CLIPS.

6.13 The ICT agreed that the ET should continue to review new verification scores as they are developed but that there was no need, at this time, to include additional verification scores in the SVSLRF. In fact it will be desirable to maintain a period of stability in the SVSLRF during its 'roll out' to users. The ICT noted one exception concerned with providing greater clarity as to how GPCs should construct confidence intervals on skill scores, and encouraged the ET to make progress in this area.

Proposed amendments to the Manual on the GDPFS

6.14 Proposed amendments to the Manual on the GDPFS, Volume I, are detailed in the annex to this paragraph. The proposed amendments are linked to the subject matter below.

- Designation of GPCs: amendments to Part I
- Data provision by GPCs: new Attachment II-11, and amendments to Appendix II-6 and Appendix II-8.
- Feedback from RCCs and NMHSs on experience with using products supplied by GPCs: new Attachment II-13
- Proposed functions of LC-LRFMME and designation Seoul/Washington Lead Centre: new attachment II-12, and amendments to Part I and Appendix II-8
- Collaboration with CCl regarding designations of Regional Climate Centres in the GDPFS: new Appendices II-10 and II-11, new Attachment I-10 and amendments to Part 1 and Part II (section 1.1.4.2).

6.15 The report of the Chairperson, revised to reflect the conclusions of the ICT is found in the annex to this paragraph.

7 Probabilistic Forecasting and Ensemble Prediction Systems, and Applications

7.1 The Chairperson of Expert Team on Ensemble Prediction Systems, Mr Ken Mylne, noted that the ET has not met since February 2006 due to lack of budget, and has already reported to the ICT on DPFS in June 2006,. The Chair has been active in representing CBS and the needs of the operational user community in plans for GIFS-TIGGE, and in the development of the SWFDP, with some assistance from ET members.

7.2 The meeting noted that EPS is becoming increasingly integrated in operational NWP systems in the more advanced centres. EPS is increasingly used in operational forecasting, and is also starting to be used in improved data assimilation systems. Regional EPS is developing rapidly, as are applications and ensembles of application models.

7.3 Multi-model ensemble research being conducted under the THORPEX TIGGE project is showing some benefits in terms of improved probabilistic forecasts. However, it remains uncertain whether the benefits will be sufficient to justify the increased cost and complexity of using multi-model ensembles operationally.

7.4 The THORPEX programme of CAS is developing plans for a new GIFS (Global Interactive Forecast System) evolving from the TIGGE project. Plans for development of GIFS need to be on a scale which is affordable and likely to gain the support of EPS producing centres and their

funders. Some ideas for GIFS have been considered unrealistic from an operational perspective, requiring large investment from funders and also requiring significant technical expertise and computing resources for NMHSs to exploit. The Chair of ET-EPS has worked closely with the GIFS-TIGGE WG to ensure the evolving GIFS plans are suitable for eventual operational use and to meet the needs of WMO Members for GDPFS.

7.5 Another related development from the TIGGE programme is the concept of TIGGE-LAM – researching multi-model ensemble combinations using LAMs. Research to determine the potential benefit of TIGGE-LAM is to be supported, but it must be recognized that the operational difficulties to be overcome are severe. The overlap of model domains is limited, and there are substantial technical and practical difficulties in exchanging ensemble data in the short timescale required for short-range forecasting. It seems unlikely that the benefits will be sufficient to justify the investment required to overcome these practical difficulties. It is recommended that CBS interest in multi-model ensembles should focus on global EPS at the current time, while keeping a watch on research results to monitor progress and the future potential for LAM EPS. Provision of LAM EPS for less-developed NMHSs may, where possible, be best provided through bi-lateral arrangements with local producing centres within the Regional Associations.

7.6 Ensemble forecasts are increasingly being used for prediction of severe or high-impact weather. A number of new diagnostics, including feature based diagnostics, have been developed for identification of risks of high-impact weather – these may be applied to either single or multi-model ensembles. Further development of such techniques, particularly to improve the prediction of tropical weather systems including tropical convection, is strongly encouraged.

7.7 The Rapporteur on Applications of NWP to Severe Weather Forecasting presented a paper on the short-range and medium-range applications of ensemble forecasting systems. In this context, severe weather episodes can be considered as high-impact events, i.e., even if the probability of occurrence is low, particular attention must be paid to early detection and providing guidance to decision-makers. Expertise is particularly important for assessing and advising in the case of rare and very rare events as the probability distribution function (PDF) of the prediction in the ensemble may be very different from the usual PDF of more frequently occurring conditions. Generally speaking, it is important to take into account as much as possible the cost model of the customer of ensemble forecasts to determine the decision process. In the case of severe weather, the cost of non-detection is most of the time much higher than the cost of false alarms.

7.8 Outputs of EPS should be designed with innovative diagnostic and visualization methods in mind, to provide early detection of possible severe weather, tracking of important features such as depressions and dynamical forcing features, and probabilistic classification of weather regimes that could possibly discriminate between severe weather producing regimes from others.

7.9 In certain specific types of high-impact weather systems, exchange of limited information in dedicated simplified coding can be of great value. The new C-XML code for tropical cyclone tracks from ensemble forecasts is an excellent example. For the benefit of vulnerable WMO members, this coding needs to be backed up by systems which turn the information into products (e.g. charts) for cascading to NMHSs of least developed countries.

7.10 Uncertainty from weather forecasts is starting to be propagated into uncertainty in the impact of the weather through coupling ensembles to application models such as storm surge, hydrology or wind energy production models. Such approaches have potential to greatly increase the value of EPS in protection of life and property.

7.11 The meeting noted that the skill set for probabilistic forecasting, including the production of warnings, is not the same as that for communicating forecasts that contain probabilistic information. Exploitation of ensemble forecasts requires education of forecasters in understanding of the systems and also in how to communicate uncertainty. To facilitate this it is strongly recommended

that the joint involvement of GDPFS and PWS in the SWFDP be continued and developed further. Training conducted under the SWFDP was particularly successful in combining PWS and GDPFS training, and also because the SWFDP provided access to EPS products so that the training could be put into practice. The SWFDP model is strongly encouraged for future training.

7.12 The cascading system of distributing NWP and EPS products to NMHSs developed for the SWFDP has been very successful in providing support to less-developed WMO members, and provides a good model for the development of GIFS. This idea, with a set of contained products and a regional structure, has now been adopted as the preferred development route for GIFS.

7.13 The meeting appreciated observations that the Chairperson made on his visit of the RSMC Pretoria while representing CBS at a meeting of the GIFS-TIGGE Working Group in March 2008, including the routine work and enthusiasm of forecasters at RSMC in relation to the Severe Weather Forecasting Demonstration Project (SWFDP). The project has clearly demonstrated real results in increased use of EPS products to improve forecasting and warning services in NMHSs of developing countries.

7.14 A common source of verification information for global EPS is provided by the Lead-Centre for EPS Verification which is hosted by JMA. The Lead-Centre has recently updated its Web pages to account for the agreed change in verification procedures which adopted new thresholds for probabilistic forecasts based around quantiles of the climate distribution (e.g. one standard deviation above normal). The revised Web site is nearly ready to be opened (removal of password) but is very lacking in content due to EPS producing centres not providing verification results. EPS centres are requested to commence providing verification data to the Lead Centre.

7.15 The report of the Chairperson, revised to reflect the conclusions of the ICT is found in the annex to this paragraph.

7.16 The Chairperson also provided a report on the interactions with CAS/TIGGE, revised to reflect the conclusions of the ICT, is found in the annex to this paragraph.

8 Emergency Response Activities (ERA)

The ERA programme is divided into two areas: nuclear ERA and non-nuclear ERA.

8.1 Nuclear ERA

8.1.1 The Chairperson of the Coordination Group on Nuclear Emergency Response Activities, Mr René Servranckx reported on the meeting of the Coordination Group (May 2008), and progress made with respect to Nuclear ERA, including improved product distribution and access methods, ensemble methods, exercises and operations including the ConvEx-3 (2008) exercise, new developments, and the implementation of the joint ATM response system with CTBTO.

Delivery of RSMC products to NMHSs

8.1.2 Faxing remains the official product transmission method of RSMC products. This continues to present a number of important challenges. Maintaining updated fax numbers and contacts points is difficult and time consuming. Regular fax tests by the RSMCs show a significant rate of delivery failure. The nERA-CG agreed at its last meeting that e-mail distribution and retrieval from Web pages of the standard products is preferred, and that fax distribution could be maintained by exception only (if requested by the NMHS Operational Contact Point). An amendment to the Manual on the GDPFS is proposed with that regard (See annex to paragraph 8.1.7, below.). An implementation plan for this will be developed by the third quarter of 2009.

Collaboration between CTBTO and WMO

8.1.3 The successful CTBTO-WMO collaboration during the last decade and a series of coordinated numerical experiments with several WMO Centres (RSMCs and other WMO Centres)

over the past few years, including a full scale exercise in December 2007, have lead to the implementation of an operational backtracking system on 1 September 2008.

ATM ensembles

8.1.4 It is proposed that a lead centre (RSMC) for ATM ensembles be established to pursue the development of ensemble techniques. However no volunteer has been found, therefore, in the mean time, cooperation with the EC-JRC is being pursued with the creation of a ''private'' WMO Ensemble session (non-operational), with permission to be given to DWD (Offenbach) to manage it. The ICT noted that this is a developmental activity and no reliance could be placed on non-operational establishments.

Exploring possible new RSMC products

8.1.5 The IAEA and the RSMCs are exploring the feasibility and usefulness of possible new products. As a first step, a radioactive plume ''time-of-arrival'' product has been proposed. This product is also well suited for an ensemble ATM technique.

Meteorological and Hydrological Siting and Operations Document

8.1.6 A need for updating the document "Meteorological and Hydrological Aspects of Siting and Operations of Nuclear Power Plants" (WMO TD-No. 170) was identified by Congress who noted that this is a matter that would require the cooperation with the International Atomic Energy Agency (IAEA) and would involve several WMO Technical Commissions. The nERA-CG agreed that if requested, it would provide input to the WMO proposed review in the area of nuclear emergency preparedness and response.

Proposed amendments to the Manual on the GDPFS

8.1.7 Proposed amendments to the Manual on the GDPFS, Volume I, are detailed in the annex to this paragraph. The proposed amendments are linked to the subject matter below.

- Distribution by email and Web access to replace fax (Part II, Appendix II-7, paragraph 5)
- Designation of RSMC Offenbach for ATM backtracking (Part I, Appendix I-1, paragraph 3)
- Request for WMO RSMC Support by IAEA (Part II, Appendix II-7, form)

8.1.8 The report of the Chairperson, revised to reflect the conclusions of the ICT is found in the annex to this paragraph.

8.2 Non-Nuclear ERA

8.2.1 The Chairperson of the Expert Team on Applications of Atmospheric Transport Modelling (ATM) for Non-nuclear ERA, Mr Chris Ryan provided input to the meeting. Mr Jim Fraser presented the report on the meeting of the expert team (June 2007), and progress made with respect to extension of the ERA program to include non-nuclear environmental response, including the demonstration experiment of the ATM-backtracking capability, and developments of the sand and dust storm prediction potentially relevant to the GDPFS and CBS.

8.2.2 A major outcome of the Expert Team's 2007 meeting at Montreal was planning for a demonstration experiment to demonstrate to WMO Members and relevant international organizations the new operational backtracking capabilities and products that the RSMCs can provide. The experiment was carried out over 29 February to 3 March 2008, with the participation of RSMCs Beijing, Exeter, Melbourne and Washington. RSMC Exeter provided the basis for the experiment by simulating a chemical release to the atmosphere from a ruptured tanker ship off the coast of France in the English Channel. Using the UK Met Office dispersion model nested in the

forecast wind field, simulated observations of chemical concentration at a number of receptor sites in Europe were generated and then supplied to the participating RSMCs. The RSMCs were then requested to perform backtracking simulations to identify the source location. Back dispersion plumes, back trajectory plots and Source Receptor Sensitivity (SRS) calculations were generated by each of the RSMCs for each simulated observation. The results were encouraging, with the SRS results showing particular promise. For this initial experiment the results were not calculated in real-time so operational procedures were not exercised. A second more comprehensive experiment is planned for 2009.

8.2.3 A Sand and Dust Storm Warning System has been proposed as an initiative of the World Weather Research Programme (WWRP), within the WMO Commission on Atmospheric Sciences, where three regional centres for sand and dust storm modelling, assessment and forecasting are being organized for eastern Asia, Europe and North Africa, and North America. The Expert Team noted that coordination between CAS and CBS would be highly desirable to ensure operational issues and requirements are considered and addressed in developing a plan for implementation.

8.2.4 The Expert Team has sought, through the Secretariat, clarification regarding WMO data and product format standards and related policy with respect to exchange of GIS-like products among WMO Members as well as with external users, recognizing that new electronic formats are in wide use and are desired by some users for product exchange.

8.2.5 While the potential areas of collaboration with agencies such as UN-OCHA and WHO have been well recognized, it has proven difficult to establish practical arrangements or plans. The Expert Team has proposed that reciprocal attendance of programme experts from the respective Organizations at technical meetings may be a useful pathway to collaboration arrangements. The World Organization for Animal Health has been identified as another potential partner.

8.2.6 The Expert Team reviewed its Terms of Reference at its 2007 meeting. Considering the progress made since CBS-XIII (Feb. 2005), and recognising that the team's work had moved from the initialising and exploration stage to ongoing activities, some modifications were proposed to the Terms of Reference for consideration at the next Session of CBS. The proposed new Terms are included under agenda item 12.

8.2.7 The report of the Chairperson, revised to reflect the conclusions of the ICT is found in the annex to this paragraph.

9 NWP Forecast Verification

9.1 The Chairperson of the Coordination Group on NWP Forecast Verification, Mr David Richardson (ECMWF), reported on the status of NWP Forecast Verification activities, including coordination with and his participation at the meeting of the Commission for Atmospheric Sciences' Joint WWRP/WGNE Working Group on Forecast Verification Research (JWGV). The Coordination Group will be formed at CBS-XIV.

9.2 Developing a link between the Coordination Group and the JWGV will benefit both groups. Two initial areas for collaboration are verification of NWP models for surface weather parameters and verification of severe weather (including meeting the needs of SWFDPs).

9.3 Standard procedures for the verification of NWP forecasts are given in the WMO Manual on the Global Data-Processing and Forecasting System (WMO-No. 485). The EPS and LRF scores are monitored and reviewed by the corresponding Expert Teams. However, there has been no similar structure to review the deterministic forecast scores. This is considered a high priority for the CG.

9.4 A questionnaire was sent to the current list of contacts for the exchange of standard scores. Questions and replies are included in the annex. There are significant differences between centres in the ways they have implemented the verification. These have substantial impact on the scores and make comparison between centres difficult. The review of the standard verification will seek to establish a consistent implementation across participating centres, in particular in the interpolation, climatology and use of observations. Once this consistency is achieved, it will need to be maintained. One way to do this could be to establish a lead centre for deterministic verification as has already been done for EPS and LRF. A number of global forecast centres are not participating in the current exchange of scores - all centres should be contacted and encouraged to participate.

9.5 The main issues were summarized as follows:

- Scores are exchanged between GDPFS centres monthly, as required. However, a number of centres are not participating in this exchange. All global forecasting centres should be encouraged to participate.
- Verification against observations should use a list of stations prepared annually by the lead centre for radiosondes and distributed to all centres (and to WMO). The email list is no longer up-to-date and in practice the centres do not all use the same stations. This can significantly affect the scores. The email contact list needs to be updated.
- Verification against analyses is specified on a 2.5° x 2.5° latitude-longitude grid. This is now substantially below the resolution of many global models, which can be as high as 0.25°. The method of interpolation to the verification grid can have a significant effect on the scores and is not consistent between centres. The methods used to interpolate to verification grid need to be agreed.
- Anomaly correlation can be significantly affected by the climatology used. The climatology is not specified, nor is there a record of what is used by each centre. Use of a common climatology would aid comparison of results.
- The range of forecast parameters, steps and areas should be extended.

9.6 The report of the Chairperson, revised to reflect the conclusions of the ICT is found in the annex to this paragraph.

9.7 The meeting welcomed the participation by Canadian experts Mr Laurence Wilson (member of the WWRP/WGNE Joint Working Group on Verification, and Mr Tom Robinson (CMC focal point for Performance Measurement – Operational NWP Verification).

10 Status of the GDPFS

The Secretariat presented the status of the Global Data-Processing and Forecasting System (GDPFS), including the role of its Regional Specialized Meteorological Centres (RSMC) relative to National Meteorological Centres (NMC), and the Emergency Response Activities.

10.1 The WMO's Global Data-Processing and Forecasting System (GDPFS) represents the function of weather forecasting including the production of alerts and warnings of severe weather. It is a network of operational meteorological centres that produce numerical guidance, and forecasts and warnings, and is a part of a global early warning system for meteorological and environmental hazards.

10.2 The GDPFS centres produce routine weather and climate data products and analyses, forecasts, advisories, warnings and specialized products required by NHMSs and other Members' agencies for providing effective services for the protection of life and property, and the environment, increased safety of activities carried out on land, at sea and in the air, enhance the quality of life through sustainable development. Each of the GDPFS centres are at the core of the

operational infrastructure of the NMHSs and operate 24 hours a day everyday in a continuous programme of data collection and exchange and data-processing, to assimilate data into objective analyses and numerical simulations, to produce numerical predictions of the future states of the atmosphere, and, through further post-processing, produce additional routine and specialized outputs and products in a wide range of applications. The end results are forecasts and warnings that support a wide range of meteorological services.

10.3 The outputs of the GDPFS meet diverse requirements of WMO Members that range from immediate support to emergency response, to routine weather forecasts and warnings for the general public and for air traffic control, to environmental prediction such as sea-state or air quality, to long-range forecasts, to products that create economic advantage for Members, tailoring products and services to different industrial sectors.

10.4 The Emergency Response Activities (ERA) programme is associated with the operational activities of the network of GDPFS centres in the application of NWP to atmospheric transport and dispersion modelling (ATM), which is the basis for specialized meteorological support to environmental emergency response. This programme is established to assist NMHSs, their respective national agencies, as well as relevant international organizations to respond effectively to environmental emergencies with atmospheric dispersion of airborne hazardous substances.

Status of the implementation of the GDPFS

10.5 Numerical Weather Prediction (NWP) systems are now implemented at 83 NMHSs worldwide with increasing resolution. Global models run in 16 centres, 11 of these are sharing global outputs with 188 NMCs (through GTS, Satellite, or Internet); 7 of these are providing boundary conditions to 83 NMCs to run Limited Area Models (LAM). Still 105 NMCs do not run any NWP model, and about 30 NMCs are still not automated. Sixteen centres are running ensemble prediction systems (EPS) with increasing resolution and increasing numbers of members.

10.6 EPS is becoming increasingly integrated in operational NWP systems in the more advanced centres. EPS is increasingly used in operational forecasting, and is also starting to be used in improved data assimilation systems. Regional EPS is developing rapidly, as are applications and ensembles of application models.

10.7 As recommended by Congress, centres running global models should consider facilitating the acquisition of boundary conditions by NMCs running LAMs, and as well, assist in the evaluation and possibly providing the necessary computing and telecommunications infrastructure for undertaking and sustaining the implementation of the LAM. It is also important that RSMCs running models ensure dissemination of the products to NMHSs of countries covered by their models' footprint and work in a consultation with NMHSs to share resources and expertise for further development of NWP for the sub-region.

10.8 The concept of a "consortium" i.e., a group of NMHSs sharing expertise, knowledge and resources, using the same NWP modelling system to enhance progress in development and improvement of the model and the use of its products, has been positively demonstrated by a number of groups to enhance their capability to produce better forecasts and warnings of severe weather.

Structure of the GDPFS

10.9 Presently, there is a class of Centres that produces global-scale NWP predictions. A second tier of centres produces regional or sub-regional NWP predictions and guidance, and a third tier includes national centres that run Limited-Area NWP or post-processing systems that cover only their respective national domains of interest.

10.10 At the regional level, there are Regional Specialized Meteorological Centres (RSMC), in two categories: Geographical Specialization, and Activity Specialization. Those of Geographical Specialization provide NWP and forecasting guidance over a region beyond their own respective national areas of responsibility. Those of Activity Specialization include specialized NWP-based applications, covering a region beyond their respective national boundaries, for specific aspects of meteorological predictions (e.g. tropical cyclone forecasting, medium-range forecasts, long-range forecasts, atmospheric transport modeling for environmental emergency response, UV-forecasts).

10.11 A recent CBS initiative is the Severe Weather Forecasting Demonstration Project (SWFDP), which is an implementation of the Cascading Forecasting Process, where global and regional NWP/EPS products from GDPFS centres are made available, to NMHSs of a subregion of developing countries. A designated RSMC synthesizes all available guidance and information to produce a RSMC Daily Guidance Product for use by the participating NMHSs. The project accelerates technology transfer of existing and proven products for use by NMHSs of participating countries, and when established allows a series of continuing cycles of demonstration and implementation, and expansion.

10.12 The GDPFS also includes designated operational centres for long-range forecasting, which contribute to climate predictions in WMO. Through close collaboration between CBS and the Commission for Climatology (CCl), Global Producing Centres for Long-range Forecasts (GPC-LRF) have been designated. Further, it is anticipated that Regional Climate Centres (RCC) will also be included in the GDPFS, as a CBS/CCl coordinated proposal to next CBS (2009). This framework of operational centres contributes directly to the functioning of Regional Climate Outlook Forums (RCOF).

10.13 Looking ahead, through collaborative work with the Commission for Atmospheric Sciences (CAS), the evolution and organizing of a global system of centres for sand and dust storm forecasting, warnings and assessment will soon need to be recognized as operational centres at a regional level as part of the GDPFS.

10.14 The ICT discussed the potential benefits of reviewing the structure of the GDPFS, in particular, with the view of improving the effectiveness of interactions and collaboration among the centres for improving the production of forecasts and warnings by WMO Members, and in general terms contributing to achieving the relevant Expected Results of WMO (ERs 1, 2, 6, 7, 9). The ICT concluded that there would certainly be a significant benefit to be gained from putting some effort into getting a clear and well structured view of the functions expected from the various GDPFS centres and how they relate to the Expected Results. However, such a review could only be decided at the Commission level.

11 Regional perspectives on NWP infrastructure

The Regional Rapporteurs on DPFS, each of whom have been appointed by their respective Regional Associations, play the role of coordinating with the OPAG relative to the implementation of DPFS activities in their respective Regional Associations. Four regional reports were presented.

11.1 The following points related to the implementation of NWP systems were noted:

- While the SWFDP is emphasizing a Cascading Forecasting Process to benefit NMHSs of developing countries, wherein the emphasis is on improving access to, and making better use of products from existing NWP/EPS systems, there is a steady increase in the number of Limited-Area Models implemented in these NMHS. Production of global and regional NWP including EPS is also increasing in sophistication, and in resolution.
- Regional NWP verification is an important activity that is integral to NWP operations, and needs careful implementation. New focus on the assessment of performance of

high resolution models and the prediction of severe or high impact weather (e.g. precipitation) require suitable datasets and new methods.

- Feedback should be considered as an important part of improvement and quality assurance of NWP products provided by all GDPFS centres.

11.2 The following points related to training and capacity building were noted:

- Use the train-the-trainers approach, particularly to build training capability within each Region to meet regional needs.
- Training materials need to be made more accessible in languages other than in their original language versions.
- Training opportunities need to be better known and coordinated.

12 Future work programme

12.1 The meeting reviewed the structure of the OPAG including its teams and rapporteurs, and their respective terms of reference, to reflect priorities, progress achieved, and looking for cost efficiencies for undertaking the activities.

12.2 The meeting concluded that it will recommend to CBS-XIV the following OPAG structure:

- Implementation Coordination Team on Data-Processing and Forecasting Systems
- Coordination Group on Forecast Verification
- Expert Team on Ensemble Prediction Systems
- Rapporteur on Infrastructure for Numerical Weather Prediction (NWP)
- Expert Team on Extended- and Long-range Forecasting
- Coordination Group on Nuclear Emergency Response Activities
- Expert Team on Modelling of Atmospheric Transport for Non-nuclear ERA
- Rapporteur on the Application of NWP to Severe Weather Forecasting

12.3 This proposed structure and their respective recommended terms of reference are found in the annex to this paragraph.

13 Other business

There was no other business arising.

14 Closure of meeting

The Meeting closed at 17:00 hours, Friday 3 October 2008.

ANNEX I

AGENDA

1 Opening of the Meeting

2 Organization of the Meeting
2.1(1) Adoption of the Agenda
2.1(2) Working arrangements

3 Introduction and Background
(OPAG Chair, Bernard Strauss; Secretariat)

4 Severe Weather Forecasting
(Rapporteur, Jean-Marie Carrière)

5 Very Short-Range Forecasting
(Rapporteur, Jean-Marie Carrière)

6 Extended and Long-range Forecasting
(ET Chair, Richard Graham)

7 Probabilistic Forecasting and Ensemble Prediction Systems, and Applications
(ET Chair, Ken Mylne)

8 Emergency Response Activities
(CG Chair, René Servranckx; ET Chair, Chris Ryan)

9 NWP Forecast Verification
(Expert, David Richardson)

10 Status of the GDPFS
(Secretariat)

11 Regional perspectives on NWP infrastructure
(Regional Rapporteurs for DPFS)

12 Future work programme
(All Chairs)

13 Other business

14 Closure of meeting

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ANNEX II

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ANNEX TO PARAGRAPH 5.4

Table of possible blending approaches with model and observational data combinations for very short-range forecasting
(from Final Report of CBS Expert Meeting on Very Short-Range Forecasting (Toulouse, Nov. 2007) ANNEX IV)

Type	Description	Time range, availability	Examples	Documents, web sites	Remarks
Observations only	Object recognition, extrapolation (radar, satellite), data fusion	Nowcasting, immediate	TRT, RDT, gridded observations		Can be centrally produced (satellites)
Observations + model analysis	Indices	Nowcasting, immediate	GII, RII		
Superposition of observations and model	“Simple” accumulations from rain gauges and radar	SRF, immediate	Sum of rainfall until now + model from now		Simple but far to be available
Climatological Postrocessing	Comparison of model analysis or forecasts with local observations on climatological basis	SRF, available at same time as model output	Regressions, discriminance, neural networks, boosting (choice of relevant predictors),…		Non linear methods can be targeted on high impact weather
Model diagnostics	Recognition of synoptic features on NWP analysis and forecasts	SRF, available at same time as model output	Troughs, dry zones, jet streams, large scale destabilization, synoptic classification…		Synoptic recognition of high impact weather is possible
Adaptive postprocessing	Comparison of model analysis or forecasts with local observations based on recent observations and model runs	SRF, available at same time as model output	UMOS, Kalman filtering		Takes into account model changes. History usually too short to deal with rare events
Observation – model blending	Observations at initial state, model after a few hours	Nowcasting, SRF. Can be immediate if older model is used.	INCA, Scribe module		
Inclusion of local observations into specific model	Gross atmospheric conditions provided by NWP model, supplementary local data used for specific model	Nowcasting, SRF	1d models (fog, road state), 2d surface models, hydrological models		
Choice of model with the help of observations	Choice of different models or ensemble members with recent observation	SRF	Heuristic?		
Assimilation of asynoptic observations	Assimilation of radar, GPS, profiler, satellite… data into NWP model	SRF	3dVar, 4dVar, Latent heat nudging		Expensive

ANNEX TO PARAGRAPH 6.7

CONTENT AND FORMAT FOR THE SUPPLY OF DATA TO THE SEOUL/WASHINGTON LEAD CENTRE FOR LRFMME BY GPCS AND TERMS OF EXCHANGE

Data formats and file naming convention

The LC-LRFMME has proposed following standardization for data formats, and file naming convention as follows:

(a) The following variables: Z500, T850, MSLP, Precip., T2m and SST, should be submitted for each of three months following the month of submission (e.g June, July, August if the month of submission is May)

(b) Acceptable data formats: GRIB1; GRIB2

(c) The number of bits of GRIB data is 16-bits

(d) The number of grid points should be **144*73** (starting from 90N and 0E)

(e) There should be one file with monthly ensemble mean anomaly. Individual members should also be provided as separate files in the same format as the ensemble mean. Therefore, if there are "n" members in the forecast, total number of files submitted will be "n+1"

(f) File naming conventions: (see LC-LRFMME website)

Terms for exchange

The terms for exchange of data between GPCs and LC-LRFMME are as follows:

a) GPCs provide their **monthly mean anomaly forecasts** (and full fields, for GPCs participating in this additional exchange; see Attachment II-12, section 4 for "additional exchange") to the Lead Center on a monthly basis and LC will be responsible for displaying them.
b) GPCs who are able to do so will submit data for monthly means and for individual ensemble members.
c) Forecast anomalies should be provided by GPCs by the 15th of the month. For example, for June-July-August seasonal forecast, data should be provided by 15th May. GPCs should inform the LC-LRFMME if any delay in submitting data is anticipated.

ANNEX TO PARAGRAPH 6.14

PROPOSED AMENDMENT TO THE MANUAL ON GDPFS RELATED TO LONG-RANGE FORECASTS, VOLUME I, (WMO-NO 485)

(Updates to the Manual on Global Data Processing and Forecasting System are listed in red)

MODIFICATIONS RELEVANT TO DESIGNATION OF REGIONAL CLIMATE CENTRES

Part I: Page I-1, section 2 (Functions of the GDPFS), Section 2.1 item (e) shall be amended to read:
'Preparation of specialized products such as limited area very-fine mesh short-, medium, extended- and long-range forecasts, regional climate watches, tailored products for marine, aviation, environmental quality monitoring and other purposes;'

Part I: Page I-1, section 2 (Functions of the GDPFS), Section 2.2 item (a) shall be amended to read:
'Preparation of special products for climate-related diagnosis (e.g. 10-day or 30-day means, summaries, frequencies, anomalies and historical reference climatologies) on a global or regional scale;'

Part I: Page I-2, section 4.1.2 (Regional Specialized Meteorological Centres (RSMCs)), insert a new paragraph 4.1.2.5 after paragraph 4.1.2.4, and rename existing paragraph 4.1.2.5 as 4.1.2.6. The new paragraph shall read as follows:
'4.1.2.5 Centres designated by WMO for the provision of global long-range forecasts are called Global Producing Centres for Long-range forecasts (GPCs). Centres designated by WMO for the provision of regional long-range forecasts and other regional climate services, or groups of centres who collectively provide these forecasts and services in a distributed network, are called Regional Climate Centres (RCCs) or RCC-Networks, respectively (see notes under (e) in paragraph 1.4.1.2 of Part II).'

Part I, Appendix I-1, section 3 (The RSMCs with activity specialization are the following:), add the following text:

GPC Beijing }
GPC CPTEC }
GPC Exeter }
GPC Melbourne }
GPC Montreal }
GPC Moscow }
GPC Pretoria }
GPC Seoul } Global Producing Centres of Long-Range
} Forecasts
}
GPC Tokyo }
GPC Toulouse }
GPC Washington }
GPC ECMWF }

RCC CITYNAME…. } Regional Climate Centres providing regional long-range forecasts
} and other regional climate services }

RCC-Network (Region) 'CITYNAME' Node 1 }
'CITYNAME' Node 2 }
…….. }
'CITYNAME' Node n }

Part II

Part II, section 1.4.1.2 (Regional Specialized Meteorological Centres (RSMCs) with activity specialization), item (b) shall be amended to read as follows:
"'Global extended- and long-range forecasts and related mean analysed values and anomalies;'
'NOTE: Centres…."

and item (e) shall be amended to read as follows:
'Regional LRF products, climate monitoring, climate watches, drought monitoring, climate data services, and tailored climate products.'

following the modified item (e), add the following Note:

'NOTE: Centres producing regional long-range forecasts and other regional climate services or groups of centres who collectively provide these forecasts and services in a distributed network, and are recognized as such by CBS and CCI at request of Regional Associations, are called Regional Climate Centres (RCCs) or RCC-Networks, respectively. Definitions of RCCs and RCC-Networks, the list of official recognized 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 can be found in APPENDIX II-11.'

In Appendix II-6, it is proposed to replace in paragraph 4.2, for the Content of basic forecast output, in (a) and (b):

- "2-metre temperature over land" by: "2-metre temperature over the globe"
- "Precipitation" by: "Total precipitation"

It is proposed to add some items to Appendix II-8

1. Centres that are designated as Global Producing Centres for Long-range Forecasts (GPCs) are as follow: Beijing, Exeter, Melbourne, Montreal, Moscow, Seoul, Tokyo, Toulouse, Washington and ECMWF.

2. In order to be officially recognized as a GPC (Global Producing Centre of Long-range forecasts), a centre must as a minimum adhere to the following criteria:

- Fixed production cycles and time of issuance;
- Provide a limited set of products as determined by chapter 4.2 of APPENDIX II-6 of this Manual;
- Provide verifications as per the WMO SVSLRF;
- Provide up-to-date information on methodology used by the GPC;
- Make products accessible through the GPC Web site and/or disseminated through the GTS and/or Internet.

3. Additional data or products to the minimum list above could also be provided by GPCs on request by RCCs or NMCs. The RCCs and NMCs would adhere to conditions, if any, attached by the GPCs to these data and products. This additional list of data and products is given in Attachment II-11

4. Given the anticipated improvements in skill of Long-Range Forecasts (LRF) by using a multi-model ensembles (MME) approach, some GPCs can serve as collectors of global LRF data to build MME and to make MME LRF predictions. Such Centres may become Lead Centres for Long-Range Forecast of Multi-Model Ensembles predictions (LCs LRFMME). The list of such Centres and the functions of LC-LRFMME are defined in Attachment II-12.

Part II, add new Appendix II-10 as follows:

APPENDIX II-10

DESIGNATION AND MANDATORY FUNCTIONS OF REGIONAL CLIMATE CENTRES (RCCs) AND RCC-NETWORKS

1. A multifunctional centre that fulfils all the required functions of an RCC for the entire region, or for a sub-region to be defined by the Regional Association may be designated by WMO as a 'WMO Regional Climate Centre' (WMO RCC). A group of centres performing climate-related activities that collectively fulfil all the required functions of an RCC may be designated by WMO as a 'WMO Regional Climate Centre Network' (WMO RCC-Network). Each centre in a designated WMO RCC-Network will be referred to as a 'Node'. A Node will perform, for the region or sub-region defined by the Regional Association, one or several of the mandatory RCC activities (e.g. long-range forecasting (LRF), climate monitoring, climate data services, training). Only centres or groups of centres designated by WMO will carry the title 'WMO RCC' or 'WMO RCC-Network' respectively. Recipients of RCC products and services will be NMHSs, other RCCs and international institutions recognized by the Regional Association and will be referred to as 'RCC Users'. WMO RCCs and RCC-Networks shall follow Guidance published by the Commission for Climatology on technical, climate-related matters.

2. Designated Regional Climate Centres and RCC-Networks are as follows: ……..

3. In order for a centre or a group of centres in a cooperative effort to be officially recognized as a WMO RCC (Regional Climate Centre), or a WMO RCC-Network, it shall perform the following minimum* set of functions, criteria and products for which are defined in Appendix II-11:

Notes: *- Additional requirements for RCC functions may vary in detail from Region to Region. A list of 'highly recommended', but not mandatory, functions is given in Attachment II-10.

- An RCC is not necessarily an NMHS, but a non-NMHS candidate for RCC designation must be nominated by the Permanent Representative of the concerned country.

- **Operational Activities for LRF*:**
  - Interpret and assess relevant LRF products from Global Producing Centres (GPCs) (some of which can be obtained through the Lead Centres for LRFMME - see Attachment II-12), make use of Lead Centre for Standard Verification System on LRF (see Attachment II-8), distribute relevant information to RCC Users; and provide feedback to GPCs
  - Generate regional and sub-regional tailored products, relevant to RCC User needs, including seasonal outlooks etc.;
  - Perform verification of RCC quantitative LRF products, including the exchange of basic forecasts and hindcast data;
  - Generate 'consensus' statement on regional or sub-regional forecasts (see Appendix II-11 for details);
  - Provide on-line access to RCC products/services to RCC Users;
  - Assess use of RCC products and services through feedback from RCC Users.

  Note: * Both dynamical and statistical, within the range of 1 month to 2 year timescale, based on regional needs.

- **Operational Activities for Climate Monitoring:**
  - Perform climate diagnostics including analysis of climate variability and extremes, at regional and sub-regional scales;
  - Establish an historical reference climatology for the region and/or sub-regions;
  - Implement a regional Climate Watch.

- **Operational Data Services, to support operational LRF and climate monitoring:**
  - Develop regional climate datasets, gridded where applicable;
  - Provide climate database and archiving services, at the request of NMHSs;

- **Training in the use of operational RCC products and services**
  - Provide information on methodologies and product specifications for mandatory RCC products, and provide guidance on their use
  - Coordinate training for RCC Users in interpretation and use of mandatory RCC products.

In Part II, add new **Appendix II-11** as follows**:**

APPENDIX II-11

DETAILED CRITERIA FOR RCC MANDATORY FUNCTIONS

Functions	Activities	Criteria
Operational Activities for LRF (both dynamical and statistical, within the range of 1 month to 2 year timescale, based on regional needs)	Interpret and assess relevant LRF products from Global Producing Centres (GPCs), distribute relevant information to RCC Users; and provide feedback to GPCs (see Attachment II-13)	***Product:*** assessment of the reliability and outcomes of GPCs or LCs-LRFMME products including the reasoning (make use of LC SVSLRF), for the region of interest, in the form of texts, tables, figures, etc. ***Element:*** 2-m mean temperature, total precipitation ***Update frequency:*** monthly or at least quarterly
	Generate regional and sub-regional tailored products, relevant to RCC User needs, including seasonal outlooks etc.	***Product:*** probabilities for tercile (or appropriate quantile) categories for the region or sub-region ***Element:*** 2-m mean temperature, total precipitation ***Output type:*** *rendered images (maps, charts), text, tables, digital data* ***Forecast period***: one month up to 6 months ***Update frequency:*** 10 days to one month
	Generate consensus* statement on regional or sub-regional forecasts. **NB: A collaborative process involves discussion with experts in the region (e.g. through Regional Climate Outlook Forums (RCOFs), teleconferencing, etc.).* *Consensus is both the agreed process, and its joint conclusion, and can be that there is limited skill in the prediction for a region or sub-region*	***Product:*** *consensus statement on regional or sub-regional forecast.* ***Element:*** *2-m mean temperature, total precipitation* ***Output type:*** *report* ***Forecast period***: *a climatologically significant period (from one month to one year)* ***Update frequency:*** *at least once per year (to be defined by the region)*
	Perform verification of RCC quantitative LRF products, including the exchange of basic forecasts and hindcast data.	***Products:*** verification datasets (e.g. SVS LRF scores, Brier Skill Score; ROC; Hit Rate Skill Score) ***Element:*** 2-m mean temperature, total precipitation

	Provide on-line access to RCC products/services to RCC Users.	***Product:*** an on-line data/information portal
	Assess use of RCC products and services through feedback from RCC Users.	***Product:*** analysis of feedback (which is made available using a template) ***Update frequency:*** annually, as part of a regular reporting of RCCs to WMO RAs
Operational Activities for Climate Monitoring	Perform climate diagnostics including analysis of climate variability and extremes, at regional and sub-regional scales	***Products:*** climate diagnostics bulletin including tables, maps and related products ***Element:*** Mean, Max and Min temperatures, Total precipitation; other elements (esp. GCOS essential climate variables) to be determined by the region, ***Update frequency:*** monthly
	Establish an historical reference climatology for the region and/or sub-regions	***Product:*** database of climatological means for various reference periods (e.g. 1931-60; 1951-80; 1961-90; 1971-2000; etc) ***Spatial resolution:*** *by station* ***Temporal resolution:*** *monthly at a minimum* ***Elements:*** Mean, Max and Min temperatures, Total precipitation; other elements (esp. GCOS essential climate variables) to be determined by the region, ***Update frequency:*** at least 30 years, preferably 10 years
	Implement a Regional Climate Watch	***Products:*** climate advisories and information for RCC Users ***Update:*** whenever required, based on the forecast of significant regional climate anomalies.
Operational Data Services, to support operational LRF and climate monitoring	Develop quality controlled regional climate datasets, gridded where applicable	***Products:*** regional, quality controlled climate datasets, gridded where applicable, following CCl guidance on QA/QC procedures ***Elements:*** Mean, Max and Min Temperature, and Precipitation, at a minimum ***Temporal resolution:*** *daily* ***Update:*** monthly
	Provide climate database and archiving services, at the request of NMHSs	***Products:*** national databases with metadata, accessible to the NMHS in question (backup service, development site, etc). ***Elements:*** as determined by the NMHS ***Update:*** at the request of the NMHS

Training in the use of operational RCC products and services	Provide information on methodologies and product specifications for mandatory RCC products, and provide guidance on their use	***Products:*** *Manuals, guidance documents and information notes*. ***Update frequency:*** when methods/products are revised or introduced or discontinued
	Coordinate training for RCC Users in interpretation and use of mandatory RCC products	***Products:*** survey and analysis of regional training needs, and proposals for training activities.

NOTE: an RCC is expected to perform certain functions (e.g. for homogeneity testing; database management; metadata management, statistical evaluation of climate data, etc.) using procedures proposed in the WMO Guide to Climatological Practices and in other official Commission for Climatology Guidance documents.

In Part II, add new **Attachment II-10** as follows:

ATTACHMENT II-10

ADDITIONAL 'HIGHLY RECOMMENDED' FUNCTIONS OF DESIGNATED WMO RCCs OR WMO RCC-NETWORKS:

- **Climate Prediction and Climate Projection**
  - Assist RCC Users in the access and use of WCRP-CMIP climate model simulations
  - Perform downscaling of climate change scenarios
  - Provide information to RCC Users for use in development of climate adaptation strategies
  - Generate, along with warnings of caution on accuracy, seasonal forecasts for specific parameters where relevant, such as:
    - onset, intensity and cessation of rainy season;
    - tropical cyclone frequency and intensity
  - Perform verification on consensus statements for forecasts;
  - Perform assessment of other GPC products such as SSTs, winds, etc.

- **Non-operational data services:**
  - Keep abreast of activities and documentation related to WMO WIS, and work towards WIS compliance and DCPC designation;
  - Assist NMHSs in the rescue of climate data from outmoded storage media;
  - Assist NMHSs to develop and maintain historical climate datasets;
  - Assist RCC Users in the development and maintenance of software modules for standard applications;
  - Advise RCC Users on data quality management;
  - Conduct data homogenization, and advise RCC Users on homogeneity assessment and development and use of homogeneous data sets;
  - Develop and manage databases, and generate indices, of climate extremes;
  - Perform Quality Assurance/Quality Control on national datasets, on request of an NMHS;
  - Provide expertise on interpolation techniques;
  - Facilitate data/metadata exchange amongst NMHSs, including on-line access, through an agreed regional mechanism;
  - Perform Quality Assurance/Quality Control on regional datasets.

- **Coordination Functions:**
  - Strengthen collaboration between NMHSs on related observing, communication and computing networks including data collection and exchange;
  - Develop systems to facilitate harmonisation and assistance in the use of LRF products and other climate services;
  - Assist NMHSs in user liaison, including the organisation of climate and of multidisciplinary workshops and other forums on user needs;
  - Assist NMHSs in the development of a media and public awareness strategy on climate services.

- **Training and Capacity building:**
  - Assist NMHSs in the training of users on the application and on implications of LRF products on users;
  - Assist in the introduction of appropriate decision models for end-users, especially as related to probability forecasts;
  - Promote technical capacity building on NMHS level (e.g. acquisition of hardware, software, etc.), as required for implementation of climate services.

- Assist in professional capacity building (training) of climate experts for generating user-targeted products.

- **Research and Development:**
  - Develop a climate Research and Development agenda and coordinate it with other relevant RCCs;
  - Promote studies of regional climate variability and change, predictability and impact in the Region;
  - Develop consensus practices to handle divergent climate information for the Region;
  - Develop and validate regional models, methods of downscaling and interpretation of global output products;
  - Promote the use of proxy climate data in long-term analyses of climate variability and change;
  - Promote application research, and assist in the specification and development of sector specific products;
  - Promote studies of the economic value of climate information.

In Part II, add new **Attachment II-11** as follows:

ATTACHMENT II-11

ADDITIONAL INFORMATION THAT MAY BE PROVIDED BY GPC'S

Other Long-Range Forecast data, products or other information, in addition to the minimum list in chapter 4.2 Appendix II-6, which could also be provided by GPCs on request by RCCs or NMCs (the RCCs and NMCs would adhere to conditions, if any, attached by the GPCs to these data and products):

1. Grid point value (GPV) products:

- hindcast and forecast data for downscaling algorithms:
- data for RCM boundary and initial conditions:
- predicted global weekly values of SST.

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

- interpretation and use of ERF and LRF products;
- downscaling techniques (both statistical and dynamical);
- verification techniques (for local verification of RCC generated products and application outputs);
- development of local user applications from RCC downscaled products;
- use and implementation of regional climate models.

In Part II, add new **Attachment II-12** as follows:

ATTACHMENT II-12

LEAD CENTRES FOR LONG-RANGE FORECAST OF MULTI MODEL ENSEMBLE (MME) PREDICTION

1. GPC Seoul and GPC Washington are jointly recognized as a Lead Centre for Long-Range Forecast of Multi Model Ensemble (MME) predictions, including responsibility for a web portal of GPC and MME products with global coverage.

2. Functions of Lead Centres for Long-Range Forecast of Multi Model Ensemble (MME) prediction

1) Maintain a repository of documentation for the system configuration of all GPC systems
2) Collect an agreed set of forecast data from GPCs
3) Display GPCs forecasts in standard format
4) Promote research and experience in MME techniques and provide guidance and support on MME techniques to GPCs, RCCs and NMHSs.
5) Based on comparison among different models, provide feedback to GPCs about the models performance
6) Generate an agreed set of Lead Centre (LC) products (see section 3)
7) Provide Web pages to satisfy requirements for regional display of Lead Centre products (e.g. for RCOF coordinators)
8) Where possible verify the LC products using the SVSLRF.
9) Redistribute digital forecast data for those GPC's that allow it.
10) Handle requests for the password for the website and data distribution; maintain a database recording the users who have requested access to data/products and the frequency of access
11) Maintain an archive of the real-time GPC and MME forecasts.

3. Core information to be available from Lead Centres for LRFMME

3.1 GPC digital products:

Global fields of forecast anomalies as supplied by GPCs, and listed below (for GPCs that allow redistribution of their digital data):

Monthly mean anomalies for individual ensemble members and ensemble mean for at least each of three months following the month of submission e.g March, April, May if the month of submission is February:

a) Surface (2m) temperature
b) Sea Surface Temperature
c) Total Precipitation rate
d) Mean Sea Level pressure
e) 850hPa temperature
f) 500hPa geopotential height

N.B definitions of the content and format for the supply of data to the Lead Centre by GPCs and terms of exchange will be made available on the Lead Centre's Web site.

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

3.2 Graphical products:

Plots and maps for each GPC forecast displayed in common format on the LC website, for the variables listed in 3.1 and for selectable regions where appropriate, showing for 3-month means or accumulations:

a) ensemble 'plumes' of Niño indices (1-month means)
b) ensemble mean anomalies
c) Probabilities of above / below median
d) Model consistency plots, i.e maps showing the proportion of models predicting the same sign anomaly.
e) multi-model probabilities of above/below median.

4. Additional information to be available from Lead Centres for LRFMME

As part of research and development Lead Centres may make available products based on forecast and hindcast data from the subset of GPCs that are able to supply them. These products are additional information to help GPCs, RCCs and NMCs to further develop MME techniques and their application.

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

4.1 GPC digital products:

Global forecast fields and corresponding hindcasts for the fields listed in 3.1, and additional variables to be agreed, for those GPCs that allow redistribution.

4.2 Graphical products

Forecast maps for each GPC displayed in common format on the LC website, for the variables listed in 3.1 and for selectable regions where appropriate, showing for 3-month means or accumulations:

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

These additional products will be distinguished from Lead Centre core products listed in 3.

5. Visualisation of graphical products

The recommended temporal resolution, lead-times, variables and update frequencies for images are those prescribed for GPCs in Appendix II-6, chapter 4.2.

a) Forecasts for individual GPCs will be displayed in common graphical format in a way that allows comparison.
b) The geographical regions displayed will be interactively selectable, or at minimum:
    - Globe
    - Northern extratropics
    - Southern extratropics
    - Tropics
    - Nino regions (for SST plumes)

c) The research and development products in section 4 will be distinguished from the Lead Centre products of section 3.
d) Graphical forecast products displayed will be accompanied by disclaimers stating that the forecasts do not have precedence over the official forecast for any country or region as produced by the NMHS or RCC for that country or region.

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

a) Access to GPC data and graphical products from LC-LRFMME websites will be by website password.
b) Digital GPC data will be only re-distributed in cases where the GPC data policy allows it. In other cases, requests for GPC output should be referred to the relevant GPC.
c) Recognized GPCs, RCCs, NMHSs, and institutions hosting RCOFs such as ACMAD, ICPAC, are eligible for password protected access to information held and produced by the LC-LRFMME.
d) Potential new users not belonging to the above categories may request access from an LC-LRFMME, who will refer the request to the designated GPCs. Decisions to allow access must be unanimous. The Lead Centre will be informed of new users accepted for access.
e) A list of users provided with password access will maintained by LC-LRFMME and reviewed by the GPCs, to measure the degree of effective use and also to review any changes in status of eligible users. The GPCs and the LC-LRFMME will report on the review to the CBS Expert Team on Extended and Long-range Forecasting[1], which will act as an advisory body for the LC-LRFMME.

[1] It is the name of the CBS Expert Team at the time of this insertion in the Manual. In the future it may be change to another entity, but still dealing with coordination of the production of long-range forecasts.

In Part II, add new **Attachment II-13** as follows:

ATTACHMENT II-13

Suggested guidelines for feedback from RCC/NMHS to GPCs

1. Products used (from the minimum list defined in Chapter 4.2 Appendix II-6)
2. Additional products used
3. Your qualitative assessment on the following aspects of products:
    a) accessibility & timely availability;
    b) completeness & quality;
    c) usefulness for your purposes.
4. How are the data processed? (e.g. is any post-processing/downscaling carried out?)
5. Forecast applications that have been developed using the data
6. Research studies that have been conducted using the data
7. Any other comments

ANNEX TO PARAGRAPH 6.15

Activities and Future Plans of the Expert Team on Extended- and Long-range Forecasting

Richard Graham, Met Office Hadley Centre (Chairperson of the ET-ELRF)

1. Introduction

The underlying aim of the ET-ELRF is to help coordinate improvements to the integration, usefulness and delivery of extended and long-range forecast products to the world-wide meteorological community. This aim is progressed by promoting common standards in forecast output and verification, and by coordinating the development of infrastructure within the GDPFS (i.e. new RSMC-type nodes) necessary to achieve these objectives. Considerable progress has been achieved against most of the objectives in recent years. Key achievements since the last ICT meeting are summarized below.

2. WMO designation of Global Producing Centres (GPCs) for Long-range Forecasts

In order to promote coordination in forecast and verification output, the ET has developed minimum criteria that forecast centres must adhere to in order to be designated GPCs. Recommended criteria were finalised at the ET meeting of April 2006, endorsed by the ICT on DPFS in June 2006, and used to assess applications for GPC status at CBS Ext. 06 (December 2006). The process of designation follows a procedure already defined for RSMCs. The basic criteria are listed below (details are elaborated in the Manual on the GDPFS).

To be designated as a GPC, centres must:

- Have a fixed production cycle and time of issuance;
- Provided a limited set of products as determined by Appendix II-6 of the Manual;
- Provide verification as per the WMO Standard Verification System for Long-Range Forecasts (SVSLRF);
- Provide up-to-date information on the methodology used;
- Make products accessible through the GPC website and/or disseminate through the GTS and/or the internet.

(Note: A brief list of additional product types and information that may be supplied by GPCs on request was developed by the ET at its Beijing 2008 meeting – see Doc. 6(1))

At CBS Ext. 06, nine centres were designated GPCs. At the ET meeting of April 2008 a further centre, the Hydromet Centre, Russian Federation, was acknowledged to have achieved the necessary GPC criteria. Accordingly it will be recommended to CBS 2009 that the Hydromet Centre is awarded GPC status. Two additional centres, CPTEC (Sao Paulo, Brazil) and the South African Weather Service (SAWS - Pretoria) have submitted applications for GPC status, and are currently being assessed by the ET-ELRF. Further details are provided in Table. 1.

GPC	System configura-tion	Resolution (atmosphere)	Hindcast period	LC-LRFMME contributor
Beijing	coupled	T63/L16	1983-2004	
ECMWF	coupled	T159/L62	1981-2005	
Exeter	coupled	2.5x3.75/L19	1987-2001	
Melbourne	coupled	T47/L17	1980-2006	√

Montreal	2-tier	4 models: T32/63/95, 2x2	1969-2004	√
Seoul	2-tier	T106/L21	1979-2006	√
Tokyo	2-tier	T63/L40	1984-2005	√
Toulouse	coupled	T63/L91	1979-2007	
Washington	coupled	T62/L64	1981-2004	√
Moscow (pending)	2-tier	1.1x1.4/L28	1979-2003	√
Pretoria (applied)	-	-	-	-
Sao Paulo (applied)	-	-	-	-

Table. 1 Status of GPCs in September 2008, with a summary of the forecast system configurations (more details may be found at http://www.wmolc.org)

3. Lead Centres for Long-range Forecast Multi-Model Ensembles (LCs-LRFMME)

The concept and functions of LCs-LRFMME have been developed and refined by the ET following initial discussions at a workshop of GPCs held at Jeju, Korea, 2005. The concept was endorsed by Cg-XV (2007). Considerable practical progress has now been made. The ET have finalised recommendations on the proposed functions of LCs-LRFMME (detailed in Doc. 6(1)). KMA and NCEP have jointly developed the capability of a LC-LRFMME, including a website providing much of the recommended functionality (http://www.wmolc.org).

A range of functions are proposed for LCs-LRFMME. However there are two central themes:

- to provide a single portal from which users (RCCs, NMSs, GPCs, Regional Climate Outlook Forums – RCOFs) can access GPC graphical and digital output;
- to promote research in to, and to generate and provide multi-model products from the GPC forecasts.

Provision of a single portal for GPC information addresses current difficulties experienced by users in merging GPC output into a consolidated forecast for their region. Data formats and forecast visualisation products have developed independently at the different centres, and consequently GPC forecasts are currently available in varying digital formats and visualised on GPC websites using a wide variety of graphical approaches with no consistent contouring intervals or colour shading conventions and no consistent set of geographical domains. This makes inter-comparison of forecast signals from different GPCs difficult, and there is evidence that this discourages users from making collective use of GPC output. The LCs-LRFMME will thus provide a much needed conduit for GPC information. The full list of functions proposed by the ET's Beijing (2008) meeting is below.

12) Maintain a repository of documentation for the system configuration of all GPC systems;
13) Collect an agreed set of forecast data from GPCs;
14) Display GPCs forecasts in standard format;
15) Promote research and experience in MME techniques and provide guidance and support on MME techniques to GPCs, RCCs and NMHSs;
16) Based on comparison among different models, provide feedback to GPCs about the models performance;
17) Generate an agreed set of Lead Centre (LC) products;
18) Provide web pages to satisfy requirements for regional display of Lead Centre products (e.g. for RCOF coordinators);
19) Where possible verify the LC products using the SVSLRF;
20) Redistribute digital forecast data for those GPC's that allow it;

21) Handle requests for the password for the website and data distribution; maintain a database recording the users who have requested access to data/products and the frequency of access;
22) Maintain an archive of the real-time GPC and MME forecasts.

The forecast information to be made available by LCs-LRFMME has been defined using two levels: core information and additional information as summarised below. Each level includes both digital and graphical products.

Core information:
a) GPC digital products:
Global fields of forecast anomalies as supplied pre-calculated by GPCs using their hindcast climatologies. Specifically, monthly mean anomalies for individual ensemble members (and the ensemble mean) for at least each of three months following the month in which the forecast is submitted, for the following variables:

- 2m temperature
- Sea surface temperature]
- Total precipitation
- Mean sea level pressure
- 850hPa temperature
- 500 hPa height

It is hoped than all designated GPCs will participate in this level of data exchange.

b) Graphical products
Plots and maps for each GPC forecast displayed in common format on a website for the above variables and for selected regions.

- ensemble 'plumes' of Niño SST indices (1-month means);
- ensemble mean anomalies;
- probabilities of above/below median;
- model consistency plots (i.e. maps showing the proportion of models predicting the same anomaly sign);
- multi-model probabilities of above/below mean.

Additional information comprises global forecast fields and corresponding hindcasts for the fields listed above. All GPCs are encouraged to participate in this level of exchange, however it is recognised that supply from some GPCs will be limited by data policy. Graphical products generated from additional data are defined as:

- tercile category probabilities;
- model consistency plots for the most likely tercile category;
- multi-model probabilities for tercile categories, using various established and experimental multi-modelling methods.

3.1 Summary of progress made by the KMA/NCEP developing LC-LRFMME

Progress to date includes the following:

- a website has been developed to make products and information available to users (http://www.wmolc.org);
- a repository of information on the GPC system configurations has been set up and is available on the website (the information in Table 1 is extracted from this repository);
- data exchange formats have been refined and agreed, and there is ongoing monthly ingestion of core and additional data from 6 centres (5 GPCs and the Hydromet centre, Moscow). The 6 centres so far participating are indicated in Table 1. Data is available for download by registered users;
- graphical products have been developed and are available on the website, specifically :

    - GPC ensemble-mean forecast maps, in a common graphical format, for each specified variable (Fig. 1);
- further products are in development and currently distributed to GPCs by email:
    - multi-model 'anomaly sign consistency' plots (Fig. 2);
    - Nino3.4 plumes.
- At time of writing 29 users have so far registered for access (including the GPCs themselves). Note: access is restricted to recognised GPCs, RCCs, NMHSs and institutions hosting RCOFs (e.g. ACMAD, ICPAC), see Doc. 6(1) for details. Additionally, in December 2007, GPC data were supplied (with GPC agreement) for use in developing seasonal forecasts for malaria control in southern Africa.

Example graphical products generated from core information by the developing KMA/NCEP Lead Centre are provided in Figs. 1 and 2. Fig. 1 shows ensemble-mean temperature forecasts from 6 GPCs (including Moscow). The identical map domain is user selected and the consistent shading convention allows ready comparison of the predicted anomaly sign.

Provision of multi-model forecast products will enable users to benefit from the improved skill (on average) and better assessment of prediction uncertainties available from multi-model methods. Example multi-model products developed so far are provided in Fig. 2, and provide information on the number of participating models with predicted ensemble-mean anomalies of the same sign.

3.2 Plans for future work at the LC-LRFMME

Plans under consideration for future work include:

a) LC-LRFMME products:

- refinement of graphical displays (i.e. 'postage stamp' displays of GPC output), consider user defined contouring intervals;
- develop individual model and multi-model probability forecast maps, utilising the GPCs ensemble members (e.g. probability of above/below mean and, from the additional data, probabilities of tercile categories);
- develop products for other variables and climate indices (e.g. SOI)
- 'fixed' (rather than user selected) map domains may be required for users with limited IT resources;
- Further development and promotion of multi-model methods.

b) Coordination with the Lead Centre for the Standard Verification System for Long-range Forecasts Coordination (LC-SVSLRF)

- coordination is needed in a number of areas including:
    - the below/above mean products planned for issue by the LC-LRFMME are not specified as requiring verification in the SVSLRF;
    - map domains for graphical products need to be matched for forecast and verification products (currently map-style verification is available only on the global domain);
    - a way of displaying forecast and verification information 'side-by-side' should be explored;
    - coordination is required in verification and display of the MME products generated by the LC-LRFMME. These may include diagnostics showing the benefit of the multi-model over the individual models.
    - the potential benefit of co-locating the two centres at some time in the future should be considered

c) Promotion of the information available and review of feedback

- There is a need to promote the available products to the user community and to encourage feedback. Timing of promotion activities should follow after designation of KMA/NCEP as a

LC-LRFMME, further development of its products and coordination with the LC-SVSLRF verification products.

d) Guidance on interpretation and use of the LC-LRFMME products could be developed by the ET and made available of the LC-LRFMME website. An initial draft of such guidance was input to the CCl-CBS IT meeting on Designation of RCCs, and could be further developed (Annex 1).

4. Verification issues and the Lead Centre for the Standard Verification System for Long-range forecasts (LC-SVSLRF)

4.1 The LC-SVSLRF (co hosted by WMC Melbourne and RSMC Montreal)

The LC-SVSLRF and its associated website (http://www.bom.gov.au/wmo/lrfvs) have been fully functional for 2 years. Verification data received from GPCs have been processed to provide skill diagnostics and maps on the website, creating a repository of hindcast verification for the GPCs forecasting systems. Support to GPCs has been provided in the form of documentation of the skill scores, software for calculating the scores, and access to the observation datasets specified by the SVSLRF (which can be downloaded from the website).

It is not mandatory for GPCs to provide the SVSLRF scores, required for GPC designation, to the LC-SVSLRF – but it is strongly encouraged. Population of the website with the scores required from GPCs increased markedly during the designation process. The status as of April 2008 is summarised below. Note: Level 1 and 2 scores refer respectively to diagnostics aggregated over regions (reliability diagrams and ROC curves); Level 2 scores to maps of scores calculated at grid-points.

- Beijing, Tokyo, Toulouse, Washington and Montreal have submitted all scores;
- Exeter have submitted all scores except maps of MSSS and its decomposition terms;
- Melbourne have submitted everything at all lead times except ROC area maps and the diagrams (ROC or reliability diagram) because an ensemble run in hindcast mode has only recently been completed;
- Seoul have submitted just the maps associated with the MSSS and its decomposition maps;
- Because the forecast system was in the process of changing, ECMWF had submitted just the aggregated scores (level 1). The rest of the scores are on their web site. Full submission of scores with the new forecast system is planned for October 2008;
- IRI (not yet a GPC) have submitted everything but the level 2 maps (ROC area, MSSS, etc.);
- Moscow (GPC designation pending) have submitted level 1 and 2 scores (except for MSSS);
- Sao Paulo (CPTEC – GPC application received) has submitted MSSS and decomposition maps for precipitation and T2m for DJF.

Example verification maps from the LC-SVSLRF website are provided in Fig. 3 and show, for 4 GPCs, the correlation term in the Mean Square Skill Score decomposition for 1-month lead predictions of DJF precipitation.

4.2 Further development of the SVSLRF

Issues raised at the 2006 ICT meeting have been considered by the ET.

New scores (including assessment of information in the ensemble spread)

There is consensus within the ET that the SVSLRF does not require expansion with new scores at present. The ET has kept abreast of developing scores and will continue to review research into new potential skill measures. The Level 1 and Level 2 scores of the SVSLRF are considered sufficient for the key intended purpose of guiding development of consensus forecasts – weighting

(subjectively) GPC forecasts according to skill. The existing SVSLRF scores are also appropriate for use with MME products and ERF products. There are also practical considerations: the SVSLRF should be a limited set of scores for operational exchange which measure skill for the required list of GPC forecast products. The level of forecast precision associated with the required GPC products (i.e. tercile categories) is considered appropriate given current prediction capabilities. Verification of forecast products with higher stratification (e.g. 'extreme' events) should be encouraged but need not, as yet, be part of the SVSLRF.

Note: The level 3 scores of the SVSLRF (verification contingency tables at grid-points) were intended to enable users to objectively weight GPC forecasts according to skill. In practice, exchange of this level of information has proved overwhelming, and is considered to provide little value at high computing cost. Consequently the ET is reconsidering the benefit of level 3 information.

Calculation of confidence intervals on skill scores
The ET acknowledges the importance of providing estimated confidence limits on scores. Work to recommended procedures is a future priority.

Standardisation of methods/datsets
For calculation of tercile boundaries the ET has recommended a counting method, described in the WMO Guide for Climatological Practice. The recommended hindcast period is now 1981-2001.

Cross-validation is currently mandatory in calculation of scores for both calibrated and re-calibrated (i.e. skill calibrated) dynamical products. Further work is still required, however, to assess the value of cross-validation for calibrated products.

4.3 Plans for future development of the SVSLRF and LC-SVSLRF

The LC-SVSLRF:
At its 2008 meeting the ET agreed that the main priority areas for the LC-SVSLRF were:

- continue building the repository of SVSLRF scores provided by GPCs (not all scores are currently available for all GPCs);
- liaise with the LC-LRFMME to work towards a consistent presentation of the forecast and verification products and a method of simultaneous display.

The SVSLRF:

- review required verification in light of new LC-LRFMME products (e.g. above/below mean probabilities);
- develop recommendations for providing confidence limits on skill scores;
- develop advice for dealing with biases in verification scores introduced by observed climate trends over the hindcast period
- when guidance on the definition of ENSO events is available, review recommendations on stratifying skill scores according to the state of ENSO;
- develop further understanding of the value of cross-validation in skill assessment of calibrated (i.e. simple bias corrected) dynamical forecasts;
- review new scores as they are developed with a view for inclusion in the SVSLRF.

5. ET-ELRF collaboration with CCl

The ET made written input to the CCl-CBS Intercommission Technical Meeting on Designation of Regional Climate Centres (RCCs), Geneva, 21-22 January 2008, advising on amendments to proposed functions of RCCs. The ET further reviewed the revised functions for RCCs at its 2008 meeting and recommended them, with slight revision, for CBS endorsement.

It would be appropriate for ET representatives to promote the GPC and Lead Centre products at RCOFs and associated capacity building sessions.

The ET reviewed a position paper on seasonal forecasting from the CLIVAR Working Group on Seasonal to Interannual Prediction, and provided specific input on infrastructure and verification activities guided by the ET-ELRF. The position paper is available at http://www.clivar.org/organization/wgsip/wgsip.php

In other cross-commission work the ET has reviewed the data needs for global LRF and passed a revised document detailing the needs to the chairman of the ET on Evolution of the Global Observing System.

6. Extended range forecasting (11-30days ahead)

A number of GPCs are engaged in operational prediction on timescales that cover all or part of the ERF timescale. At most, but not all, centres ERF and LRF activities are closely connected, and are generally under the remit of the same research group with related dynamical models used in prediction for the two timescales. For this reason, the team agreed that it was appropriate that ERF and LRF be included in the terms of reference of a single Expert Team. However, it was noted that responsibility for both timescales would potentially restrict the attention given to each. It was agreed that the Team would monitor the practicalities of its expanded remit, and report back to CBS. Some indication of priorities in the ET's ToRs may help in this regard. For example with the current need to consolidate products from the LC-LRFMME and the LC-SVSLRF and to promote their activities (particularly in light of the emphasis on seasonal forecasting at the World Climate Conference-3), there would seem a need to continue with seasonal forecasting as the highest priority for at least the next two years.

It was noted that there is currently little uniformity between centres in ERF outputs, with differences in, for example, issuance times and update frequency, sub-division of the 11-30 day period, and in the specific quantities predicted. Some convergence of forecast outputs from operational centres would be required before a meaningful exchange of ERF data could take place. Once variables and time averaging (if any) were agreed, a simple exchange of anomalies relative to the hindcast climatology (as in the 'core' information defined for the LC-LRFMME) would be relatively straightforward. However, an exchange of hindcasts would have complications for centres which're-make' the hindcasts ahead of each forecast – a practise which ensures post-processing adjustments are automatic following any changes to the prediction model. Frequent exchange of large hindcast datasets would not be practical.

The ET agreed that, as development of ERF capability is relatively new at some centres, it would be timely to begin the definition of recommended infrastructure for ERF. However, with the remit of the current ET now covering both infrastructure and verification (formerly dealt with by two teams), clear priorities would need to be agreed. First steps to guide exchange and convergence between centres could include

- a questionnaire to GPCs and other centres to further clarify the status of activities in extended range prediction;
- a workshop on infrastructure and verification of ERF.

7. Inter-annual and decadal timescales

The definition of 'long-range' is up to 2 years ahead. Some centres are extending operational seasonal forecasting to inter-annual time-scales. Decadal forecasting is of considerable interest in climate change adaptation, and is arguably more related to seasonal forecasting (through its use of observed initial conditions) than to centennial-range climate prediction. The ICT may wish to consider the future role of the ET-ELRF in developing infrastructure and standards in these activities.

8. Promotion of activities to the user community

As forecast and verification products becoming increasingly available from GPCs, the LC-LRFMME and the LC-SVSLRF there is an increasing need to promote the products, develop guidance on their use, and to seek user feedback. Some possible activities to help achieve this are listed below,

- formal notification to WMO members, from WMO secretariat, of the availability of GPC products and (after designation) LC-LRFMME products
- prepare an article describing GPC and LC-LRFMME products and their benefits for publication in the WMO bulletin.
- a workshop on practical long-range prediction including GPCs, LC-LRFMME, LC-SVSLRF, NMSs, RCCs and RCOF coordinators;
- representation of ET members at RCOFs in 2009, particularly the capacity building sessions, to demonstrate the use of GPC/LC-LRFMME/LC-SVSLRF products (both graphical and digital) and to gather feedback. In addition to training in the use of the products, the aim would be to achieve 'traceable' impact of the forecast products – if appropriate given skill - in the RCOF consensus forecast. This may need some short-term activity from the LCs to ensure forecast and verification products are available for the RCOF region. It would also require agreement and coordination with the institutes hosting the RCOFs.
- World Climate Conference-3: Our participation could, in collaboration with CCl, range from
    - presentations on GPC and Lead Centre products
    - if the representation at RCOFs can focus on PRESAO (West Africa), usually held May/June at ACMAD, a case study of the use of the products could be developed ahead of the conference and form one presentation.
    - it may be possible to have a stall at the conference at which we could give live demonstrations of the web products.
    - Building capacity to responses to predictions of (seasonal) climate variability will assist capacity to adapt to climate change. This is becoming increasingly recognised, and it would be a useful theme to develop at WCC-3. Time may be too short to develop practical demonstrations of this idea at work. However, through liaison with e.g. ACMAD it may be possible to include this theme to some degree at PRESAO and incorporate the results in the case study presentation at WCC-3.

9. Future development of long-range forecast prediction models and possible implications for the SVSLRF and data exchanges with Lead Centres

In many centres current long-range forecast models have been adapted from those used in NWP or climate change prediction, with little specific development to optimise performance for seasonal timescales. With increasing interest in seasonal prediction, this situation is now changing. In particular there is much research interest in the need for higher resolution long-range prediction models. For example, higher resolution models are better able to capture relatively small-scale, short-lived features which may trigger 'blocking' - and may therefore have significant benefits for prediction on longer timescales. The computational expense associated with long ensemble runs of a high resolution model makes long hindcast periods, recommended by the SVSLRF, difficult to achieve. Moreover, if model improvement is rapid with many operational changes, hindcasts need to be generated frequently – adding to the impracticality of long hindcast periods. Note: The next generation Met Office LRF system will re-make hindcasts ahead of each monthly update, to allow for a program of rapid model development.

There is also an argument that skill assessments based on long hindcasts are likely to under-estimate current levels of prediction skill, since the important global network of subsurface ocean observations provided by ARGO floats did not reach maturity until around 2005.

In summary whilst the ET-ELRF must continue to work towards standards in operational seasonal prediction, care must be taken that such standards do not become a hindrance to new initiatives

designed at improving the skill of the models. Improvement in prediction skill is, of course, central to increasing the benefit of forecasts to the user.

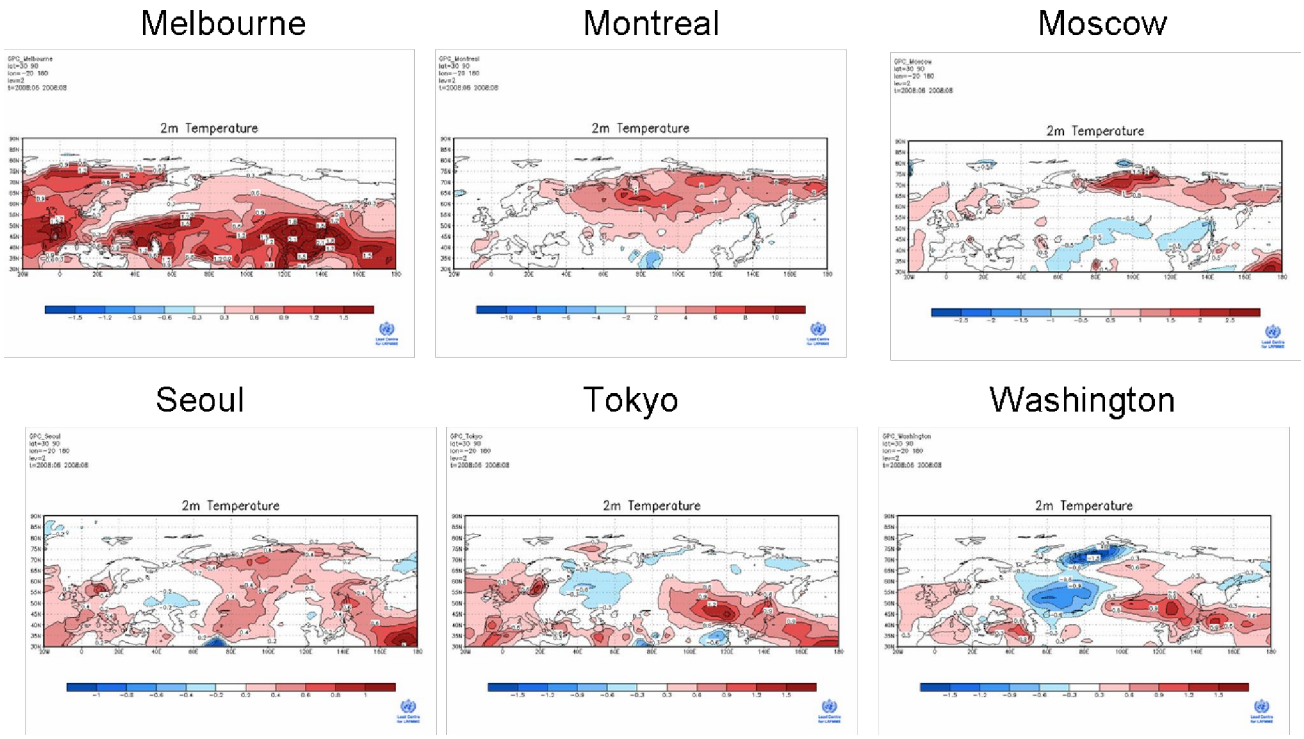

Fig. 1: Example output available on the developing KMA/NCEP LC-LRFMME website. Forecasts shown are 1-month lead ensemble-mean predictions of JJA 2008 2m temperature anomaly for Europe and northern Asia from five GPCs (and one pending GPC, Moscow) contributing to the developing KMA/NCEP LC-LRFMME.

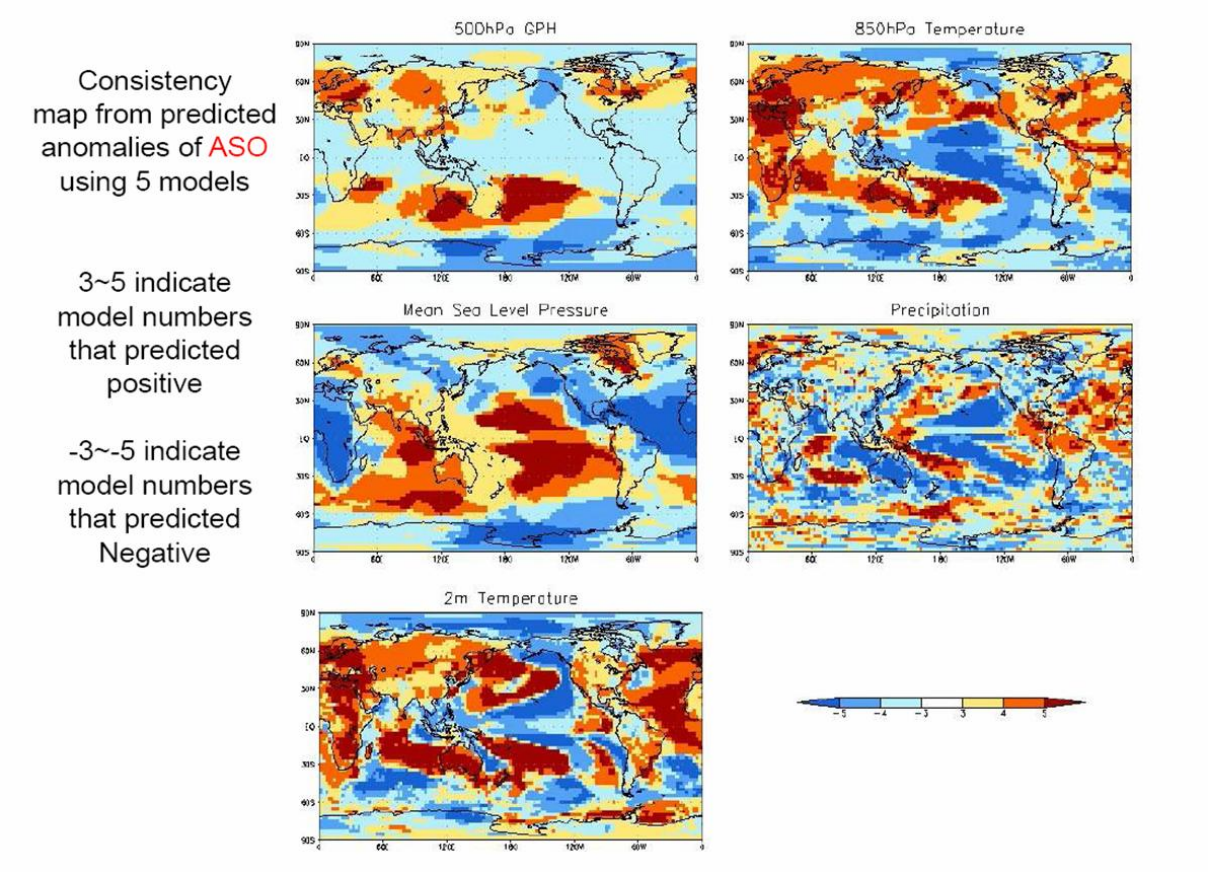

Fig.2: Model consistency products showing the number of models (out of 5) with predicted ensemble-mean anomalies of the same sign. For 1-month lead predictions of ASO 2008 anomalies in 500hPa geopotential height, 850hPa temperature, MSLP, precipitation and 2m temperature.

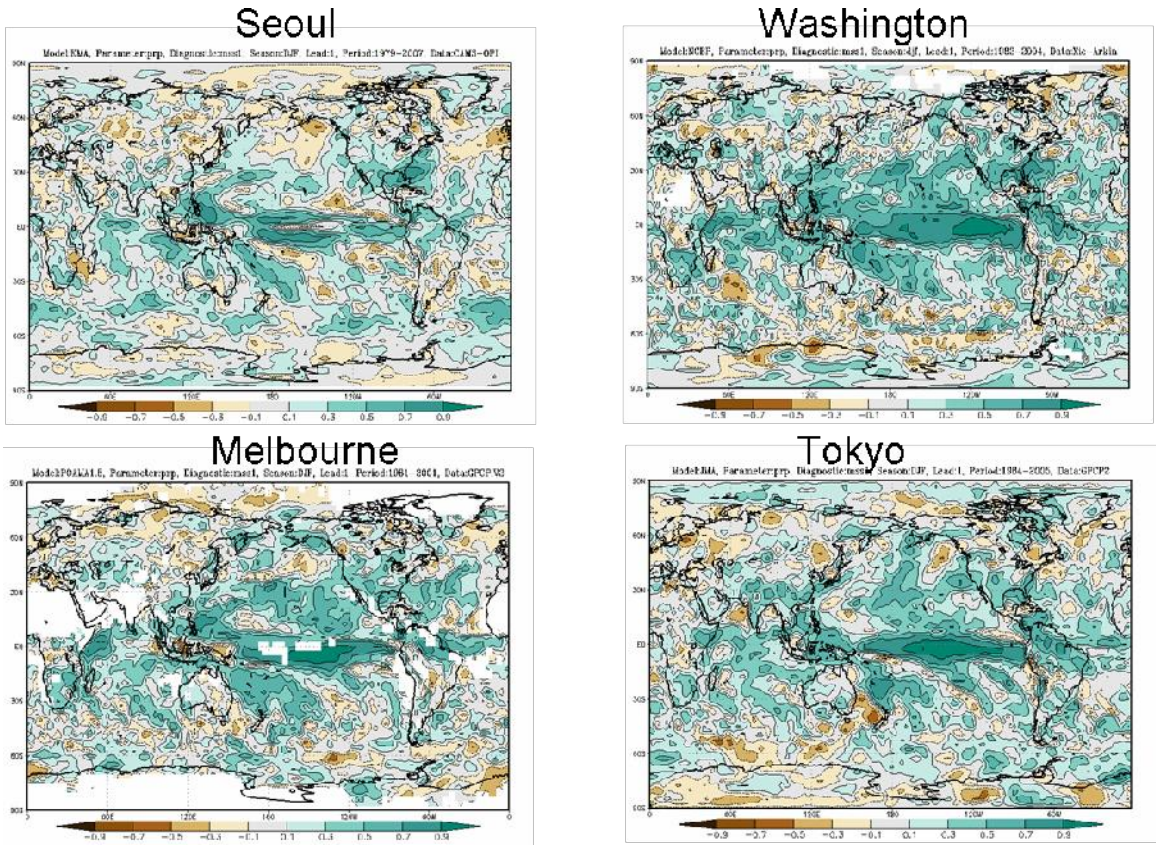

Fig. 3: Example verification plots from the LC-SVSLRF website showing term 1 of the Mean Square Skill Score decomposition (term 1 is related to correlation). Scores are for 1-month lead prediction of DJF precipitation. Note the verification dataset used varies (datasets used are CAMS-OPI, GPCP, Xie-Arkin).

Annex 1

(Extracted from Richard Graham's input to: CCl/CBS Intercommission Technical Meeting on Designation of Regional Climate Centres (RCCs), for discussion regarding providing guidance to forecast users.)

In the long-range forecasting process, Members should:

1. Evaluate the current and expected state of climate modes known to have teleconnections with the region (eg. ENSO, Indian Ocean SST dipole).
2. Assess the likely seasonal climate response in the region, given the characteristics of the climate mode (eg. phase, intensity, variance from usual life cycle)
3. In light of 1 and 2, evaluate output from numerical prediction systems, including multi-model systems (provided by the GPCs and collated by the Lead Centre for Long-range Forecast Multi-Model Ensemble Prediction, LC-LRFMME).
4. In light of 1, 2 and 3 evaluate output from statistical prediction systems for the region.
5. Take account of relevant underlying climate change/trends in the region.
6. Where possible combine all prediction inputs objectively, taking account of prediction system skill, to produce a skill-calibrated consolidated probability forecast.

7. Prediction inputs are often expressed as anomalies relative to varying and non-standard climatological periods. Adjustments should be made such that the consolidated forecast is expressed relative to a standard climatology (e.g. 1971-2000), which should be stated.
8. Downscale to provide geographical detail as is feasible/appropriate
9. Decide on the necessity to issue a climate watch
10. Distribute products to users
11. When the forecast period has expired, provide observed conditions for user comparison with the forecast. When sufficient forecasts have accumulated verification should be performed using procedures in Attachment II-8.

ANNEX TO PARAGRAPH 7.15

Report of Chairperson of ET-EPS
Ken Mylne (Met Office, UK)

1. Introduction

1.1 The ET-EPS has not met as a team since its last meeting in February 2006 which was reported at the 2006 meeting of the ICT-DPFS. As a result the activities of the team have mainly been carried out on its behalf by the Chairman, Mr Ken Mylne (Met Office, UK), who has attempted to represent the views of the team in a number of interactions with other WMO activities.

2. Progress with EPS Development

2.1 Ensemble Prediction Systems (EPS) continue to become increasingly integrated into the GDPFS, both nationally in the more advanced NWP centres, but also through use in collaborations and WMO projects which increasingly make EPS data available to some of the less-developed WMO members. Whereas a decade ago EPS was considered only as a tool used with global models to understand the uncertainty in mid-latitude synoptic-scale development in the medium-range of 3-10 days, EPS is now being used with regional models for short-range forecasting and is being coupled to a range of ensemble impact or application models such as storm surge and atmospheric dispersion.

2.2 In many of the more advanced NWP centres EPS is becoming an essential component of the complete NWP system, rather than a low-priority supplement. In the UK Met Office, for example, the long-term plan is to run all NWP in ensembles to provide the complete forecast distribution. In the shorter term it is intended to cease having a higher resolution deterministic forecast from the regional model and move towards having only a regional ensemble at around the current deterministic resolution. Related to this, centres are increasingly planning to use ensemble data to improve the quality of data assimilation schemes, whether by using an Ensemble Kalman filter directly or by using ensemble information to quantify background error statistics in 4D-Var. In either case this means that having an effective EPS becomes an essential requirement of a top-quality NWP system.

2.3 Regional EPS – Increasing numbers of centres are now running regional ensembles with LAMs (Limited Area Models) to assess the uncertainty in more local weather on short-range timescales. Some centres such as the Spanish Met Service approach this by running a number of different models from different initial and boundary conditions taken from different NWP centres. Others such as the UK Met Office and NCEP (USA) are developing perturbation methods explicitly designed for the LAM ensemble. Some regional ensembles provide essentially a downscaling of the uncertainty information from a global ensemble by taking low-resolution perturbations from the same ensemble providing the boundary conditions; others attempt to generate perturbations explicitly designed for the higher resolution regional model, although as yet it is not clear whether this provides any improvement in performance over a downscaling approach.

2.4 Convection-allowing ensembles – many of the more advanced NWP centres are now experimenting with high-resolution non-hydrostatic mesoscale models with grid-lengths of around 1-4km which are capable of explicitly resolving some aspects of convection. While these models open the possibility of forecasting more information on the location and intensity of convective storms, they also incorporate additional highly non-linear development processes which can be expected to lead to chaotic development and forecast uncertainty. Useful forecasting is therefore likely to require the use of ensembles, and some centres are looking towards doing this in the future. In the USA the National Severe Storms Laboratory is already experimenting with convection-allowing ensembles as part of its annual Spring Programme of quasi-operational

research. The UK Met Office is planning to introduce a small experimental ensemble with a 1.5km model over the UK in 2011.

2.5 Multi-model Ensembles (NAEFS and THORPEX-TIGGE) – The USA and Canada have implemented an operational multi-model ensemble system by combining outputs from their global ensembles and generating joint products for the north American region (NAEFS). The TIGGE project under the THORPEX programme is providing a larger non-operational database of forecasts from around 10 different ensembles for research purposes. Recent research is starting to show promising benefits of multi-model ensembles for surface weather parameters such as surface temperature – benefits for large-scale parameters like 500hPa Geopotential are minimal compared to the best single-model ensembles.

2.6 Surface weather parameter and high-impact weather – in the early years of EPS development, verifications and products were centred around the ability to forecast medium-range synoptic scale evolution, with the emphasis on performance for 500hPa height for example. Today there is much more emphasis on surface weather parameters of interest for day-to-day weather forecasting, and on the ability to forecast high-impact or severe weather. Forecasting severe weather makes verification much more difficult because of small samples, but is more relevant to the users and should be strongly encouraged.

2.7 Severe weather diagnostics – a number of new diagnostics have been developed to aid application of EPS in forecasting, particularly for severe or high impact weather. ECWMF has the EFI (Extreme Forecast Index) which identifies when the entire EPS distribution is extreme compared to the climate distribution as an alert to severe weather risk. The UK Met Office has developed a range of feature-based diagnostics such as tracking of both tropical and extra-tropical cyclones and frontal systems, which help forecasters to interpret ensembles in terms of synoptic features. Such developments help greatly in the application of EPS for operational forecasting, and are to be strongly encouraged.

2.8 Specialist ensembles – a few centres are starting to run ensembles designed specifically to address uncertainties in aspects of the weather of particular importance to them. For example the Japan Meteorological Agency (JMA) is running an ensemble targeted specifically at improving forecasts of tropical cyclone (typhoon) tracks.

2.9 In Europe the EU Project PREVIEW has developed a multi-model ensemble-based Windstorm warning system which provides alerts and forecasts for strong wind events up to 5 days ahead at a large number of sites around Europe. See www.preview-windstorms.eu (username: nms, password: welcome2). Ensemble-based flood forecast systems are also in place for some large river catchments.

2.10 Ensemble data provided a key element of the NWP information supplied from global centres (ECMWF, NCEP (USA), and the UK Met Office) to the RAI Severe Weather Forecasting Demonstration Project (SWFDP) covering southern Africa. Ensemble products helped forecasters to pinpoint the areas at greatest risk of heavy rain and strong winds, with much extended forecast lead-times. The ECMWF EPS-based Meteograms were reported to be particularly useful.

2.11 Application ensembles (eg. dispersion, storm surge, wind power) – As ensembles become more established in forecasting systems there is increasing interest in propagating the uncertainty through application models to estimate the uncertainty in the impact of the forecast weather. This is most appropriate where weather is the dominant source of uncertainty in the application forecast, but even in other circumstances can be used as part of a wider ensemble effort, or to isolate the uncertainty due to the weather. ECMWF has long included ocean wave forecasts in its EPS, and other centres are developing wave model ensembles. Storm surge prediction for coastal flooding is an ideal application where weather provides the dominant source of uncertainty. Around the North Sea the UK Met Office is running a storm surge ensemble driven by weather inputs from

MOGREPS, and the Dutch Met Service KNMI is doing the same using weather from the ECMWF EPS. In pollution dispersion modelling weather is only one of several sources of uncertainty – others include the source characteristics for example. Nevertheless dispersion models can be run in ensembles by combining outputs from multiple dispersion models, or by running ensembles with the same model using ensemble forecasts of the driving meteorology (eg The UK Met Office is running ensemble forecasts with the NAME model driven from either Met Office MOGREPS or ECMWF ensemble forecasts for the EU project PREVIEW.) There are many other possible applications which are either under development or are being considered for future development, such as wind power production forecasts, energy demand modelling, road-ice modelling and clear-air turbulence for aviation.

2.12 A common source of verification information for global EPS is provided by the Lead-Centre for EPS Verification which is hosted by JMA. The Lead-Centre has recently updated its web-pages to account for the agreed change in verification procedures which adopted new thresholds for probabilistic forecasts based around quantiles of the climate distribution (eg. one standard deviation above normal). The revised website is now ready to be opened (removal of password) but is very lacking in content due to EPS producing centres not providing verification results. More details are provided in section 6 below.

2. Co-ordination with PWS Programme

2.1 At the last meeting of ICT-DPFS the ToR of ET-EPS was updated to note that coordination is needed with the Public Weather Service programme regarding their requirements for EPS products that support probabilistic forecasting. This was addressed through a joint Expert Meeting on the Application of Probabilistic Forecasts held in Shanghai, China from 24-28 September 2007. This meeting was organised by the PWS Programme and was chaired by Mr Ken Mylne (Met Office, UK) representing the ET-EPS and ICT-DPFS.

2.2 The main product from the Expert Meeting was a document setting out a set of Guidelines on Communicating Uncertainty which are published on the WMO website at http://www.wmo.int/pages/prog/amp/pwsp/documents/TD-1422.pdf

2.3 While the guidelines prepared at the Expert Meeting in Shanghai provide a good starting point for communication of uncertainty, it is expected that there will be a continuing need for collaboration with the PWS Programme as ensemble forecasts become more integral to the GDPFS.

2.4 Training of forecasters in the use of new products such as EPS products would benefit from being integrated with the PWS programme training. Some cooperation has already been successfully undertaken, particularly in the training for the SWFDP, but future training should aim to further integrate the DPFS and PWS training programmes. Forecasters need two distinct sets of skills – understanding of NWP and EPS systems, and communication skills. Traditionally the former has been seen as the role of GDPFS training while the latter has been the preserve of PWS training. It is normally the same forecasters who perform both roles, so to ensure the effective exploitation of EPS for public safety and security it is highly desirable that the training be combined so that the same forecasters develop both sets of skills.

3. Co-ordination with THORPEX

3.1 At the last meeting of ICT-DPFS the ToR of ET-EPS was updated to note that coordination is needed with research and development activities such as THORPEX that they should recognize existing operational NWP/EPS production and be advised on operational implementation issues, where relevant. To provide this co-ordination, Ken Mylne as Chair of ET-EPS has participated as an observer on the GIFS-TIGGE working Group responsible for the development of the GIFS (Global Interactive Forecast System) Plan. GIFS is anticipated to be the next major development of

the global NWP capability under WMO, providing improved access to NWP data in the form of multi-model ensembles for WMO members. The aim of Ken Mylne's contribution has been to ensure that the GIFS plan is realistic and useable in an operational framework. A report from the latest GIFS-TIGGE Working Group meeting, presented at the ICT meeting, indicated that the main proposals from Chair ET-EPS have been adopted in the latest version of the GIFS-TIGGE plan – notably that GIFS should develop through a number of targeted projects focusing on particular hazards (such as tropical cyclones) and through regional projects following the model of the SWFDP.

3.2 TIGGE-LAM – Ensemble forecasting is becoming increasingly recognised and used as a tool for short-range forecasting using regional models as well as for medium-range using global models. There is therefore growing interest in whether collaboration through the combination of over-lapping regional ensembles to form multi-model ensembles could be a useful way of providing improved short-range forecasts, in the same way that TIGGE aims to provide improved global medium-range forecasts. To coordinate efforts on regional multi-model ensembles, the GIFS-TIGGE WG has created another working group to consider LAM (Limited Area Models) efforts – TIGGE-LAM. Ken Mylne is a full participating member of the TIGGE-LAM WG to represent the ET-EPS and the needs of WMO members (as well as the interests of the UK Met Office.) There is considerable concern about whether the combination of multiple ensembles is practical in an operational framework on the timescales required for short-range forecasting. The opportunity for support to WMO members is very limited by the limited coverage and overlap of LAM EPS systems. GDPFS input to TIGGE-LAM has already developed the exchange of a small subset of the most important parameters. Some research is encouraged, but further work will be required to ensure the operational feasibility of TIGGE-LAM developments.

3.3 Work on coordination with THORPEX is described in more detail in Document 7(2) on Cooperation with CAS/THORPEX.

4. Support for SWFDP

4.1 The Severe Weather Forecasting Demonstration Project (SWFDP) has been highly successful in demonstrating how forecast information can be useful cascaded from the most advanced centres to reach some of the least developed and least resourced NMHSs and aid in the provision of critical severe weather forecasts and warnings. A key part of the information cascaded in the initial project in RA I (Southeast Africa) was a variety of ensemble forecast products, and in many cases this was the first opportunity that forecasters in the NMHSs had had the opportunity to see and learn about ensemble products, especially products for their own regions.

4.2 Ken Mylne, as Chair of ET-EPS, sits on the Steering Committee of the SWFDP, and has sought to ensure that EPS data is at the core of the data cascaded. The Steering Committee met in Geneva in March 2008, and some highlights are listed in paragraphs 4.7 To 4.14 below.

4.3 Ken Mylne also took the opportunity to visit the forecast office in the leading regional centre for the RA I SWFDP, at the South African Weather Service (SAWS) in Pretoria during a WMO-funded visit to SAWS to attend the GIFS-TIGGE WG. Coincidentally this meeting was the week before the SG meeting so provided a timely opportunity to see the ensemble products in operation, and discuss the experience of using them with the forecasters. Some conclusions are listed in paragraphs 4.4 to 4.6 below.

4.4 Forecasters were very enthusiastic about their experience of the SWFDP. They clearly found it a worthwhile and rewarding exercise, and were very appreciative of the additional data supplied by the cascading process.

4.5 Both ECMWF and MOGREPS ensemble forecasts were found to be very useful for pinpointing areas most likely for heavy rain and strong winds. The ECMWF EFI (Extreme Forecast Index) was

useful in highlighting areas at risk. However, some products which are found to be very useful in the producing centres (where EPS usage is more established) were under-used, and further training may be required to ensure that SWFDP products are used to their full potential. Some additional parameters and thresholds were proposed.

4.6 One problem expressed was that products designed for use in the extra-tropics were not always well-suited to use in tropical areas. Some additional products were proposed for use specifically in the tropics, notably CAPE, precipitable water, upper divergence and low-level moisture convergence. The possibility of developing some feature-based diagnostics for tropical convection, such as objective diagnosis of convergence lines, was also proposed.

4.7 The overall summary of the SWFDP was that it had been successful in cascading information and had made a real difference to capability in southern African NMHSs. There is strong support from MASA (Meteorological Association of Southern Africa) and a desire to see it made permanent and operational for the whole region. This view was supported by the SG.

4.8 Objective verification is almost non-existent due to shortage of suitable observations. Evidence of success was largely based on subjective assessment. It is not known what would have happened, or what warnings would have been issued, without the SWFDP.

4.9 The success was very dependent on the very strong support and contribution of SAWS which did an excellent job as a regional centre. Without such a strong and proactive centre other projects may not be so successful.

4.10 Another critical root of the success was the training programme run as part of the project. This was often the first time many forecasters had received training on ensemble products, and in some cases on any NWP products. The training was highly praised. For continued success of the on-going service as it becomes operational it will be necessary to provide regular training, at least annually, to update forecasters and train new forecasters joining the system. Training should also be reviewed to ensure that forecasters are making the best use of the full range of products available.

4.11 It was felt that the use of the data beyond the NMHS was limited, and that there was insufficient engagement with Disaster Risk and civil protection authorities as the end-users.

4.12 The SC supported the continuation of the southern Africa project with an expansion to include all the NMHSs in the region. It also supported the establishment of two further projects in the Pacific Islands and in South America.

4.13 There was support for the development of improved diagnostics for ensembles and deterministic NWP appropriate to tropical weather systems, although it was noted that no resources are available and this would be dependent on development work in the global centres.

4.14 There were interactions at the SC meeting with several other WMO programmes (Disaster Risk Reduction, aviation, marine and flood risk) which wished to engage with the SWFDP to expand its success to their own programmes. While the model used for the SWFDP was strongly supported for use in other areas, direct expansion of the SWFDP to incorporate other areas was largely resisted to avoid the project growing too large too quickly and risking becoming unmanageable.

5. Training

5.1 The main training activity of WMO for EPS in the last two years has been that associated with the SWFDP. This was seen as a critical part of the success of the SWFDP (see para 4.10 above) and in many cases provided forecasters with their first contact with ensemble forecast products.

This is a significant improvement over some previous WMO training programmes on EPS where forecasters were inspired to use ensembles but had no access to suitable products for their regions on their return to their home stations. The need for ongoing training is recognized, and the concept of training the trainer should also be employed where possible.

5.2 Some EPS training has been included in training workshops on NWP, but no specific ensemble training workshops have been held in recent years.

5.3 As noted in para 2.4, it is essential that EPS training reaches the forecasters who provide the essential services. Future training should be integrated within the PWS, SWFDP and similar training programmes rather than being run in isolation. GDPFS training covers NWP and EPS, while PWS training on probabilistic forecasts should focus on communication of uncertainty – by merging the two we can ensure that forecasters have the dual set of skills to exploit the EPS and communicate the forecast effectively.

6. Verification

6.1 A common source of verification information for global EPS is provided by the Lead-Centre for EPS Verification which is hosted by JMA. The Lead-Centre maintains a website for presentation of verification results and includes guidance on the procedures for verification in the required formats. However the Lead-Centre has been poorly supported by EPS producers as very few of them (only JMA and ECMWF) provide verification results regularly to the Lead-Centre for inclusion in the website.

6.2 The Lead-Centre has recently updated its web-pages to account for an agreed change in verification procedures which adopted new thresholds for probabilistic forecasts based around quantiles of the climatological distribution (eg. one standard deviation above normal). The revised website is now ready to be opened (removal of password) but is very lacking in content due to EPS producing centres not providing verification results. Currently only JMA and ECMWF are providing verification results in the required formats. The reason for this is believed to be that most EPS producers do not have the capability to verify their systems in relation to climatologically defined thresholds. (Several more centres were providing results before the requirements were changed.) The change was made for good scientific reasons, but does make the verification systems more complex to design and operate.

6.3 EPS producers have been focusing much of their verification efforts on TIGGE for providing an intercomparison of systems. However there is also a requirement for operational verification, and producing centres should be encouraged to contribute more verification to the Lead-Centre. It was noted at the meeting that ECMWF have a climatology based on reanalysis which can be made available to any EPS producers for this purpose.

7. Future Plans

7.1 The main issue going forward is the development of GIFS-TIGGE and the potential operational spin-offs from that. The key role of the ET-EPS should be to ensure that research is directed towards systems and solutions which are operationally feasible and realistic, and which meet the needs of WMO members, particularly in relation to severe and high-impact weather. The method of cascading data from global centres through regional guidance centres to NMHS developed for the SWFDP is seen as a good model for the future development of GIFS.

7.2 To date ET-EPS input into GIFS-TIGGE and related areas has mostly been from the Chair, Ken Mylne, plus also from Zoltan Toth in his role as co-chair of the GIFS-TIGGE WG. As there has not been a meeting of the ET-EPS since Feb 2006 there has been little opportunity to discuss the issues and provide a brief for the Chair so he has had to act largely on his own judgement. It is therefore highly desirable that funding should be made available for an ET-EPS meeting to review

the CBS requirements and provide an agreed brief to the Chair on future strategy. To this end a proposed Agenda for an ET-EPS meeting has been drawn up by the Chair (Ken Mylne) and the Secretariat (Peter Chen) – see Annex.

7.3 As discussed in paragraphs 2.4 and 5.3, joint training with PWS programme on the use of ensembles and the communication of probabilistic forecasts is strongly encouraged. Conducting training in preparation for an SWFDP is particularly effective as the SWFDP makes ensemble projects available for operational use, which builds experience and allows the training to be reinforced with practical experience.

Annex
Draft Proposal:
Meeting of CBS Expert Team on Ensemble Prediction Systems (ET-EPS) 2008-09
(prepared by Mr Ken Mylne, Chairperson of ET-EPS)

Issue and proposal
The ET-EPS last met in February 2006. CBS and Congress continue to express high degree of interest and priority to enhance the use of forecasters of EPS-based products from GDPFS Centres especially for severe weather and probabilistic forecasting. This is a proposal to hold a meeting of the Team prior to CBS-XIV, to coordinate activities in a number of EPS area that have advanced since the last meeting, in particular to address the needs of enhanced weather forecasting expressed by WMO Members (WMO Strategic Plan's Expected Result 1).
The key aims of the meeting are to:

- Propose and plan activities (CBS-CAS linkages) to ensure operational benefits are realized from the THORPEX research programme, including to review the GIFS-TIGGE plan for operational benefits, and provide feedback to the THORPEX research programme on the identified gaps in operational capability of EPS that require on-going research
- Improve the use of EPS in the Severe Weather Forecasting Demonstration Project (SWFDP)
- Further develop guidance materials for forecasters on use of EPS products
- Review the Terms of Reference of the ET-EPS relative to accomplishments and future priorities

Draft Provisional Agenda
The following draft agenda of items is proposed for the meeting, which would likely require a 4 to 5 day meeting.

1. Opening
2. Organization of meeting
3. Brief review of the key research outcomes of THORPEX, achieved and anticipated, and their benefits for operational EPS
4. Review the Terms of Reference and progress of EPS since the previous meeting, in particular the emergence of high-resolution regional EPS
5. Review the emerging GIFS plans for their operational practicality and potential benefits
    a. Prepare feedback on the GIFS plan for the THORPEX programme
    b. Prepare proposals for PWS and DRR on the potential benefits of GIFS.
6. Review plans for TIGGE-LAM
    a. Prepare feedback on TIGGE-LAM plan to ensure the practical usability of emerging proposals
    b. Prepare guidance for CBS on the potential benefits of TIGGE-LAM and the ability to spread benefits beyond the producer nations

7. Review the use of EPS in the SWFDP
    a. Review the existing products for severe weather prediction, the benefits of a risk-based approach and the spreading of EPS products to less-developed countries
    b. Consider the requirements for additional products to support severe weather forecasting in different parts of the world with particular regard to upcoming SWFDPs
    c. Prepare a user-requirement document for THORPEX for R&D to support improved severe weather prediction from EPS, particularly in the tropics.
8. Developing Guidance for forecasters on the use of EPS
9. Review of verification at Lead-Centre.
10. Review upodates required to the Manual of GDPFS.
11. Close

(Initially submitted by Ken 20 Mar 2008, revised by Peter 25 Apr 2008, updated at ICT, Oct 2008)

ANNEX TO PARAGRAPH 7.16

Cooperation with CAS/THORPEX

Ken Mylne (Met Office, UK)

1. GIFS-TIGGE WG

1.1 THORPEX is a 10-year international research and development programme to accelerate improvements in the accuracy of 1-day to 2-week high impact weather forecasts for the benefit of society, the economy and the environment. THORPEX research topics include: global-to-regional influences on the evolution and predictability of weather systems: global observing system design and demonstration; targeting and assimilation of observations; societal, economic and environmental benefits of improved forecasts. THORPEX is organized under several Working Groups (WG) leading aspects of the programme. Further details of THORPEX are available at http://www.wmo.ch/pages/prog/arep/thorpex/index_en.html

1.2 One of the key themes of THORPEX is the TIGGE (THORPEX Interactive Grand Global Ensemble) project. TIGGE is a research project aimed at assessing the benefits in the forecast of combining ensembles from different centres to form multi-model ensembles. In order to provide a large enough dataset to make statistically valid assessments, the TIGGE archive is accumulating ensemble forecasts from 10 centres over a period of several years. There are 3 designated TIGGE archive centres at ECMWF in Europe, NCAR in N. America and CMA in China. The first TIGGE data started to be archived in Jan 2006, so up to 2.5 years worth of data are now available for the first 3 ensembles to contribute – other systems have joined at intervals since. (For easy access to TIGGE data simply Google TIGGE which will give immediate access to all three archive centres.)

1.3 GIFS – One of the key aims of TIGGE is to lead to a new framework for a Global Interactive Forecast System (GIFS) to provide a shared forecast system for the benefit of all WMO members. Potential benefits are making available larger ensembles, with a more comprehensive range of perturbations, than any one nation can afford to run independently. To achieve this means taking TIGGE beyond the research project it currently is into an operational framework. The project is led by a joint WG, named the GIFS-TIGGE WG (co-chairs Philippe Bougeault, ECMWF and Zoltan Toth, NCEP), with the aim of ensuring that the work of TIGGE is steered towards the creation of GIFS. Ken Mylne as Chair of ET-EPS acts as an observer to the GIFS-TIGGE WG to try to ensure that the plans for GIFS meet the operational needs of WMO members.

1.4 NAEFS – A separate but related project to GIFS-TIGGE is the NAEFS (North American Ensemble Forecast System). This is a joint project between the Canadian Met Centre and NCEP (USA) to generate multi-model ensemble forecasts by combining bias-corrected outputs from their two EPSs. The Mexican Met Service also participates as a user. NAEFS can be seen as an operational equivalent of TIGGE using a subset of the ensembles, and provides a demonstration of what is possible in real-time operational multi-model ensemble prediction.

2. TIGGE Research Results

2.1 Some results from TIGGE-based research are now starting to be published in the literature. Both ECMWF and the UK Met Office have completed initial studies into the benefit of multi-model ensembles based on combining 3 ensembles, ECMWF EPS, the Met Office MOGREPS and the NCEP EPS.

2.2 Early results have mostly focused on standard medium-range diagnostic parameters such as the 500hPa Height, and indications are that the multi-model ensemble provides little benefit compared to the best-performing individual ensembles.

2.3 Some studies, notably at the UK Met Office, have started to look at the multi-model ensemble forecasts of surface weather parameters which are of more direct relevance to end-users, such as surface (2m) temperature. Early results show that for 2m temperature there is a significant benefit from combining the outputs of 3 ensembles compared to any individual ensemble. In terms of skill scores, this benefit may be equivalent to what can be achieved from several years worth of investment in improvements in NWP and EPS systems, and therefore has potentially high economic return on investment.

2.4 These results are still early in the process, and much more work is required to determine the benefits over a wider range of parameters, and to determine the optimum system for GIFS. For example, it is likely that there is a law of diminishing returns as more EPSs are added to the multi-model combination, but work is required to determine the benefit of adding more inputs versus the increased complexity of the system in an operational environment. Work on more parameters, and particularly those related to high-impact weather, is required before we can adequately assess the real benefits of multi-model EPS to WMO members in comparison to what can be obtained from single model ensembles.

3. GIFS plans

3.1 The GIFS plan is being developed by a sub-group of the GIFS-TIGGE WG. This plan was extensively reviewed at the WG meeting in Pretoria in March 2008. A report from this meeting is attached at Annex A. A revised version of the plan is being prepared by the sub-group, and it is hoped to provide a copy of this in time for the ICT meeting. A number of comments and suggestions have been proposed by Ken Mylne with the aim of ensuring that the plan is achievable and will meet the needs of WMO members.

3.2 A key part of the GIFS plan is based on what is termed TIGGE Phase 2. Under TIGGE Phase 1 ensemble data were archived in 3 central archive centres as explained in para 1.2 above. Data are made available to researchers with a 48h delay, making it unsuitable for operational use. Under TIGGE Phase 2 it is proposed that live forecasts should be made available directly from producing centres, with a common user interface which allows access to the data. There are several potential difficulties with this as a planned future operational system:

- Some operational centres which have commercial interests may restrict the data they are prepared to make available in operational timescales, or limit it to data deemed essential for the protection of life. WMO should not therefore assume that such data will be made freely available.
- The technical capability to make these data available in real time is likely to be expensive, and there is no funding so it relies on voluntary contributions from national funding sources.
- Archiving of data locally is also expensive; one option is to continue central archiving at the existing archive centres, but this separates the operational and archive data sources. It is not clear that funding will be available for on-going operational archiving in the long term.
- Development of the capability to obtain and exploit data from the producing centres is likely to require considerable technical expertise and hardware capability, which is likely to be beyond the resources of many of the less-developed NMHSs.

3.3 In light of the above concerns with TIGGE Phase 2, the position of the Chair ET-EPS has been that a good model for the development of GIFS should be the cascading approach developed and demonstrated in the SWFDP in southern Africa. In this way the technically demanding tasks are undertaken by the global and regional centres, and prepared products, along with appropriate guidance, are supplied to the NMHSs so that they can use them to serve the essential needs for warning of severe and high impact weather. Global centres thus retain control of their data for commercial purposes, but can make use of multi-model ensemble data by collaboration. The system can be supported in manageable structures, rather than a single global structure. Funding

may remain a problem, but may be more easily obtained through organizations such as the World Bank, or Voluntary Co-operation Programme to meet specific needs.

3.4 An early demonstration of TIGGE Phase 2 work is being run as part of the T-PARC experiment (THORPEX Pacific Asian Regional Campaign) which is a multi-national field campaign planned by the Asian and North American Regional Committees and their associated national science committees that address the shorter-range dynamics and forecast skill of one region (Eastern Asian and the western North Pacific) and its impact on the medium-range dynamics and forecast skill of downstream regions (eastern North Pacific, North America and perhaps stretching to Europe).

3.5 Under T-PARC there will be an exchange of tropical cyclone track data from different ensemble systems using a newly defined common data format (C-XML) designed for the purpose. This C-XML will enable the efficient combination of outputs from different ensemble systems to form multi-model ensemble products, and the T-PARC experiment should allow assessment of the improved skill of these multi-model products. This specific approach, focusing on a specific capability to predict tropical cyclone tracks, is a practical and contained example of how multi-model ensemble data can be exchanged and used efficiently.

4. TIGGE Metadata

4.1 Good Metadata, which provides effective documentation of what the data are and how they can be used, is vital to the success of any data archive such as TIGGE. In order to ensure that metadata for TIGGE meets the needs of operational centres, the ET-EPS was tasked with helping to draw up a specification for TIGGE metadata contents.

4.2 From a CBS perspective the main requirements were that the Metadata provides adequate information about the different ensembles in the archive, and about upgrades to these systems as they occur which must be kept up to date. To complement this, the original TIGGE plan specifies the list of parameters which are stored in the TIGGE archive, and the archive centres provide documentation on how to obtain the data.

4.3 The ET-EPS has drawn up a standard format for EPS producing centres to provide information on their EPS and to record upgrades as they occur. This documentation is provided in the form of an Excel spreadsheet which makes it accessible and easy to use and update for both producers and users. A finalized version of this spreadsheet was prepared and submitted to the GIFS-TIGGE WG following the meeting in Pretoria in March 2008. The contents of the spreadsheet are reproduced in Annex B.

4.4 WMO has a standard XML format for the presentation and exchange of Metadata. An Excel spreadsheet, while user-friendly for producers and users, does not meet this WMO standard. To make it compliant, the spreadsheet is provided within an XML framework developed at ECMWF which meets the WMO Metadata specifications.

5. TIGGE-LAM

5.1 There is now rapid development of LAM (Limited Area Model) EPS taking place in some parts of the world. Following the principal of TIGGE, there is interest in whether multi-model ensembles can provide increased skill also for LAM EPS. As with the GIFS plans, there is also the possibility that sharing of LAM ensembles can reduce the cost of producing large ensembles and could provide high-quality EPS forecasts to WMO members who do not run their own ensembles. To develop this idea and support research, the GIFS-TIGGE WG has supported the creation of a second group called the TIGGE-LAM WG. Ken Mylne (Chair ET-EPS) is a full member of the TIGGE-LAM WG representing the UK Met Office but also in a position to represent the interests of CBS.

5.2 One of the difficulties for TIGGE-LAM, unlike global TIGGE, is that the overlap of LAM EPS domains is very limited in most parts of the world. One exception is Europe where there are a number of EPS systems covering the whole of Europe, but in other regions there is currently limited scope. In Europe the Eumetnet SRNWP collaboration is running a project on Interoperability, and has plans for an ensemble project termed EurEPS, which together share many of the interests of TIGGE-LAM. However there is also anxiety to ensure that TIGGE-LAM retains a global interest and scope and is not dominated by the interests of Europe.

5.3 LAM EPS is generally focused on the short-range forecast, so there are additional practical difficulties for any operational setup in ensuring that forecast data can be exchanged on short-enough timescales to be useful.

5.4 TIGGE-LAM has produced a suggested list of output parameters to be made available for sharing. This is broadly based on the TIGGE list, but includes a number of additional variables most suitable for short-range forecasting from LAMs. TIGGE-LAM has agreed that outputs should be shared in GRIB-2.

5.5 A concern about the parameter list is that it is very comprehensive, and to make all variables available would be expensive in both computing and telecoms. With TIGGE-LAM currently at an early stage of development, it is unlikely that many users would use more than a very few of the variables on the list. The Chair of ET-EPS therefore proposed a small subset list of High Priority variables which could be provided as a minimum. These were chosen since they are the most commonly used and verified for short-range forecasting, and would allow an initial assessment of the value of TIGGE-LAM data for operational forecasting, with the emphasis on short-range. These high priority variables are:

- Mean sea level pressure
- 10m U-velocity
- 10m V-velocity
- Wind Gust
- Surface air temperature
- Surface air dew point temperature
- Total precipitation (liquid + frozen)
- Convective & large scale precipitation.

5.6 For global TIGGE there are 3 designated archive centres storing all ensemble outputs for research purposes (see para 1.2). For TIGGE-LAM there are no such designated centres and it is assumed that producing centres will archive data and make them available. However not all producing centres will have the resources to do this. The main TIGGE archive centres (ECMWF, NCAR and CMA) have agreed that they will provide an archive service for the High Priority list of variables only for TIGGE-LAM, and for their own regions only (ECMWF for Europe, NCAR for N. America and CMA for Asia).

5.7 In addition to the basic capability of sharing ensemble outputs to produce larger multi-model ensembles, there is also an interest from some countries in sharing initial and boundary conditions from global (or lower resolution LAM) ensembles to aid the construction of LAM EPS. For example, part of the perturbation for a LAM EPS can be created by taking initial and lateral boundary conditions from different sources. To allow this, TIGGE-LAM is asked to consider how to exchange fields for initial and boundary conditions, in common formats that all can use. This is technically difficult and there are widely differing views among LAM experts.

5.8 From a CBS perspective, TIGGE-LAM is at an early stage of development, and there remains considerable doubt about whether the practical difficulties can be overcome to offer a viable solution for short-range forecasting application. The nature of LAMs and their limited overlap and coverage also means that, compared to global EPS, there is relatively little scope for supporting

and helping the less developed WMO members. It is likely that the interests of CBS are better served by concentrating on the benefits which can be obtained from global GIFS-TIGGE in the next few years, while keeping a watch on TIGGE-LAM research for possible benefits which may be obtainable in the future.

6. Summary of Conclusions and Future Strategy

6.1 The ICT Meeting is invited to consider the following conclusions and make recommendations on the policy for future development.

6.2 Plans for development of GIFS need to be on a scale which is affordable and likely to gain the support of EPS producing centres and their funders. Support to less-developed WMO members is best provided through a cascading approach as developed under the SWFDP. From a CBS perspective this may be more likely to provide the required support to vulnerable WMO members than a system which makes large amounts of multi-model ensemble data available for members to use themselves.

6.3 In certain specific types of high-impact weather systems, exchange of limited information in dedicated simplified coding can be of great value. The new C-XML code for tropical cyclone tracks from ensemble forecasts is an excellent example. For the benefit of vulnerable WMO members, this coding needs to be backed up by systems which turn the information into products (eg charts) for cascading to least developed NMHSs.

6.4 Opportunities for operational benefits from TIGGE-LAM are very limited in the next few years by practical difficulties and lack of coverage in most parts of the world. Much further research is required to overcome these difficulties and demonstrate the benefits. It is recommended that CBS interest should focus on global EPS at the current time, while keeping a watch on research results to monitor progress and the future potential for LAM EPS.

Annex A – Report from GIFS-TIGGE WG Meeting in Pretoria

Report for CBS on the
Fifth Meeting of the THORPEX ICSC GIFS-TIGGE Working Group
Pretoria, South Africa, 11-13 March 2008
Ken Mylne, Chair ET-EPS

1. Background and Purpose of Attendance

1.1 An important part of the 10-year THORPEX programme to improve forecasts of severe weather on time-scales of 1-14 days is the creation of the TIGGE (THORPEX Interactive Grand Global Ensemble) archive in order to facilitate research on the benefits of multi-model ensembles. The overall vision of THORPEX is that the TIGGE concept should ultimately develop into an operational framework to form the basis of a new GIFS (Global Interactive Forecast System), which could potentially provide a forecast system for the world, bringing the benefits of the most advanced centres to the entire globe.

1.2 The work on TIGGE and GIFS is led by the GIFS-TIGGE Working Group, co-chaired by Philippe Bougeault (ECMWF) and Zoltan Toth (NCEP). This was the fifth formal meeting of the group. I am not a full member of the WG, but am invited to attend as an observer in my role as Chair of the Expert Team on EPS (Ensemble Prediction Systems). This was the second time I have attended a meeting of the GIFS-TIGGE WG.

1.3 From the early stages, the TIGGE project has been planned in two Phases. Phase I was intended to create an archive database of global ensemble forecasts from as many centres as possible, and to make this database available to the research community as a resource for research on the optimal forecast system. The database was to be archived at 3 archive centres (ECMWF in Europe, CMA in China and NCAR in the USA) in near-real time, and forecasts were to be made freely available 2 days after their creation date. Some forecasts could be made available in real-time for specific research purposes only, such as research on observation targeting which is another strand of the THORPEX programme. Under Phase II the concept was to create a distributed database whereby dedicated software would allow forecast data to be accessed directly from any of the producer centres in real-time for the creation of multi-model ensemble forecast products. This would potentially provide the basis for GIFS, and also ultimately remove the need for the global archive centres.

1.4 Progress of TIGGE under Phase I is fully documented elsewhere, and is not repeated here. It is sufficient to report that the TIGGE archive has been successfully created at all three archive centres with a large number of NWP centres contributing data. Research uptake of the data has been rather slow, but a few groups are starting to generate some interesting results, and some strong evidence for the benefits of multi-model ensembles is starting to emerge. Benefits are greatest when looking at surface weather parameters such as surface temperature rather than the standard fields used to assess medium-range forecasts such as 500hPa geopotential height. A number of new techniques have also been developed to aid diagnosis of high-impact weather from ensemble forecasts, and are starting to be applied to forecasts based on the TIGGE archive.

1.5 In March 2008 the project is successfully approaching the end of Phase I and is planning Phase II . A sub-group of the WG, led by Zoltan Toth, has drafted a plan for GIFS under Phase II entitled *High Impact Weather Forecasting for GEOSS: The Global Interactive Forecast System (GIFS)*. A major part of the purpose of the Pretoria meeting was to review the Phase II plans for GIFS.

1.6 Another strand of the TIGGE work which has been developed over the last 18 months is the concept of TIGGE-LAM. This proposes a similar development to TIGGE based on LAM (Limited Area Model) Ensembles. The scope for combined LAM multi-model ensembles is much more limited than for global models, because of the limited regions in which there are significant over-lapping domains. Nevertheless there is considerable scope within Europe where a number of LAM Ensemble domains do overlap, and there is the potential for Europe to act as a test-bed for the concept elsewhere in the world.

1.7 The purpose of my attendance at this WG meeting was to review the progress of the GIFS-TIGGE project on behalf of CBS, and to contribute to discussions to try to ensure that the plans for GIFS were suitable to meet the future needs of CBS and the user community. It was also important to consider the plans from an operational perspective to ensure that they were realistic and have a good prospect of delivering the benefits to the CBS community.

1.8 Another separate but related purpose of the visit was to review progress with the Southern Africa Severe Weather Forecast Demonstration Project (SWFDP). The SWFDP project, for which I am on the Steering Committee, has recently completed its first demonstration in southern Africa, led from the forecast office of the South African Weather Service which was also hosting this meeting. The meeting provided an opportunity to visit the forecast office and gain feedback from the forecasters prior to the SWFDP Steering Group meeting the following week in Geneva.

1.9 Bringing the two aims together, the cascading process used in the SWFDP to provide NWP and other data from global and regional centres to the least developed NMHSs for improvement of severe weather warnings may provide a practical and achievable model for the exploitation of the GIFS concept.

2. Progress with TIGGE Research
As noted above, I do not propose to provide a full review of progress here as it is already available in other reports and papers provided to the meeting. (Also due to a missed flight connection caused by bad weather, I missed the first day of the meeting which covered this review.)

3. TIGGE-LAM
3.1 Tiziana Paccagnella reported on the progress of the TIGGE-LAM WG.

3.2 The WG has proposed that a small number of weather parameters be defined as the key variables for most purposes, and has requested that these be archived at the main TIGGE archive centres. Two of the three TIGGE centres have to-date agreed to do this. In addition a number of centres have expressed interest in acting as regional archive centres for Phase II, suggesting that TIGGE-LAM may be able to move rapidly to a Phase II concept of a distributed archive.

3.3 A major issue for TIGGE-LAM is Interoperability, the ability to take outputs from different LAM ensembles in a common format for post-processing, and also to be able to run different LAMs from boundary conditions provided from different global centres.

3.4 An initial proposal from the TIGGE-LAM WG to provide boundary conditions from all global models in a common format based on pressure levels has been heavily criticised by LAM modellers due to the need for double interpolation to the pressure levels and then again to the LAM levels. On the other hand, several members of the GIFS-TIGGE WG expressed a preference for pressure levels, and it was suggested that errors in interpolation may even provide a useful extra source of ensemble perturbations.

3.5 There is a European project on Interoperability planned by Eumetnet and likely to be led by the UK Met Office which will address these issues. It was agreed that TIGGE-LAM should aim to integrate with this project to ensure consistency and avoid duplication of work. However there was concern that the Eumetnet project would deliver too late for the purposes of TIGGE-LAM, and it was therefore proposed that TIGGE-LAM should press ahead with a wider survey of the issue of boundary conditions.

4. SWFDP Experience
4.1 Eugene Poolman of South African Weather Service (SAWS) presented the experience of the SWFDP in southern Africa.

4.2 The cascading process for supplying global ensemble data (from ECMWF, NCEP and the UK Met Office), plus regional deterministic forecasts generated at SAWS, was very successful. Model data were accompanied by guidance generated by the SAWS forecast office.

4.3 Objective verification was very hard to obtain, due to lack of suitable observations in many of the receiving countries.

4.4 Subjective assessment was that the project had been very helpful and the receiving countries were very enthusiastic about the benefits. Although there were reports of missed events and of false alarms, there was a general view that the quality of warnings issued by the NMHSs had improved. Reports from end-users also reported a much improved confidence in the local forecasters, which in turn improved their confidence and therefore willingness to respond to warnings. There was some subjective evidence that the major flooding in Mozambique and Zimbabwe during the trial period had been well-handled and that this was in part due to the support of the SWFDP.

5. GIFS Plans

5.1 The original GIFS concept, which was outlined in the draft plans presented to the meeting, proposed a distributed archive of real-time forecasts which could be accessed by any centre through an interface which would allow the generation of multi-model ensemble products using data pulled from several producer centres in real-time. The plans also set out a timetable for the creation of such a system.

5.2 The plan recognised the complexity and cost (currently unfunded) of creating this system, and also proposed that an initial demonstration of the concept be based on multi-model ensemble forecasts of tropical cyclone tracks. A new XML-based format for exchange of TC track forecast data has been proposed and agreed to serve this purpose. It is planned that this concept for TCs will be fully tested during the T-PARC experiment.

5.3 I had a number of concerns about the plans as presented from a CBS point of view:

- The timetable was unrealistically optimistic considering the complexity of technical development required.
- The plans assumed complex and costly voluntary contributions from producer centres in setting up archives and distribution systems – it was not clear that these contributions were likely to be forthcoming.
- Little consideration was given to data-policy issues which would likely prevent some producer centres from making their data freely available.
- The concept puts in place a facility to allow end-users to pull multi-model ensemble forecasts from the distributed database and create products, but this still assumes technical and scientific know-how in the end-users to know what to create. I felt this was not a realistic way to support under-resourced NMHSs in least-developed countries in particular.
- Some proposals in the plans were based on questionable science, in particular ideas around ad-hoc production of probabilistic products to assess the risk from specific anticipated weather events.

5.4 During discussions it became clear that some of my concerns were shared by others, and there was a considerable revision of the thinking during the meeting. In particular:

- There was very little support from any producer centres for the costly development of the interface required to provide access to data from the distributed database.
- It was realised that there is a difference between an archive centre – storing data for long-term research purposes – and a real-time distribution centre. It was suggested that the two could be separated and that the existing three archive centres may be asked to continue to provide that function. The reps of the archive centres present at the meeting did not seem to have any objection to this, but it is not certain that they were in a position to make any commitments.
- On data-policy it was suggested that each centre would contribute according to their preference, but it was not clear how many centres would contribute data freely.
- Some major centres expressed a strong view that they would not be able to support Phase II as proposed because of cost and technical issues.
    - It was agreed that a survey of producer centres to gain their official views on contributions to Phase II would be useful.
- The science suggests that most of the benefit of multi-model ensembles can be gained from using output from 2-3 centres, and that investment in infrastructure to create products from around 10 centres could be wasteful.
- I challenged the ideas of generating ad-hoc probabilistic products for specific events on several grounds:
    - It is not practicable to set up model systems for specific events or systems in regions where they have not been extensively tested; model problems are likely to occur and performance will be unknown.

    - Ensemble forecasts are inherently probabilistic, but probabilistic performance is unknown and cannot be tested or estimated for one-off events – this goes against the whole concept of proper testing of probabilistic forecasts which requires large samples of forecasts.
    - From an operational point of view, the time when forecasters have least capability to generate new or specific products is when they are under pressure of time and extra work caused by a threat of a high-impact weather event.
- My concerns were largely supported by the meeting.
- It was proposed that the SWFDP approach to cascading information through regional centres (DCPCs – Data Collection and Product Centres in the terminology of the new WMO WIN system) to support less-developed NMHSs was a more practical way to implement the GIFS. This has the advantage of keeping each project on a manageable scale, including guidance rather than relying on the least developed services to generate their own products. This proposal was not formally agreed by the meeting, but was not heavily challenged either.

5.5 It was proposed that the initial focus on demonstrating the Phase II concept just with TCs was too narrow and restrictive, and that an additional product type should be considered. Precipitation was proposed.

5.6 It was recognised that some aspects of the plan need some more specialised consideration. It was proposed that Focus Groups with Experts should be created to consider:

- Distributed archiving.
- Toolbox – to define proper procedures for joint development and sharing of Phase II tools.
- Web interfacing.

5.7 The GIFS planning group were tasked with revising their plans in light of the discussion. Their report will then be submitted to the ICSC, and with their approval to CBS.

6. User Workshop

6.1 It is planned to hold a user workshop in conjunction with the next THORPEX Scientific meeting. The date is not yet fixed but it is expected to be in California in March 2009. I agreed to join the organising committee to ensure the CBS Users perspective is represented.

6.2 It was suggested that I should submit a paper on the role of SWFDP in meeting the needs of GIFS.

7. Actions

Two actions for Ken Mylne from the meeting:

i) Do one more iteration of the content of the TIGGE Metadata proposal, taking account of feedback. *Note for DPFS-ICT – Action completed.*

ii) Participate in the organising committee for the User Workshop to be held in conjunction with the next THORPEX Science Meeting. *Note for DPFS-ICT – Action in progress.*

Annex B – TIGGE Information Spreadsheet, Version 4 as updated in April 2008.

The TIGGE Information Spreadsheet, which is incorporated within TIGGE Metadata, is set out below. The first sheet provides some guidelines about the contents and updating instructions. Subsequent sheets provide the data, and the example given below includes some sample entries based on the ECMWF EPS.

Sheet 1: Information about the Ensemble Documentation

WMO Standard Documentation for Ensemble Prediction Systems (EPS)

Name of Producing Centre:

This spreadsheet provides a standard format for Documentation describing Ensemble Prediction Systems (EPS). It has been designed to meet the needs of potential users of ensemble forecasts and also the needs of the users of the TIGGE (THORPEX Integrated Grand Global Ensemble) archives.It will be incorporated within WMO standard Metadata for archives of ensemble forecast data

A copy of this doumentation should be made available by each EPS producing centre and updated immediately as system upgrades are implemented. Copies of this documentation should also be provided to the TIGGE archive centres.

Each Worksheet of the spreadsheet provides the documentation for a different version of the ensemble; the different columns in the worksheet represent different models used within the ensemble where required. Whenever an ensemble producing centre updates its system it is therefore responsible for providing a new worksheet for the spreadsheet.

Multi-model ensembles: where an ensemble includes more than one model, or significantly different versions of a model, a separate column must be completed for each model.

Where a producing centre provides a control forecast at a higher-resolution than the ensemble model, this should be described in a separate sheet of the table; a control forecast at the ensemble resolution should be included in the ensemble sheet. Where a separate sheet is used for a high-resolution control, the tab label must clearly indicate this.

Responsibility for updating the Documentation lies with the producing centres; updates should be supplied to the TIGGE data centres at NCAR, ECMWF and CMA.

This spreadsheet is designed by the WMO CBS Expert Team on Ensemble Prediction Systems (ET EPS) in collaboration with the TIGGE Working Group.The ET EPS can be contacted via WMO Headquarters in Geneva.

Additional lines may be added to the table in future if required. Users are requested to contact the ET-EPS with any new requirements, so that tables at different centres can be kept consistent.

The Master version of the Metadata spreadsheet will be available from the WMO Secretariat, from the ET-EPS contact, currently Peter Chen (Pchen@wmo.int)

Instructions for updating:

To add a new EPS version:

1. Create a new Worksheet as a copy of the Template sheet (Right-click on Template tab, select Move or copy…, Tick copy and select location relevant to other sheets, Click OK). Alternatively, copy the previous version and change only the parts which need updating.
2. Place new worksheet at left end nearest this Info page. Worksheets should be ordered from the current version at the left to the oldest available version at the right next to the Template sheet.
3. Give the Worksheet tab an appropriate name (eg Version 1.1)
4. Complete or update the information in the Worksheet.

Sheet 2: Main information page, with examples taken for ECMWF EPS

Ensemble Name: ECMWF EPS	***Sample answers for ECMWF***
Ensemble Characteristics	**Different Models (or model configurations) used in the Ensemble in different columns**
1. Ensemble Version	**Model 1**
Version Identifier Code	
Date of first implementation of this version	
Please provide a short description of the Ensemble Prediction System	
Research or Operational? If not operational, are there any plans to become so?	
Global or Regional EPS? (See section 7 for items specific to regional EPS)	*Global*
Data time of first forecast run	
Date of last forecast with this version (if applicable)	
Data time of last forecast run (if applicable)	
Is there a higher-resolution control forecast available? (If yes, this should be described in a separate sheet of this spreadsheet.)	*Y/N?*
Brief summary of main changes from previous version (keywords).	*N/A - First version listed*
2. Configuration of the EPS	
Horizontal resolution of the model. (Where variable resolution is used, please describe in full.)	*TL399*
Horizontal configuration and resolution of the output grid	*??*
Number of model levels	*62*
Type of model levels (eg sigma)	
Forecast length and forecast step interval	*T+0h to T+240h at 6h*
Runs per day (Times in UTC)	*2 (00, 12)*
Is there an unperturbed control forecast included? (Y/N)	*Y*
Number of perturbed ensemble members (excluding control)	*50*
Integration time step	*30 min*
Top of model - **model section**	*~5hPa*
Is model coupled to an ocean	*No*

model?	
If yes, please describe ocean model briefly including any ensemble perturbations applied	
Additional comments	

3. Initial conditions and Perturbations

Data assimilation method for control analysis	*4D-Var 12h window*
Resolution of model used to generate control analysis	
Control variables used in data assimilation	
Ensemble initial perturbation strategy	*Singular Vectors (Total energy norm)*
Optimisation time in forecast (if applicable)	*T+48*
Horizontal resolution of perturbations (if different from model resolution)	*TL42*
Initial perturbed area	*Extra tropical (<30S, >30N) + up to 6 tropical areas*
Are perturbations to observations employed? (Y/N)	
Perturbations added to control analysis or derived directly from ensemble analysis	*Added*
Perturbations in +/- pairs? (Y/N)	*Y*
Additional comments	

4. Model Uncertainty Perturbations

Is model physics perturbed? If yes, briefly describe method(s).	*Y. Stochastic perturbation of physics tendency by factor in range [0.5,1.5]*
Do all ensemble members use exactly the same model version, or are, for example, different parameterization schemes used? Please describe any differences.	*Same*
Is model dynamics perturbed? If yes, briefly describe method(s).	*N*
Are the above model uncertainty perturbations applied to the control forecast?	*N*
Additional comments	

5. Surface Boundary Perturbations

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

Perturbations to soil moisture? If yes, briefly describe method(s).	*N*
Perturbations to surface wind stress or roughness? If yes, briefly describe method(s).	*N*
Any other surface perturbations? If yes, briefly describe method(s).	*N*
Are the above surface perturbations applied to the control forecast?	*N/A*
Additional comments	

6. Other details of model

Description of model grids.	
List of model levels in appropriate coordinates	
What kind of Large scale dynamics is in use (e.g. gridpoint semi-Lagrangian)?	*Spectral semi-lagrangian*
What kind of boundary layer parametrization is in use?	*Moist EDMF with Klein/Hartmann stratus/shallow convection criteria*
What kind of convection parametrization is in use?	*Tiedtke 89, Bechtold et al 2004 (QJ) which improved the triggering*
What kind of large-scale precipitation scheme is in use?	
What Cloud scheme is in use?	*Tiedtke 93 prognostic cloud fraction*
What kind of land-surface scheme is in use?	
How is radiation parametrized?	
Other relevant details?	

7. Regional Ensemble specifics

Regional domain descriptor (lat/long of boundaries)	
Normal source of boundary conditions	
Are boundary conditions perturbed?	
Specification of boundary conditions required.	
Are boundary condition requirements compatible with any other global models or standards? If so, please describe	

Are initial conditions downscaled from a global analysis or is a regional analysis used?	
Is regional ensemble a downscaling of global ensemble perturbations, or are specific regional perturbations calculated?	
Additional comments	

8. Further Information

Scientific contact	
URLs for Scientific documentation	
Technical contact point	
URLs for Technical documentation	
Other contact points	
List key reference papers for model	
List key reference papers for EPS	*Molteni,F., Buizza,R., Palmer,T.N. and Petroliagis,T., 1996: The ECMWF Ensemble Prediction System: Methodology and Validation Q.J.R Meteorol.Soc. (1996) Vol 122, pp 73-119*
URLs for system documentation	http://www.ecmwf.int/products/forecasts/guide/index.html
Data policy of originating centre for usage of data in TIGGE	*Users of the ECMWF data sets are requested to reference the source of the data in any publication, e.g. "ECMWF ERA-40 data used in this study/project have been provided by ECMWF/have been obtained from the ECMWF Data Server".*

9. TIGGE Specific Information

Version Identifier Code	
Date of first forecast in TIGGE	
Data time of first forecast run in TIGGE	
Date of last forecast in TIGGE	
Data time of last forecast run in TIGGE	
Is there a higher-resolution control forecast included in TIGGE? If so give tab name	*Y/N?*

where it is described.

Brief summary of main changes *N/A - First version in TIGGE*
from previous version
(keywords).

ANNEX TO PARAGRAPH 8.1.7

Proposed Amendment to the Manual on the GDPFS related to Emergency Response Activities

Proposed amendment to the Manual on the GDPFS (WMO-No. 485) to CBS-XIV (March 2009)

A. Volume I, Part II, Appendix II-7, sub-section 5, last paragraph, regarding faxing and e-mail, replace entire paragraph with:

"The RSMCs will distribute their standard products to the NMHS Operational Contact Points by email and retrieval from designated Web pages. Standard products in the ITU-T T4 format suitable for both group 3 facsimile machines and transmission on parts of the GTS will be maintained by exception and only if requested by the NMHS Operational Contact Point. The RSMC may also make use of other appropriate technologies."

B. Volume I, Part I, Appendix I-1 (paragraph 3), add "RSMC Offenbach" to list of RSMCs with Activity Specialization in Atmospheric Transport Modelling / backtracking, as follows:

3. The RSMCs with activity specialization are the following:

RSMC Nadi – Tropical Cyclone Centre

RSMC New Delhi – Tropical Cyclone Centre

RSMC Miami – Hurricane Centre

RSMC Tokyo – Typhoon Centre

RSMC La Réunion – Tropical Cyclone Centre

RSMC Honolulu – Hurricane Centre

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

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

RSMC Beijing

RSMC Exeter

RSMC Melbourne

RSMC Montreal

RSMC Obninsk

RSMC Offenbach (backtracking only)

RSMC Tokyo

RSMC Toulouse

RSMC Washington

C. Volume I, Part II, Appendix II-7, modifications to the IAEA Request Form, shown in tracked changes, within Appendix II-7 (see following images of the form):

Environmental Emergency Response
Request for WMO RSMC Support by IAEA

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

Date/Time of Request: yyyy-MM-dd/HH:mm(UTC)

STATUS: ☐ **EMERGENCY** ☐ **EXERCISE**

REQUESTED RSMCS : (indicate the lead RSMCs by a checkmark below)

☐ EXETER ☐ TOULOUSE ☐ MELBOURNE ☐ MONTREAL ☐ WASHINGTON

☐ BEIJING ☐ TOKYO ☐ OBNINSK ☒ RTH Offenbach

SENDERS NAME :**INTERNATIONAL ATOMIC ENERGY AGENCY**

COMMUNICATION DETAILS: Tel .: +43 1 2600 22023 use to confirm receipt of request

Fax: +43 1 26007 29309 use to confirm receipt of request

Email: jec3@iaea.org use to confirm receipt of request

Deleted: eru

NAME OF RELEASE SITE AND COUNTRY (facility and place

GEOGRAPHICAL LOCATION OF RELEASE: . decimal degrees ☐ N ☐ S
(MUST BE COMPLETED) . decimal degrees ☐ E ☐ W

DECLARED EMERGENCY CLASS:

☐ NONE ☐ other, specify:

ACTION REQUIRED :

☐ NONE

☐ GO ON STANDBY (request for products or for assistance on weather conditions is to be expected)

☐ LEAD RSMCs ONLY: GENERATE PRODUCTS* AND SEND TO IAEA ONLY

Deleted: STANDARD

☐ ALL RSMCs: GENERATE PRODUCTS* AND DISTRIBUTE WITHIN THEIR REGION(S)

Deleted: STANDARD

Deleted: FOR THE IAEA

Deleted: REGIONAL

Deleted: ION

☐ OTHER ACTION :

* Appendix II-7, Manual on the Global Data Processing and Forecasting System, WMO No. 485

Deleted: 2006

Deleted: 6

(essential accident information for model simulation - if not available, model will execute with standard default values)

RELEASE CHARACTERISTICS:

START OF RELEASE: Date/Time: - - / : (UTC)

DURATION: (hours) or END OF RELEASE: Date/Time: - - / : (UTC)

RADIONUCLIDE SPECIES:

TOTAL RELEASE QUANTITY: (Becquerel)

OR POLLUTANT RELEASE RATE: (Becquerel/hour)

EFFECTIVE HEIGHT OF RELEASE: ☐ surface or

☐ release height: base: (m) top: (m)

Deleted: ☐ stack height: (m), or¶

Deleted: aloft

Deleted: top

Deleted:

Deleted: base

(helpful information for improved simulation)

SITE ELEVATION: (m)

LOCAL METEOROLOGICAL CONDITIONS NEAR ACCIDENT:

(wind speed and direction/weather/cloudiness/precipitation, etc.)

OTHER INFORMATION:

(nature of accident, cause, fire explosion, controlled release, foreseeable development, normal activity, projected conditions, etc)

(to be completed by RSMC)

DATE/TIME OF RECEIPT OF REQUEST: ..... (UTC)

FOR LEAD RSMC(s) ONLY
DATE/TIME OF RETURN CONFIRMATION OF RECEIPT: ..... (UTC)

Note: All times in UTC

Deleted: 2006

Deleted: 6

ANNEX TO PARAGRAPH 8.1.8

NUCLEAR EMERGENCY RESPONSE ACTIVITIES
Report of the Chairman of the Nuclear ERA-CG

Submitted by René Servranckx (Canada)

1. BACKGROUND

1.1 The programme of "Regional Specialized Meteorological Centres with Activity Specialization in the Provision of Atmospheric Transport Model (ATM) Products for Environmental Emergency Response", as it was first named, has been in operation for over 14 years. The first meeting on Users Requirements was held in Montréal in September 1993.

1.2 The programme, known as the ''Emergency Response Activities'', is today composed of the nuclear ERA Coordination Group (nERA-CG) and the Expert Team for non-nuclear ERA.

1.3 The first meeting of the Expert Team on Modelling of Atmospheric Transport for Non-Nuclear Emergency Response Activities was held in Melbourne, Australia in September 2005. The second meeting took place in Montreal, Canada in June 2007.

1.4 The last 2 meetings of the nuclear ERA Coordination Group took place in Vienna, Austria in May 2006 and in Melbourne, Australia in May 2008.

2. INTRODUCTION

2.1 The main purpose of the Nuclear Emergency Response Activities (nERA) programme is to assist NMHSs in their respective national organizations, and as well relevant international organizations to respond effectively to nuclear environmental emergencies that imply large-scale trans-boundary dispersion of airborne hazardous substances, caused by major nuclear facility accidents or incidents.

2.2 Today, there are eight designated RSMCs (Beijing, Exeter, Melbourne, Montréal, Obninsk, Tokyo, Toulouse and Washington) that are operationally prepared to provide specialized atmospheric dispersion model products to authorized requests. In addition, the RTH Offenbach provides the telecommunications link for notification and information by the International Atomic Energy Agency (IAEA) Incident and Emergency Centre (IEC) to the WMO Members.

2.3 While the primary focus of these RSMCs has been to provide global coverage specialized products to support nuclear emergency response, they have from time to time also provided support for other kinds of emergency response incidents based on atmospheric transport modelling technologies, e.g., smoke dispersion in wild-land fires, volcanic ash and gases in the atmosphere, airborne diseases, etc.

2.4 The collective operational capability of these RSMCs and the RTH under the present arrangements and procedures is quite substantial and requires continuing attention to ensure that preparedness and response are up to standards and expectations, in global coverage.

2.5 The nuclear ERA Coordination Group is a standing expert group including representatives of each of the RSMCs, RTH Offenbach, the International Atomic Energy Agency (IAEA), the Comprehensive Test Ban Treaty Organization (CTBTO), and the International Civil Aviation Organization (ICAO). The nERA-CG last met at the Bureau of Meteorology in Melbourne Australia, 5-8 May 2008. The report of the meeting is available at

http://www.wmo.int/pages/prog/www/CBS-Reports/DPFSERA-index.html .

3. SUMMARY OF ACTIVITIES

IMPROVED PRODUCT DISTRIBUTION / ACCESS METHODS

3.1 Advances in numerical modeling, numerical weather prediction and atmospheric transport models, technologies for product exchange, access and distribution continue to be realized. They contribute to a continual improvement of these specialized services.

3.2 All RMSCs use web-based technologies to exchange information and products. Significant progress has been made in the installation of the common-look-and-feel mirrored but independent password protected web pages, as well as the transfer of standard image products by RSMCs. The key advantage is that the RSMCs web sites have identical content while being completely independent from one another. Therefore, even when one server is down, congruency allows accessibility to the RSMC products. Some remaining steps need to be completed at a few RSMCs, where there may be technical problems or local security policy impediments to overcome.

3.3 The mirrored Web pages face serious limitations if additional products were to be made accessible or if a long duration event were to occur, requiring multiple simulations following the default initial response scenario. Work has begun to supplement the current mirrored Web pages of standard products with mirrored Web page of “meta-data”, which is essentially a Web page of product descriptions that point to a server and files in a directory on that server. The mirrored meta-data page could accommodate, for example, links to GRIB files, non-standard products or historical products.

3.4 Faxing remains the official product transmission method of RSMC products. This continues to present a number of important challenges. Maintaining updated fax numbers and contacts points is difficult and time consuming. Regular fax tests by the RSMCs show a significant rate of delivery failure. The nERA-CG agreed at its last meeting that e-mail distribution and retrieval from Web pages of the standard products is preferred, and that fax distribution could be maintained by exception only (if requested by the NMHS Operational Contact Point). Draft text for a proposed amendment to the Manual on the GDPFS was adopted at the meeting An implementation plan for this will be developed by the third quarter of 2009.

3.5 In addition to supporting relevant international organizations, one of the fundamental roles of the RSMCs remains the provision of support and specialized products to Members that do not produce or do not have access to the products otherwise. Basic RSMC products must continue to meet the needs of NMHSs with limited telecommunications or Internet capabilities.

RSMC PRODUCTS AND SERVICES FOR NUCLEAR EMERGENCIES

3.6 The RSMC “standard products” are defined for production in the initial response to an emergency, when most likely there is no information on magnitude of the release of radioactivity (i.e. the source term). Products beyond the standard set could be requested. RSMCs have developed over the years a broad range of capabilities with respect to atmospheric transport modelling for nuclear accidents and radiological emergencies. From a consideration of the types of nuclear events that could occur, the natural question is whether there is a need to formally extend the current scope of RSMC services, beyond those specified in the Manual on the GDPFS, for example, time-dependant releases, longer forecast periods, etc.

3.7 While much could be developed, priorities have to be set to ensure the limited resources are put to produce the most effective improvements. There is also a need to improve our understanding of the end-users' needs for the services to be provided by NMHSs and RSMCs. It also was noted that the last WMO "users workshop" was held in 1993 and that another such workshop could be useful and timely to demonstrate the capabilities that have been developed, to engage users for improving the understanding of their needs, and to guide the future direction of this RSMC Activity Specialization.

3.8 The relationship of the WMO and the designated Centres with the IAEA is solid and also strongly recognized by other relevant International Organizations. Exercises and regular testing are key elements to ensure operational readiness. The current organized and structured operational emergency meteorological support service with global coverage is an important programme achievement.

3.9 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, some RSMCs exercise on a monthly basis as well. Starting in 2009, every quarterly test will include the GTS message distribution and distribution of products by the lead RSMCs to the NMHSs in their Regions of responsibility. A calendar of quarterly tests has been established for 2009 and 2010. This will allow RSMCs to inform in advance the NMHSs of their respective Regions. In parallel, the IAEA will inform their Contact Points.

3.10 A major international exercise called ConvEx-3 (Convention Exercise) took place over a continuous 46-hour period in July 2008, simulating a severe accident scenario at the Laguna Verde Nuclear Power Plant in Mexico. The exercise used actual weather in real-time. Requests were made by the IAEA for RSMC support and distribution of products. The evaluation of the exercise and recommendations will be made in a report currently under preparation.

ENSEMBLE ATMOSPHERIC TRANSPORT MODELLING

3.11 No statement of requirement has been expressed by IAEA nor NMHSs for emergency response products based on the ensemble method but the members of the nERA-CG are exploring the use and various tools for combining and comparing multiple model outputs for environmental emergency response purposes, including through possible collaboration with the EC-JRC (Ispra) ENSEMBLE project. There is also work being conducted on producing and exchanging GRIB files between the RSMCs as another possible step towards producing ensemble products.

REVIEW OF REQUIREMENTS FOR RSMC PRODUCTS / SERVICES

3.12 The IAEA's review of the user requirements was outsourced to an expert group of the IAEA's "Action Plan for Strengthening the International Preparedness and Response System for Nuclear and Radiological Emergencies". The expert group (Working Group on Assistance, Expert Group "B.5") had for objectives to define updated standard meteorological products and to enhance arrangements for providing associated assistance. The work finished with the meeting of IAEA's National Competent Authorities in July 2007. Based in part on this work and some input by staff of the Incident and Emergency Centre (IEC), it was decided to start a process with the RSMCs for identifying improved users products. The following have been suggested: ''plume arrival time'', uncertainty in dispersion calculations and inclusion of precipitation data in deposition calculations. As a first step, a few RSMCs have been identified to develop an experimental ''plume time of arrival'' prediction over a 10-day period.

3.13 It must be 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. There is a clear need to improve and promote contacts, coordination and liaison between NMHSs, who receive RSMC products, and their counterpart National Competent Authorities for nuclear emergencies.

COOPERATION BETWEEN CTBTO AND WMO

3.14 The successful CTBTO-WMO collaboration during the last decade and a series of coordinated numerical experiments with several WMO Centres (RSMCs and other WMO Centres) over the past few years, including a full scale exercise in December 2007, have lead to the implementation of a provisional backtracking operational system on 1 September 2008. This is a truly remarkable achievement that follows the approval by CBS-ext.(06) to include formal arrangement between CTBO and WMO in the *Manual on the GDPFS* (WMO-No. 485).

3.15 The arrangement allows the CTBTO Provisional Technical Secretariat (PTS) to request and obtain, semi-automated and in near-real-time, atmospheric transport modelling (ATM) results from WMO RSMCs in case of Treaty-relevant detections at radionuclide (RN) sampling stations of the International Monitoring System (IMS) to supplement its own computations. Nine WMO Centres (7 RSMCs: Beijing, Exeter, Melbourne, Montreal, Obninsk, Tokyo, Toulouse; and 2 NMCs: Offenbach, Vienna) have committed to participate. Others centres are expected to join as well. The response system helps corroborate the confidence in the backtracking calculations of the PTS and benefits both sides regarding constant feedback and the evaluation of the backtracking systems and methods. An announced test will be conducted once per year while an unannounced but more limited-scope test will be done on a quarterly basis.

3.16 The Secretary-General WMO received a correspondence from Germany wherein it was indicated that Germany is prepared to seek an expanded WMO Designation of its RSMC Offenbach to include backtracking, for RSMC Offenbach. It is therefore anticipated that Germany will propose to CBS-XIV (March 2009), with suitable supporting documentation (see Manual on the GDPFS (WMO-No. 485). Draft text for a proposed amendment to the Manual on the GDPFS, to add the designation of RSMC Offenbach for backtracking, in addition to its role as RTH Offenbach has been adopted at the meeting. .

3.17 The backtracking modeling capacities of the RSMCs can be used for other, non-CTBTO applications and are available to all WMO Members upon request.

COOPERATION BETWEEN ICAO AND WMO

3.18 ICAO has been trying for many years to identify a single contact point to distribute IAEA IEC's notifications of a nuclear accident or radiological emergency to air traffic control operations worldwide. The challenge is to find a way to meet that requirement while at the time respecting existing arrangements between the IAEA, WMO and National Competent Authorities. A solution that fulfills both is being tabled for discussion at the next meeting of ICAO's International Airways Volcano Watch Operations Group (IAVWOPSG) that will be held in Paris from 15 to 19 September 2008 (See WP/10 on http://www.icao.int/anb/iavwopsg/meetings/iavwopsg4/wp/). It is expected that it will resolve this long standing issue.

DOCUMENTATION / ERA WEB PAGE

3.19 In addition to maintaining the operational readiness of the RSMC / RTH Centres, it is important that potential users be aware of the services and arrangements. The WMO Technical Note No. 778 (Documentation on RSMC support for EER targeted for meteorologists at NMHSs) is the technical reference to the ERA programme. It contains a great deal of scientific and technical information related to the Emergency Response Activities programme, including the current relevant regulatory texts of the Manual on the GDPFS. CBS-Ext.(06) noted that the document required updating. A review / redesign / updating of the document as of the WMO ERA web pages was undertaken starting in October 2006 and completed in March 2008 by the nERA-CG members from Australia, Canada and the WMO Secretariat. It is important for this documentation to continue to serve as the definitive information reference on the ERA for all Members. While there are technical documents that indicate the arrangements, promoting the ERA programme to the NMHSs through the Regional Associations is worth further consideration by the DPFS ICT.

OTHER BUSINESS

3.20 A need for updating the document "Meteorological and Hydrological Aspects of Siting and Operations of Nuclear Power Plants" (WMO TD-No. 170) was identified by Congress who noted that this is a matter that would require the cooperation with the International Atomic Energy Agency (IAEA), and requested the Secretary-General to correspond with the IAEA. Congress also noted that several Technical Commissions could be involved in the updating of this technical document (from General Summary, Cg-XV, paragraph 3.1.3.24). The nERA-CG was informed that exchanges of correspondence have started between WMO and IAEA on this matter and agreed that it would provide input to the WMO proposed review in the area of nuclear emergency preparedness and response.

PROPOSED CHANGE TO THE FORM "ENVIRONMENTAL EMERGENCY RESPONSE REQUEST FOR WMO RSMC SUPPORT BY IAEA''

3.21 Proposed changes recommended for inclusion in the WMO *Manual on the GDPFS* (WMO-No. 485) regarding this request form has been accepted at this meeting.

4. FUTURE WORK

4.1 At the last meeting of the nERA-CG, the group reviewed the list of actions from the Vienna May 2006 meeting and proposed new ones. These are presented in Annex III of the Melbourne May 2008 meeting report (http://www.wmo.int/pages/prog/www/CBS-Reports/DPFSERA-index.html). They are formulated to ensure that the current operational procedures and responses capabilities are maintained and tested regularly.

4.2 In light of the progress achieved over the recent years and considering the importance of maintaining the real-time response capabilities of the nERA programme and the RSMCs, the Coordination Group suggested adjustments to the Terms of Reference to beproposed to CBS-XIV (March 2009)

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ANNEX TO PARAGRAPH 8.2.7

Non-NUCLEAR EMERGENCY RESPONSE ACTIVITIES
Report of the Chair of the ET non-Nuclear ERA

(Submitted by Jim Fraser & Chris Ryan (Australia))

The Chair of the CBS DPFS Expert Team on Atmospheric Transport Modelling for non-Nuclear Emergency Response Activities (ET-nNERA) reports on the meeting of the expert team (June 2007), and progress made with respect to extension of the ERA program to include non-nuclear environmental response.

1. BACKGROUND

1.1 The goal of the Emergency Response Activities (ERA) programme is to assist NMHSs, with other relevant agencies of Member countries and in cooperation with relevant international organizations, to respond effectively to environmental emergencies. Until 2005 the programme mainly focused on emergencies caused by nuclear accidents and radiological incidents. Eight designated RSMCs (Beijing, Exeter, Melbourne, Montréal, Obninsk, Tokyo, Toulouse and Washington) are prepared to provide atmospheric dispersion model products on request, and RTH Offenbach provides the communications link for notification by the International Atomic Energy Agency (IAEA) Incident and Emergency Centre (IEC) to the RSMCs.

1.2 It being widely recognized that the tools used to model the dispersion of nuclear contaminants in the atmosphere can also be applied to other hazardous materials, the ERA programme was directed to expand its activities into non-nuclear environmental emergencies. A WMO survey of NMHSs carried out in mid-2004 helped in developing an understanding of their requirements and capabilities in the programme. The results of the survey were considered at a WMO Workshop on Development of Scope and Capabilities of the ERA in December 2004. The workshop recommended that priority should be given to expanding the programme to atmospheric transport and dispersion modelling to support response to chemical accidents and smoke from large wild-land fires.

1.3 At CBS-XIII (2005) a new Expert Team on Modelling of Atmospheric Transport for non-Nuclear Emergency Response Activities (ET-nNERA) was established. The team membership and Terms of Reference (Annex 1) were adopted by the CBS Management Group in April 2005. The ET complements the nuclear ERA Coordination Group (nERA-CG) and shares many of its members. The Expert Team met in September 2005 at Melbourne and in June 2007 at Montreal. Reports of those meetings can be found at
http://www.wmo.int/pages/prog/www/CBS-Reports/DPFSERA-index.html

1.4 CBS-Ext.(06, November 2006) adopted all the key results of the Expert Team, which were reported through the Implementation Coordination Team for the OPAG on DPFS, including:

- Chemical incidents are predominantly of the localized and short-lived nature where very rapid emergency response is essential; therefore concentrate efforts on developing the necessary capabilities at the NMHSs;

- A higher priority would be the trans-boundary transport of airborne hazards such as in the case of smoke from large fires where a regionalized approach would be appropriate, i.e., through a designated RSMC(s) to provide emergency support to and build capacity at NMHSs; and similarly, for large trans-boundary dust or sand storms;

• Cooperation with International Organizations is important, e.g. with the IAEA on nuclear aspects, with ICAO on the airborne volcanic ash advisory service, with the UNEP/UN Office for the Coordination of Humanitarian Affairs (UNEP/UN-OCHA) Joint Unit, and with World Health Organization's (WHO) International Programme on Chemical Safety (IPCS), in particular operational components that could be linked to the developing operational framework;

• Expanding the official services provided by the RSMCs on Atmospheric Transport Modelling to include backtracking, and that a backtracking experiment is to be planned and undertaken in 2007.

1.5 Congress (Cg-XV, May 2007) continued to support the extension of the ERA programme to include non-nuclear aspects, including airborne and waterborne hazards.

2 PROPOSED CHANGES TO THE TERMS OF REFERENCE

2.1 At its meeting in June 2007 at Montreal the Expert Team reviewed its Terms of Reference. Considering the progress made since CBS-XIII (Feb. 2005), and recognising that the team's work had moved from the initialising and exploration stage to ongoing activities, some modifications were proposed to the Terms of Reference for consideration at the next Session of CBS..

3 SCIENTIFIC AND TECHNICAL DEVELOPMENTS FOR ERA

Backtracking Demonstration Experiment

3.1 A major outcome of the Expert Team's 2007 meeting at Montreal was planning for a demonstration experiment with the goals of:

- demonstrating to WMO Members and relevant international organizations the new operational backtracking capabilities and products that the RSMCs can provide; and
- exploring the concept of operations for the requesting and the provision of backtracking products and services.

3.2 The experiment was carried out over 29 February to 3 March 2008, with the participation of RSMCs Beijing, Exeter, Melbourne and Washington. RSMC Exeter provided the basis for the experiment by simulating a chemical release to the atmosphere from a tanker ship off the coast of France in the English Channel. Using the UK Met Office dispersion model NAME III nested in the forecast wind field, simulated observations of chemical concentration at a number of receptor sites in Europe were generated.

3.3 The participating RSMCs were then requested to perform backtracking simulations to identify the source location. Back dispersion plumes, back trajectory plots and Source Receptor Sensitivity (SRS) calculations were generated by each of the RSMCs for each simulated observation. The results were encouraging, with the SRS results showing particular promise. Annex 1 provides more detail on this aspect of the experiment.

3.4 For this initial experiment the results were not calculated in real-time so operational procedures were not exercised. A second more comprehensive experiment is planned for 2009.

ATM Ensemble Techniques

3.5 Collaboration with the European Commission Joint Research Centre (EC-JRC, Ispra) in its ENSEMBLE project could assist the WMO ERA programme in exploring and developing ensemble approaches for atmospheric transport modelling. The Expert Team has requested the Secretariat to contact the manager of the ENSEMBLE project with the goal of developing a suitable cooperative framework for this work. In addition, arrangements are being made between RSMCs

to establish a routine exchange of atmospheric transport model products in GRIB format, so as to allow investigation of ensemble methods.

Biological Hazards

3.6 Present understanding of the behavior and spreading of animal diseases other than Foot and Mouth Disease (FMD) by the atmospheric pathway remains poor, Interactions between the meteorological and animal health communities are encouraged. This subject should continue to be monitored by the Expert Team.

Chemical Hazards

3.7 US NOAA is developing a new chemical interface to the CAMEO chemicals database for the Web-based HYSPLIT dispersion model, used for emergency response applications that will permit the specification of the emission source characteristics from simple pull-down menus. When completed, the interface will be available to other countries using HYSPLIT.

Sand and dust storms

3.8 A Sand and Dust Storm Warning System has been proposed as an initiative of the World Weather Research Programme (WWRP), within the WMO Commission on Atmospheric Sciences, where three regional centres for sand and dust storm modelling and forecasting are being organized for eastern Asia, Europe and North Africa, and North America. The Expert Team noted that coordination between CAS and CBS would be highly desirable to ensure operational issues and requirements are considered and addressed.

Formats for exchange of ATM products

3.9 In order to ensure rapid and effective communication of time-critical information, data and product formats have to permit efficient exchange and usage, for example for immediate visualization, input and layering of fields within specialized decision support or mapping systems.

3.10 The Expert Team has sought, through the Secretariat, clarification regarding WMO data and product format standards and related policy with respect to exchange of GIS-like products among WMO Members as well as with external users, recognizing that new electronic formats are in wide use and are desired by some users for product exchange.

4 COOPERATION WITH OTHER INTERNATIONAL ORGANIZATIONS

4.1 While the potential areas of collaboration with agencies such as UN-OCHA and WHO have been well recognized, it has proven difficult to establish practical arrangements or plans. The Expert Team has proposed that reciprocal attendance of programme experts from the respective Organizations at technical meetings may be a useful pathway to collaboration arrangements. The World Organization for Animal Health has been identified as another potential partner.

ICAO

4.2 In the context of air navigation and air traffic control operations, significant benefits continue to be realized from the specialized atmospheric and transport modelling of airborne volcanic ash. This major threat to aviation is considerably reduced with the use of modelling and specialized forecast products and services provided by the 9 Volcanic Ash Advisory Centres designated to support ICAO's International Airways Volcano Watch programme.

5 DESIGNATION OF RSMCs FOR ATMOSPHERIC TRANSPORT MODELLING

5.1 In the event of a request to WMO for designation of a centre as an RSMC in the specialization of Atmospheric Transport Modelling, that centre must demonstrate to CBS its capabilities against the requirements stated in the Manual on the GDPFS for nuclear emergency response and for CTBTO backtracking.

ANNEX 1: SRS Results from the March 2008 Backtracking Experiment

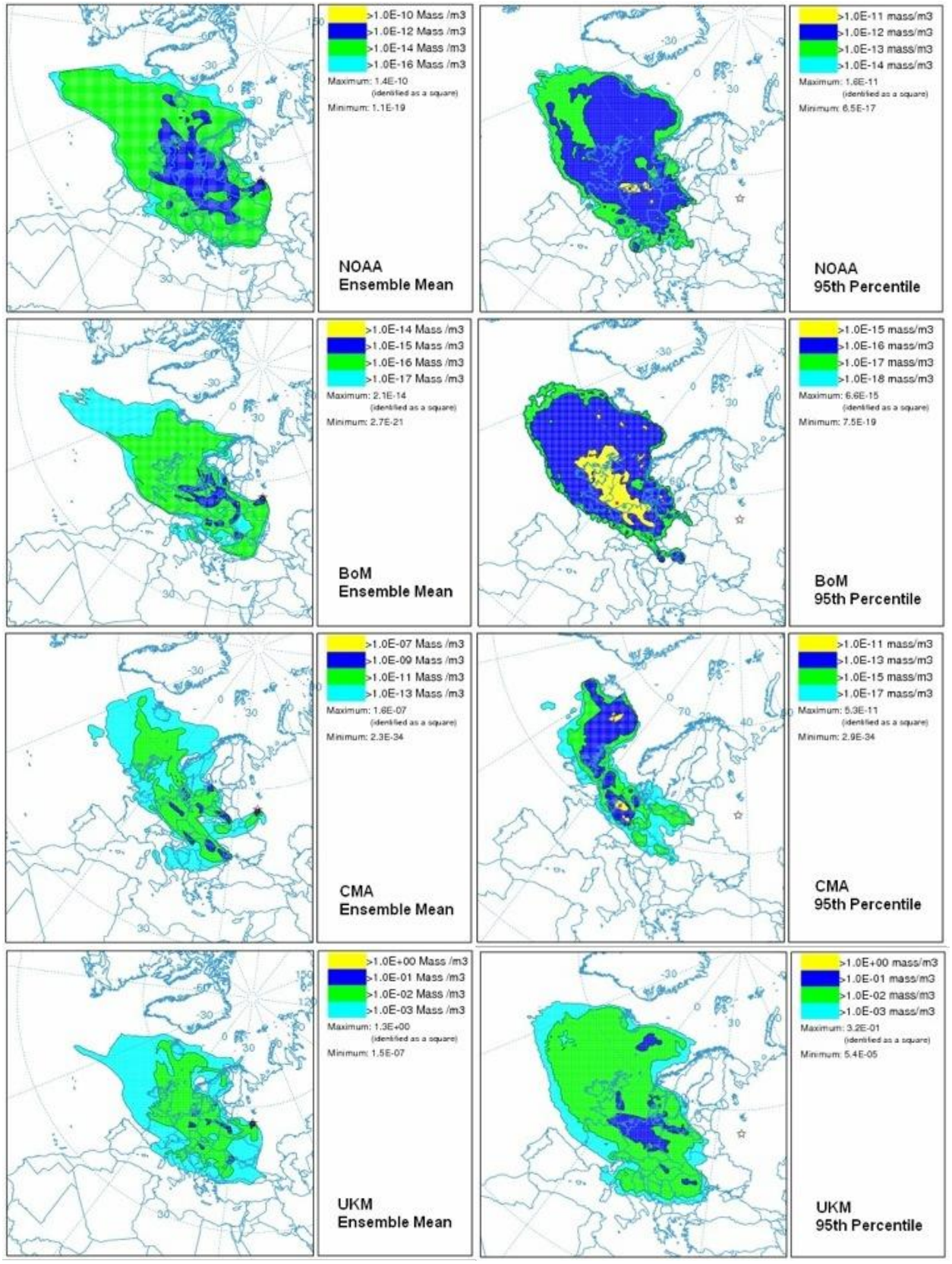
Results and text prepared by Roland Draxler from NOAA

An SRS (Source Receptor Sensitivity) calculation consists of a single backtracking simulation to correspond with each measurement by releasing a tracer at the sampling location over the duration of the measurement. The atmospheric transport model is integrated in the upwind direction with a 6-hour average output of the measurement mass divided by the upwind source area, the value which represents the relative contribution that each source area could have made to that particular measurement (the SRS function).

All integrations were terminated at the same time (0000 UTC 29 February). Each RSMC contributed 28 SRS files, each representing a different sample at different locations and starting times.

Each of these files was post-processed into a binary file compatible with the NOAA display software and time-standardized so that regardless of the start time of the calculation, all SRS fields consisted of 12 six-hour duration time periods over the duration of the experiment. SRS fields after the measurement period to the end of the sampling period were set to zero. These 28 simulations were then combined into an ensemble SRS mean or the 95th percentile SRS. The 95th percentile SRS shows a map of the highest SRS values at each grid cell location. The graphics were computed independently for each RSMC, for each six hour sampling period and for all 12 sampling periods combined. The combined results for the ensemble means and 95th percentiles are shown below.

These preliminary results show that the upper percentile SRS appears to provide a more focused representation of the potential source regions than the ensemble mean. Further, the individual RSMC products are very similar to each other when comparing the 95th percentiles. The ensemble means tend to show too much structure associated with the individual measurement locations. There are substantial differences between the RSMC SRS values, suggesting that not the same release rate was used by all centres. In a more realistic simulation, the release rate should be scaled to the actual measurement value, resulting in higher SRS fields from locations that are nearer to the actual source location. In this exercise, the simulated measurement data were not used to scale the SRS calculations. For instance, upwind calculations from the zero measurements at the other sampling locations could have been used to reduce the potential source area.


>1.0E-10 Mass /m3
>1.0E-12 Mass /m3
>1.0E-14 Mass /m3
>1.0E-16 Mass /m3
Maximum: 1.4E-10
(identified as a square)
Minimum: 1.1E-19
NOAA
Ensemble Mean
>1.0E-11 mass/m3
>1.0E-12 mass/m3
>1.0E-13 mass/m3
>1.0E-14 mass/m3
Maximum: 1.6E-11
(identified as a square)
Minimum: 6.5E-17
NOAA
95th Percentile
>1.0E-14 Mass /m3
>1.0E-15 Mass /m3
>1.0E-16 Mass /m3
>1.0E-17 Mass /m3
Maximum: 2.1E-14
(identified as a square)
Minimum: 2.7E-21
BoM
Ensemble Mean
>1.0E-15 mass/m3
>1.0E-16 mass/m3
>1.0E-17 mass/m3
>1.0E-18 mass/m3
Maximum: 6.6E-15
(identified as a square)
Minimum: 7.5E-19
BoM
95th Percentile
>1.0E-07 Mass /m3
>1.0E-09 Mass /m3
>1.0E-11 Mass /m3
>1.0E-13 Mass /m3
Maximum: 1.6E-07
(identified as a square)
Minimum: 2.3E-34
CMA
Ensemble Mean
>1.0E-11 mass/m3
>1.0E-13 mass/m3
>1.0E-15 mass/m3
>1.0E-17 mass/m3
Maximum: 5.3E-11
(identified as a square)
Minimum: 2.9E-34
CMA
95th Percentile
>1.0E+00 Mass /m3
>1.0E-01 Mass /m3
>1.0E-02 Mass /m3
>1.0E-03 Mass /m3
Maximum: 1.3E+00
(identified as a square)
Minimum: 1.5E-07
UKM
Ensemble Mean
>1.0E+00 mass/m3
>1.0E-01 mass/m3
>1.0E-02 mass/m3
>1.0E-03 mass/m3
Maximum: 3.2E-01
(identified as a square)
Minimum: 5.4E-05
UKM
95th Percentile

ANNEX TO PARAGRAPH 9.6

NWP Verification

(Submitted by D Richardson)

1. Introduction

In this document I report on progress since I was asked to begin this work in spring 2007. Two initial activities were identified as:

- Review WMO standard scores for NWP verification
- Initiate link with the WWRP/WGNE verification group to begin dialogue on how research developments can be brought into operational use

These activities are summarized below. Contact in both area is so far informal; there is at present no formal membership of the CG.

2. WMO CBS standard scores for forecast verification

Standard procedures for the verification of NWP forecasts are given in the WMO Manual on the Global Data-Processing and Forecasting System, WMO-No. 485:

- Attachment II.7 Table F (deterministic and EPS medium-range)
- Attachment II.8 (SVS for LRF)

The EPS and LRF scores are monitored and reviewed by the corresponding Expert Teams. However, there has been no similar structure to review the deterministic forecast scores. This is considered a high priority for the CG.

2.1. CBS standard scores for deterministic forecasts

Current procedures were introduced in 1998 and have not changed since. Given the significant developments of global NWP models in the last 10 years, a review of these procedures is appropriate. This is now underway. A questionnaire was sent to the current list of contacts for the exchange of standard scores. Questions and replies received so far are included in the annex. It is too early to provide any conclusions yet, however some early feedback is reported below.

- Scores are exchanged between GDPFS centres monthly, as required. However, a number of centres are not participating in this exchange. All global forecasting centres should be encouraged to participate.
- Verification against observations should use a list of stations prepared annually by the lead centre for radiosondes and distributed to all centres (and to WMO). However, this list does not always reach the person responsible for verification. In practice the centres do not all use the same list. Differences are large (some use up to 50% more observations than others). The email contact list needs to be updated.
- Verification against analyses is specified on a 2.5° x 2.5° latitude-longitude grid. This is now substantially below the resolution of many global models, which can be as high as 0.25°. The method of interpolation to the verification grid can have a significant effect on the scores. How each centre does this is not recorded. The methods used to interpolate to verification grid need to be agreed.
- Anomaly correlation can be significantly affected by the climatology used. The climatology is not specified, nor is there a record of what is used by each centre. Use of a common climatology would aid comparison of results. This should be reviewed.
- The range of forecast parameters, steps and areas should be extended.

There are significant differences between centres in the ways they have implemented the verification. These have substantial impact on the scores and make comparison between centres difficult. The review of the standard verification will seek to establish a consistent implementation across participating centres, in particular in the interpolation, climatology and use of observations. Once this consistency is achieved, it will need to be maintained. One way to do this could be to establish a lead centre for deterministic verification as has already been done for EPS and LRF.

The procedures for deterministic forecasts are also applied in the EPS verification procedures. Changes such as to the verification grid will also therefore affect the EPS producers. The CBS procedures are followed by other groups (see below). These should not be forgotten when changes are proposed to CBS procedures.

Although the first priority is to consolidate the current verification, the variables that are verified should also be reviewed. Some initial suggestions were raised in discussion with the JWGV; see below.

3. Joint Working Group on Verification (JWGV)

The JWGV is established under the WWRP and WGNE and has an expertise on research on verification. They have been involved in real-time verification activities for WWRP demonstration projects, such as for recent Olympics. However, there is not an established link between the JWGV and CBS. Such a link would be valuable to facilitate transition to operations of new verification procedures.

I attended the meeting of the JWGV 21-22 April 2008. The final report of the meeting is not available yet; agenda and list of participants are attached for information.

I presented an overview of the CBS activity on verification and the purposes of the new CG on verification. A summary of the discussions is given below.

3.1. Link between JWGV and CG

Members of JWGV were very positive about developing links with CBS and welcomed the CBS initiative on this. Several members of the JWGV expressed strong interest in joining the CG. The JWGV will propose one of its members to participate in the CG.

The development of guidelines for verification of NWP models for surface weather parameters and for severe weather are two areas where close liaison between CBS and the JWGV will be especially beneficial.

JWGV have prepared a draft document on verification of precipitation (December 2004). It will be valuable to publish this. A similar review of verification for cloud forecasts is in preparation. These are comprehensive reviews of the verification for these variables. It will still be necessary to select and define procedures specifically for the verification of global NWP models appropriate to add to the CBS scores.

Severe weather is an area of increasing interest for verification of NWP models. There is active research on this, although at present no clear recommendations.

3.2. Discussion of CBS standard scores

A number of suggestions were made to extend the range of parameters covered by the CBS guidelines:

- Add humidity at standard pressure levels
- Weather parameters, including precipitation, surface temperature
- Move to finer grid for verification against analysis than the current 2.5° grid

Recommendations for the verification of European Limited Area Models (LAMs) have been based on the CBS scores (C Wilson). Changes to CBS guidelines would therefore affect this community. There may be other groups in similar positions. Any changes to the CBS guidelines should be widely advertised. C Wilson will act as contact point for the European LAM community.

3.3. SWFDP

The JWGV are willing to help in the evaluation of future SWFDP projects. This may include verification of the model forecasts and also verification of the issued warnings. It would be worth inviting JWGV to participate at the planning stage of the next SWFDP.

Annex: *Questions for review of CBS standard verification*

A questionnaire was sent to the current list of contacts for the exchange of standard scores. The questions and a summary of replies received so far are given below.

1. Information on current procedures for calculating the CBS scores
    a. How do you interpolate to the 2.5 degree grid
        - ECMWF: direct interpolation from model full resolution spectral fields
        - CMC: bi-cubic interpolation
        - JMA: Direct interpolation from computational grid (Gaussian, 60-1920 x 960).
        - Met Office: Area-weighted technique
        - BoM: Linear interpolation from 240x480 Gaussian grid (0.75°)
        - Meteo-France: horizontal spline interpolation (12 nearest model points)

    b. How do you interpolate to radiosonde locations
        - ECMWF: bilinear from 2.5° grid
        - CMC: bi-cubic interpolation
        - JMA: Interpolate from 2.5° grid (using surrounding 12 points)
        - Met Office: Spatial bilinear interpolation, no time interpolation
        - BoM: grid is native model grid (240x480, 60 sigma levels)
        - Meteo-France: a bilinear interpolation

    c. What bias correction and/or screening do you use for the radiosonde data
        - ECMWF: screening as operational assimilation, no bias correction
        - CMC: No screening, bias correction for radiation effects for geopotential only.
        - JMA: Same as operational analysis in JMA

- Met Office: operatinoal quality control. Statistical bias correction.
- BoM: None.
- Meteo-France: assimilation scheme quality control

d. Do you receive the WMO list of radiosonde stations issued annually by ECMWF to use for verification
   - ECMWF: No
   - CMC: Yes - as of Aug 11, 2008 use latest list from Antonio Garcia-Mendez.
   - JMA: No
   - Met Office: No.
   - BoM: No, but implemented latest list1st September.
   - Meteo-France: yes, it is provided by A. Garcia-Mendez

e. What climatology do you use for anomaly correlation
   - ECMWF: climatology from NCEP (NMC) in 1980s
   - CMC: An ECMWF climatology obtained in the early 1990's
   - JMA: Japanese 25-year Reanalysis (JRA-25). Averaging period is 1979-2004.
   - Met Office: We use a climatology based on ECMWF Reanalysis for 1979-1993
   - BoM: ECWMF climatology
   - Meteo-France: ERA40 reanalysis on a 2.5 degree grid

f. How do you calculate the monthly mean scores
   - ECMWF: simple average (mean) of daily scores
   - CMC: Simple arithmetic average of the daily values.
   - JMA: Averaging the values of each day
   - Met Office: average the daily scores for 00Z and 12Z separately.
   - BoM: monthly average is then computed from the daily statistics.
   - Meteo-France: This is performed by an average of the daily scores

2. Consideration of possible revisions to the current CBS procedures
   a. Change from 2.5 degree to higher resolution grid (given current resolution of global models)?
      - ECMWF: would prefer higher resolution grid
      - CMC: 0.5 degree? discontinuity in the scores, but more accurate
      - JMA: higher resolution would be good (0.5 degree?).
      - Met Office: sensible (1.25 degree?) but discontinuity in statistics.
      - BoM: could change to high resolution grid for new model in 2009
      - Meteo-France: currently also use 1.5 degree grid.

   b. How to interpolate from model grid to verification grid – remove information on scales not resolved by verifying grid
      - ECMWF:
      - CMC: This is currently under examination.
      - JMA:
      - Met Office: Clearly it is important that everyone uses the same technique.
      - BoM: All centres should use a consistent grid interpolation method.
      - Meteo-France: Nothing is done for the upscaling of the model forecasts

   c. Climatology can affect the anomaly correlation - can we consider using a common climatology to minimise the effect

- ECMWF: would like have a common climatology
- CMC: This is a must.
- JMA: It may be difficult to decide what climatology to use.
- Met Office: I think we'd all agree to using a common climatology!
- BoM: Agree to use a common climatology.
- Meteo-France: ERA40 provide a common climatology.

3. Consideration of possible extension of CBS verification
    a. Add verification of humidity

    b. Include some surface weather (e.g. EPS verification includes precipitation verified against GSN data, though I don't know if anyone actually does this)

ANNEX TO PARAGRAPH 12.3

CBS OPAG on Data-Processing and Forecasting Systems (DPFS): Proposed Structure and Terms of Reference to CBS-XIV (2009)

1. Implementation Coordination Team on Data-Processing and Forecasting Systems

(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.

2. 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.

3. 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, 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 :

1. To ensure that the proposed GIFS (Global Interactive Forecast System) is suitable for operational implementation and application,
2. To review progress on the use of EPS for targeting of observations.

4. Rapporteur on Infrastructure for Numerical Weather Prediction (NWP)

(a) In consultation with the relevant Expert Teams and in coordination with the Regional Rapporteurs on GDPFS, provide guidance on the NWP products to be exchanged on the GTS (WIS);

(b) Review the need for establishing standards and guidelines for the provision of initial and boundary conditions to NMCs for limited area models for operational NWP;

(c) Communicate the resulting user requirements to the OPAG/ISS to help them determine appropriate technical means of meeting these requirements;

(d) Provide guidance on the benefits of different options for capacity building concerning the infrastructure requirements for operational implementation of new NWP systems.

5. 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, 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), and the Lead Centre for the Standard Verification System for Long-range Forecasts LC-SVSLRF).

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

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

(d) In consultation with relevant experts in CAS and CCl and with the Coordination Group on Forecast Verification, review developments in verification scores and practices with a view to updating the Standard 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) Establish the status of extended-range forecasting activities and recommend a timetable for developing an exchange of extended-range forecasts and verification products;

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

6. Coordination Group on Nuclear Emergency Response Activities (ERA)

(a) Test and improve the collective ability of all RSMCs, the IAEA, the RTHOffenbach and NMHSs in the ERA to fulfil the operational requirementsspecified in global and regional arrangements, according to adoptedstandards and procedures;
(b) Implement and explore further improved distribution/access methods forspecialized products to NMHSs, and the IAEA in collaboration with the IAEAand 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.

7. 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.

8. Rapporteur on the Application of NWP to Severe Weather Forecasting

(a) Review the application of NWP to severe and high impact weather forecasting at all ranges in consultation with relevant expert teams;
(b) Report on new developments and advances in severe and high impact weather forecasting;
(c) Provide advice on the proposed demonstration project(s).