WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

OPAG ON
DATA PROCESSING AND FORECASTING SYSTEMS

EXPERT TEAM ON
ENSEMBLE PREDICTION SYSTEMS

GENEVA, 27-31 OCTOBER 2003

Final Report

REPORT OF MEETING OF EXPERT TEAM ON ENSEMBLE PREDICTION SYSTEMS
(Geneva, 27-31 October 2003)

Summary

Twelve experts representing 10 countries and ECMWF participated in the meeting. Experts gave presentations on the status of operational EPS activities and related research developments and future plans in their respective WMCs/RSMCs/NMCs, for medium-range and short-range forecasting in general. From the presentations, the meeting noted the following trends:

- Producers have been upgrading their ensemble system by increasing the number of members and models to be used in the EPS
- Work has been pursued on new methods to build initial conditions (e.g. using various approaches with Ensemble Kalman Filter or refining use of SVs)
- Some centres are now using the climatology of their own model to calibrate their delivered probabilities.
- Specific EPS for Tropical Cyclone forecasting have been implemented and specific products for TC are generated like strike probabilities and storm tracks. EPS is found very useful for cyclone tracks in the medium-range.
- Short-range ensembles, using regional models, are being implemented in an increasing number of centres, many are still in an experimental mode, but are moving fast towards operational mode
- The Team noted the potential benefits of cooperation between countries for development and implementation of operational EPS with regional models.

Since the users of ensemble prediction system have to be well aware of the value of probability forecasts for the risk management, the education on EPS needs to in part be focused on the interpretation of probabilistic forecasts for the high impact weather. In this regard, a joint training seminar for EPS and Disaster Prevention and Preparedness (DPP) would be useful for maximizing benefit of EPS to the end users faced with decision making with uncertainty.

The Team considered the necessity and the difficulty of delivering information to the public, which takes into account the uncertainty inherent in deterministic forecasts. The EPS products can help to quantify that uncertainty and deliver more realistic forecasts. They also help to detect potential occurrence of extreme weather. The Team stressed that new products like confidence index, or probabilities for specific customers can improve the quality of the delivered information and the satisfaction of the customers. Products can be tailored to the different type of customers.

The Team discussed the availability of EPS products on GTS and Internet. It also considered the use of EPS products made by the forecasters. The members of the Team reported on the increasing use of EPS products within their centres. Products in chart form are also the products most widely available on the web. EPS gridded data are currently available by anonymous FTP from NCEP and CMC. Several producing Centres have bilateral agreements to exchange their gridded ensemble data, allowing the potential for combined ensemble systems to be developed. It was emphasized that in order to tailor EPS products to local requirements and extract the full value of EPS forecasts, gridded data are essential. The Team made the following recommendations:

- The Team repeated that GRIB 2 should be the format for dissemination of gridded EPS products. In order to assist the migration to GRIB 2, the Team requested Centres with GRIB 2 encoders/decoders to make their software freely available for implementation in NMCs.
- Producers of global EPS are encouraged to generate EPSgrams on a selected set of locations world-wide.
- The Team noted the benefit for forecasters of being able to generate the products interactively to adapt them for a given meteorological situation, but also the technical difficulty for offering this service. The Team recommended that EPS producers should consider this requirement in designing their new Web sites.
- The Team noted that EPS products can be especially valuable for high impact weather forecasting. NMHSs are strongly encouraged to adopt the use of EPS for that purpose.

The Team reviewed the implementation of verification scores for EPS products and the exchange of results between producing centres. JMA made a proposal to operate an Internet site with verification scores of medium-range EPS generated by producing Centres. JMA will seek CBS recognition as Lead-Centre for verification of Global medium-range EPS in 2004. All producing centres would be asked to pass their scores every month to JMA. The Team welcomed and agreed to this proposal, but with the idea that for the time

being it will be experimental. It was recommended that CBS review the proposal and make a final recommendation on the project in its next session in 2004.

The Team reviewed current material and education methods for training forecasters on interpretation and application of EPS products, and considered necessary enhancements. The Team considered the requirement related to training on EPS and made the following recommendations:

- The Team recommends that workshops be organized to train trainers on the concepts and use of EPS. Computer Aided Learning (CAL) will be the prime training material for the trainers. CAL will then provide the principal tool for the trainers to use in their own countries.
- The Team recognized the existence and high value of the COMET CAL system and considered that it could be the basis for the development of training materials. The Team recommends that WMO contract one or more expert consultants to develop workshop materials to go alongside a CAL, and to work with a CAL producer, like COMET, to create or expand an existing CAL to meet WMO requirements.
- The Team recognised the need for assistance from various Centres to contribute to the development of training material and provide lecturers.
- Directors of NMHSs be informed of the benefit of EPS during one of the WMO meetings organized for them (e.g the Regional Management Group meeting).
- There is a risk that forecasters become overwhelmed with the addition of EPS products, Forecast office managers are encouraged to establish a suitable methodology for incorporating them into the forecast process.
- Implementation of coherent education and training activities remains critical for realising the benefits of EPS. EPS training as described in chapter 7 is necessary to help NMHSs make full use of EPS to improve their forecasts.
- The Team recommended sending a questionnaire on EPS to WMO Members to assess their interest and requirements on EPS which would help guide the training programme. The questionnaire should be preceded by some general explanations.

The Team developed an outline plan for a workshop on EPS. The Team considered the themes, subject of sessions, organizing committee and lecturers. The Computer Aided Learning tool should be an integral part of the WMO workshop on EPS programme and designed accordingly. The CAL tool will be used as follow-up to the workshop and used by the trainees to transmit EPS knowledge to their colleagues.

REPORT OF MEETING OF EXPERT TEAM ON ENSEMBLE PREDICTION SYSTEMS
(Geneva, 27-31 October 2003)

1. OPENING OF THE MEETING

1.1 The meeting of the CBS Expert Team on Ensemble Prediction Systems was opened, at 10.00 a.m. on Monday 27 October 2003 by the Deputy Secretary General of WMO, Mr Michel Jarraud. Mr Jarraud welcomed the participants of the Expert Team on Ensemble Prediction Systems for its second meeting. He recalled that the fourteenth WMO Congress noted that ensemble forecasting was becoming increasingly important and was evolving as a vital tool for weather forecasting on all time scales, from short-range to seasonal-range and beyond. There was a growing interest in EPS and the number of EPS producers and users had been increasing. Noting that probabilistic forecasts were very different from deterministic forecasts, the WMO Congress agreed on the need for education and training on EPS approach and the interpretation of EPS. With respect to training, emphasis should be given to severe weather forecasting and specifically to the enhanced use of EPS products. Consequently, WMO was planning to implement regional workshops with focus on EPS training, in particular training of forecasters to make the best use of the new products, promote development and use of Computer Aided Learning (CAL) modules on EPS and organize EPS roving seminars and workshops. WMO also will have to produce guidance material on use of EPS products by forecasters that could be a new chapter in the guide on the GDPFS. Mr Jarraud stressed that this expert meeting had been asked by the CBS to develop and recommend solutions and practical guidance for the implementation of such an ambitious training programme. At first, the meeting will review the status of operational EPS production systems, their applications and the products available world wide. It will then consider the skill of the products and the use which can be made of them. The last two agenda items of your meeting will actually address the training needs and it should be the main delivery of this meeting. Mr Jarraud stressed that the Team was in particular invited to make:

- recommendations on education and training on EPS with a plan at regional and global levels;
- recommendations on guidance material on EPS (concept, interpretation, applications, etc....);

and furthermore to:

- examine and recommend the development of a virtual training laboratory
- develop an outline plan for an international workshop on EPS. The workshop should be aimed at forecasters and include a strong tutorial component on interpretation and use of EPS products.

Therefore, the main aspect to be discussed by the team should not be the development of EPS techniques as such, but more their present operational applications for the National Meteorological Centres, and more specifically, how the forecasters can understand EPS products, and make best use of them. This should include appropriate methodologies for use of probabilistic data and for delivering more objective forecasts to the public, and in particular, improved warnings of severe weather risk.

2 ORGANIZATION OF THE MEETING

2.1 The Agenda of the meeting, as adopted by the meeting, is given in Appendix I.

2.2 In absence of the official chairman of the Expert Team, Mr Nobuo Sato from Japan, the Team, agreed, after nomination of Dr Steven Tracton, from USA, as acting –chairman by Mr Sato, to confirm him in this position. After, proposition by the acting chairman, the Team also agreed to have Mr Ken Mylne as co-chairman for the Team.

2.3 The meeting agreed on its working arrangements and the list of participants is given in Appendix II.

3. REVIEWING PROGRESS ON EPS AND ITS APPLICATIONS

Experts gave presentations on the status of operational EPS activities and related research developments and future plans in their respective WMCs/RSMCs/NMCs, for medium-range and short-range forecasting in general. Recommendations and scientific statements were also made. A summary of the presentations follows.

Operational ensemble prediction at the European Centre for Medium-Range Weather Forecasts (ECMWF) *(François Lalaurette)*

3.1.1 The major changes in the operations of the Ensemble Prediction Systems since the meeting of the ET on EPS in 2001 have been summarised. They include the introduction of perturbations of the initial conditions in the vicinity of observed Tropical Cyclones and the running twice per day (00UTC and 12UTC) instead of only once (12UTC) before. Probability maps for wind gust in excess of 15 and 25m/s and for rainfall in excess of 10 and 20mm/day have also been made available to all WMO NMHS having requested a login/password from ECMWF. They cover all extratropical areas beyond 20° of latitude.

3.1.2 Developments of new products have included the Tropical Cyclone Strike Probability Maps, Tropical Cyclone EPSgrams and a revised, more selective formulation of the Extreme Forecast Index. The Tropical Cyclone forecast website that is planned for operational release later in 2003 was demonstrated. It will be accessible by all WMO NMHS.

3.1.3 Recent developments in the verification of EPS forecasts have been reported. The include the systematic verification of Tropical Cyclone forecasts (strike probabilities, mean track errors and mean intensity). The use of upscaled observations from high resolution observing networks was also discussed, and new proposals for the verification of the EPS spread were made, namely the spread is defined as half the inter-quartile distance, and it should match the median of the distribution of absolute errors (observation - ensemble forecast median).

3.1.4 Plans for the development of the Ensemble Prediction System were presented; they include the use of moist singular vectors at higher resolution, the development of an Ensemble Data Assimilation and of a seamless ensemble forecast system across a range of timescales, e.g.: T399(50 km) to D+7 twice daily, once a day at T255(80 km) to D+15, and then twice a week at T159(123 km) to D+30, in coupled ocean-atmosphere mode.

Perspective of ensemble prediction at Korea Meteorological Administration (KMA) ***(Woo-Jin Lee)***

3.2 Requirements on ensemble prediction system and its products were considered from the point of operational center, NWP center, and research center with perspective of developing EPS center, and the meeting was invited to take into account the information. An EPS with Bred vectors (BVs) is on operation at Korea Meteorological Administration (KMA), some details of which are described in Doc. 3(4) ADD 1 including latest progress (see WMO web site: http://www.wmo.ch/web/www/DPS/ET-EPS-GENEVA/DocPlan.html).

3.2.1 Operational Centers

It is desired to develop an approach for the optimal use of all available information in practical sense with the understanding that a forecaster could only afford to concentrate on a few different scenarios at a time before making judgement. Demonstration projects would be particularly useful for encouraging forecasters to be acquainted with practical knowledge on how EPS products are interpreted for forecast episodes such as blocking lows or transition between high and low index flows. At times when the bundle of EPS guidance are drifted toward the model climate, it is probable that most of them are going to be wrong in a systematic manner regardless of the spread among EPS members. It should be identified when the EPS guidance has such symptom for the drift. For the reference to deterministic NWP guidance, the consistency of sequence of forecast scenarios is one of attribute for the forecaster to put credibility on. The EPS Probability of Precipitation (POP) in its current form is not able to convey pre-warning of heavy precipitation beyond the guidance available from the deterministic forecast.

3.2.2 NWP Centers

The NWP centers should support systems and/ or interpretation tools for forecasters to identify outliers, and their synoptic characteristics. The exchange of expertise and experience among EPS centers on those areas is very beneficial for the NMCs to support their forecasters on pre-warning of severe weather in advance with EPS guidance. Coordinated and collaborative efforts among EPS centers are desirable to conduct comprehensive case studies which clearly demonstrates the usefulness of such guidance on identifying typical and extreme synoptic scenarios, evaluating the potential for severe weather in medium-range, and utilizing latest observations and mesoscale model products in the framework of seamless forecast process from medium-range EPS forecasts to nowcasting. The CAL modules on EPS further promote forecasters to get experience with EPS products and to develop expertise on its interpretation. Considering the pressure at forecast office for prompt decision on high impact weather with very tight working schedule, an interactive system should be developed to process massive amount of EPS products and to visualize them in a compact form. The probability of extreme weather on medium range has potential value for the commercial sector engaged with the decision making under uncertainty. It is, however, little known at EPS center how useful and beneficial the information is, and what is required to meet the requirements of users from various sectors. It is desirable to assess the social and economic value of EPS guidance, and to exchange experience on the EPS service for the risk management.

3.2.3 Research Centers

Tropical cyclones (TC) in their early stage and mature stage before recurvature are generally surrounded with weak vertical shear, and strongly coupled with marine boundary layer through deep convection process. Large errors are associated with the observation and analysis of TC vortex structure, and the instability or error growth mechanism for TC is quite different from that for mid-latitude cyclones. The SVs or BVs should be developed to fully reflect the initial condition uncertainty of TC dynamics. To adopt the cascading strategy from the early warning for medium-range to the nowcasting of severe weather, the downscaling of EPS should be developed to account for the uncertainty involved with the timing and place of transient meso-systems and stationary orographic systems. While the EPS community maintains certain degree of consensus for the approach on the generation of optimally growing perturbations at initial analysis, it seems that wide range of options are pursued for the generation of stochastic forcing inherent to the incompleteness of model itself. The exchange of research outcomes on this area is beneficial to develop more sound error growth algorithms for EPS. The predicted uncertainty or error growth from SVs or BVs, based on a single NWP system, is a useful information for the data assimilation of sequence of observations with appropriate background fields. In this way, the EPS functions is an indispensable component of a data assimilation system. The derivation of background error covariance from a limited number of EPS members is one of challenging issue at hand among data assimilation community, and exchange of research outcomes on this area is highly desired.

3.2.4 International Cooperation

A guideline for the exchange needs to be established to meet with the conflicting interests arising from the concept of public goods and commercial interest. Depending on the extent EPS producers provide free access to EPS products, the strategies of development and application of EPS at NMCs may have to be adjusted at regional level to appreciate the full benefit of EPS technology.

EPS at Canadian Meteorological Centre *(Louis Lefaivre)*

3.3.1 Reviewing progress in EPS:

Ensemble forecasts are run operationally at the Canadian Meteorological Centre since February 1998, with outputs up to 10 days that are launched at 00 UTC. The ensemble size was increased from eight to sixteen members in August 1999 and their resolution was increased from equivalent of T95 to T149 in July 2001. The method of producing the perturbed analyses consists of running independent assimilation cycles using an Optimal Interpolation (OI) data-assimilation scheme that uses perturbed sets of observations and which are driven by eight perturbed models, different by their physical parameterizations. Perturbed analyses thus obtained are then doubled by taking the opposite addition to the operational analysis. A multi-model approach is then used to obtain the forecasts: 8 members launched with same model (SEF model) and options as the ones in the data-assimilation cycle and 8 members using another model (GEM) with another set of 8 options. Several forecast products, all tailored over North America, are available in real time on the web (http://weatheroffice.ec.gc.ca/ensemble/index_e.html). A large number of raw global EPS outputs are also made available via ftp anonymous in GRIB format.

3.3.2 Verification:

The following verifications are regularly performed:

- EPS mean of the geopotential 500 hPa RMS errors over 4 areas (Northern Hemisphere, Southern Hemisphere, Tropics and North America) as compared to the global deterministic CMC forecast (~100 km resolution) and to the spread in the ensemble.
- Spread/skill relationship for 500 hPa heights over the same four regions.
- Rank histograms for 250, 500 and 850 hPa heights over the same four regions.
- Probability of precipitation forecasts verified over North American stations using Relative Operating Characteristics (ROC) curves for 2, 5, 10 mm thresholds. The 25 mm threshold is forecast but not verified.

3.3.3 Plans for CMC EPS:

The OI scheme will be replaced by an Ensemble Kalman Filter (EnKF). The EnKF scheme will use 96 members to define model error covariance terms. This should improve the initial quality of the ensemble forecasts, obtain a large number of well balanced perturbed analyses and get rid of the opposition addition to deterministic model technique. This would thus permit to increase the number of members (32 members). We would also like to launch ensemble forecasts both at 00 and 12 UTC and extend their range to 15 days. A single model approach, using stochastic physics sub-grid scale parameterizations, is also envisioned.

CMC wants to increase the probabilistic products suite and use the spread/skill relationship to extend the public forecast range to 7 days. CMC wants to foster the use of EPS to better forecast high impact weather and eventually develop and extreme forecast index for precipitation. CMC is also involved in exchanging ensemble forecasts with NCEP and has started a collaboration effort with them to develop probabilistic forecast products for high impact weather and harmonize verification technique.

Present and planned configurations of Ensemble Prediction Systems at the National Centers for Environmental Prediction (NCEP) *(Steve Tracton)*

3.4 The National Centers for Environmental Prediction's medium-range ensemble forecasts (MREF) have been available operationally to National Weather Service (NWS) meteorologists since 1993. In 2000, a companion short-range ensemble forecast system (SREF) was developed, which became operational in 2002. The MREF concentrates on the medium-range synoptic to planetary wave time and spatial scales, while the SREF focuses on the mesoscale in time and space. Taken together, the MREF and SREF make available a "seamless product", through which the forecaster can ascertain uncertainty in the forecast throughout the forecast time range, at scales appropriate to the ability of NWP models to forecast into the future. This paper describes the current MREF and SREF systems, and then discusses some short-term future plans to upgrade those systems.

3.4.1 MREF: As of 15 October 2003, two MREFs are run per day, using the EMC Global Forecast System (GFS) model. Using the breeding method (Toth and Kalnay, 1993), five (5) initial condition perturbations are created, which are then added to and subtracted from T126 control initial conditions at 00 UTC and 12 UTC. The control and perturbation initial conditions are integrated to create 11 ensemble members for the 00 UTC run, while the 12 UTC run consists of runs of the perturbed members only. This gives a total of 21 ensemble members per day. Each ensemble member is run at T126 (115 km) for the first 84 forecast hours. Subsequently, the resolution of the model is reduced to T62 (230 km) and run to 6 days. Graphical MREF products are available through NCEP/EMC at http://wwwt.emc.ncep.noaa.gov/gmb/ens/index.htm. Included are probabilistic precipitation forecasts, the relative measure of predictability, ensemble mean and spread products, and ensemble spaghetti plots. Additionally, ensemble grid data (grib files) can be accessed at http://wwwt.emc.ncep.noaa.gov/gmb/ens/info/ens_grib.html. The next implementation of the MREF will include:

> i) increase of ensemble member resolution from T62 to T126 in the 84-to-180-hour forecast period, ii) addition of 10 ensemble members at both 06 and 18 UTC, and iii) addition of more probabilistic forecast products for precipitation, including joint probabilistic forecast products for rain, ice pellets, freezing rain, and snow. Longer term plans include the *North American Ensemble Forecast System (NAEFS)*- (http://wwwt.emc.ncep.noaa.gov/gmb/ens/naefs.ppt)

3.4.2 SREF: The operational SREF currently consists of three different model configurations with five members each. The models are i) Regional Spectral Model (RSM), ii) Eta with the Betts-Miller-Janjic (BMJ) adjustment convective parameterization, and iii) the Eta with the Kain-Fritsch mass flux convective parameterization. All members are run with 48 Km horizontal resolution with perturbations to initial conditions derived from the breeding method. SREF is run at 09 UTC and 21 UTC daily up to 63 hours. Products are available via a unified web interface (http://wwwt.emc.ncep.noaa.gov/mmb/SREF/SREF.html) which includes animations and zooming capabilities. The forecaster can view the combined 15 member ensemble graphics, or graphics from each of the five individual model. The horizontal resolution of the three models will be increased to 32-38 km and additional physics diversity (at the expense of initial condition perturbations) is targeted for December 2003. Post-processed products for aviation, severe weather, and general forecasting will be added to the product suite. In the longer term there are plans to explore using Kalman Filter techniques following the work of Xuguang Wang and Bishop (*J. Atm. Sci.,* 2003).

Presentation by *Ken Mylne* (UKMO)

3.5.1 Results from recent work on Early Warnings and PEPS (Poor Man's EPS) were presented. The main conclusions to note are:

- Early warnings based on ECMWF EPS have probabilistic skill at 4 days but not at 2 days, and illustrates that performance of ensemble systems will vary in complex ways. Most of the skill comes from warnings issued at low probabilities so we need to understand how to use low probabilities effectively. We must be careful about the assumptions we make about what EPS can and cannot do. This is important to note in future training programmes.
- Calibration of EPS probabilities does not guarantee to improve forecasts - experience with calibration using Rank Histograms is that it improves probabilities of non-extreme events but actually degrades probabilities of severe events.
- Aspects of PEPS performance are competitive with ECMWF EPS at short range. Best performing versions are hybrids combining PEPS members with a few (e.g. 6) randomly selected members of the ECMWF EPS, indicating that it is useful to include a contribution from Singular Vector perturbations. These versions are better than EPS at short-range, especially up to 48h. Main benefit is in the reliability term, but resolution is also better for non-extreme events. PEPS rank histograms are very flat compared to EPS, and absolute numbers of outliers are less at 24h despite being a much smaller ensemble. PEPS could provide useful and relatively cheap ensemble performance.

3.5.2 Plans for LAMEPS were also briefly described. This will provide a short-range ensemble based on the Met Office model at 20km resolution over a domain covering the Atlantic and Europe. Initial condition perturbations will be provided from ETKF, with model physics perturbations also applied. Perturbed lateral boundary conditions will be provided from a global ensemble using the Met Office model, also using ETKF, although experiments will also be conducted to determine whether these can be satisfactorily provided from the ECMWF EPS.

3.6 The applications of EPS to high impact weather events at Japan Meteorological Agency (JMA) by *Masayuki Kyouda*

3.6.1 As of October 2003, JMA operates an ensemble prediction system (EPS) for one-week, one-month and seasonal forecasts. The suite of three EPSs covers a wide temporal range of forecast periods from medium-range forecast to seasonal forecast. Products and their verification of both one-month EPS and seasonal EPS are available by accessing the web site(http://okdk.kishou.go.jp/products/model/index.html). Gridded data of the ensemble mean and spread derived from one-week EPS are available at the JMA RSMC Data Serving System. These verification results show that the ensemble means except 24 hours forecast have more skill than the deterministic forecasts, especially in longer lead time. JMA has a plan to provide soon the verification scores of one-week EPS via Internet site.

3.6.2 In order to detect a rare but high impact weather event, JMA is providing forecasters and some specific users with two indices derived from the one-week EPS, which are a strike probability of typhoon center and a potential index (PI). They are helpful for end users to understand the predictability of severe weather events. JMA introduced a point strike probability of a typhoon by counting the number of ensemble members in which the typhoon center hits a designated location. The verification results of strike probability forecast show that EPS is very useful for typhoon track forecast within 5 days. Especially, the verification results of Typhoon Etau, which moved across the main island of Japan, show that point strike probability is very helpful to understand not only the strike probability but also the time zone when the strike probability is relatively high.

It could be possible for EPS to give a measure of potential that a heavy rainfall will occur in a designated area and period such as an extreme forecast index (EFI), which is one of the EPS products at ECMWF. JMA introduced two PIs, one is for a heavy rain (PIHR) and the other is for a drought (PID). PIHR(PID) is defined as the ratio of the predicted probability of EPS above(below) the median to the climatological frequency above(below) the median. The verification result of PIHR and PID shows that high PIHR and/or low PID is useful for assessing the abnormal rainfall in medium-range forecast although they have the high false alarm rate.

3.6.3 In order to improve probabilistic forecasts of extreme weather events, JMA has a plan to increase both the horizontal resolution of the model to TL319L60 and the ensemble size to 51 members for medium-range forecast EPS in 2006. JMA also has a plan to introduce a new operational EPS focused on the typhoon center track forecast in 2007. The typhoon EPS will run up to 84 hours four times a day so that JMA will be able to issue the timely typhoon probabilistic forecast. The current circle type storm warning forecast area, based on statistical measure, will be replaced by the typhoon EPS product.

3.6.4 Proposal by JMA:

EPS products from some centers should be placed on Internet sites in accordance with the recommendation for their distribution at the previous meeting of the ET on EPS. However, the EPS verification scores were not exchanged.

JMA offers to host the Internet site for the exchange of verification scores and display so that the exchange of these data will be effective.

3.7 EPS rescaling and downscaling to forecast high impact weather *(Pierre Eckert, Meteo-Swiss)*

Global EPS usually show a significant underestimation of high energy weather (strong wind, strong precipitation,…) which can be corrected by various rescaling and downscaling techniques. Three of them were studied. 1) The Extreme Forecast Index (EFI) is a rescaling with respect to the model climatology. 2) Artificial Neural Networks (ANN) are devised for the recognition of situations which exhibit certain characteristics. They can be considered as a nonlinear statistical downscaling. 3) LEPS is dynamical downscaling of the EPS with the help of a Local Area Model.

A verification of the EFI and ANN can be carried out by computing the hit and false alarm rates for various probability (or index) thresholds. For rare events, it is suitable to use the definition of the false alarm rate where the denominator is the amount of “yes” forecasts (i.e. warnings). It can be shown that the false alarm rate is approximately equal to the hit rate for the rare type of events, meaning that a hit rate of 80% also leads to fact that 8 warnings out of 10 turn out to be wrong. This fact has to be communicated to the forecasters and the users.

A more expensive method in terms of computer time is the LEPS. A clustering is first performed on the EPS. A representative of each cluster is chosen to drive (initial and boundary conditions) a limited area model. Different scenarios and probabilities can be extracted from model runs. Various case studies show that strong events can be quantitatively well forecasted and spatially resolved. The “correct” solution is most of the time included in the ensemble, although it is sometimes present in a very limited number of members.

3.8 From the presentations, the meeting noted the following trends:

- Producers have been upgrading their ensemble system by increasing the number of members and models to be used in the EPS

- Work has been pursued on new methods to build initial conditions (e.g. using various approaches with Ensemble Kalman Filter or refining use of SVs)

- Some centres are now using the climatology of their own model to calibrate their delivered probabilities.

- Specific EPS for Tropical Cyclone forecasting have been implemented and specific products for TC are generated like strike probabilities and storm tracks. EPS is found very useful for cyclone tracks in the medium-range.

- Short-range ensembles, using regional models, are being implemented in an increasing number of centres, many are still in an experimental mode, but are moving fast towards operational mode

- The Team noted the potential benefits of cooperation between countries for development and implementation of operational EPS with regional models.

3.8.1 The Team recommended that all Tropical Cyclone RSMCs transmit their TC observations in BUFR format for acquisition by NWP Centres, and especially global EPS producers, to improve their data assimilation and initialization by facilitating insertion of data on TCs.
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3.8.2 The meeting expressed the view that many NMHSs would benefit from the availability of operational PEPS forecast data as experimentally generated by UKMO.

4. AVAILABILITY OF EPS PRODUCTS ON INTERNET AND GTS

The list of known Centres running EPS, based on information consolidated by the WMO Secretariat, is listed in Appendix III.

The members of the Team reported on the increasing use of EPS products within their centres. Within most forecasting environment EPS products were viewed as pre-formatted charts rather than being plotted on demand. Products in chart form are also the products most widely available on the web. At the time of writing there are no medium range ensemble products disseminated via GTS. WMO was congratulated for assembling a web site containing a summary of many locations where charts may be found (http://www.wmo.ch/web/www/DPS/EPS-HOME/eps-home.htm). Particular interest was expressed in the development of Tropical Cyclone tracks from EPS systems.

EPS gridded data are currently available by anonymous FTP from NCEP and CMC. Several producing Centres have bilateral agreements to exchange their gridded ensemble data, allowing the potential for combined ensemble systems to be developed. It was emphasized that in order to tailor EPS products to local requirements and extract the full value of EPS forecasts, gridded data are essential.

GRIB2 is not yet being used for the exchange of any ensemble data. However a number of Centres are committed to the format and it is expected it will become more widely used, particularly for EPS products, over the next few years.

When developing the outline for a training workshop on EPS (see chapter 7), the Team recommended that the training be matched with the types of data that are currently freely available to NHMSs.

4.1 **Availability of EPS products on Internet and GTS by *Tony Simmers*, Meteorological Service of New Zealand**

Since the last meeting of the ET/EPS (October 2001) there has been an increase in the number of sites where ensemble data can be found. Apart from the appearance of sites displaying forecasts from short-range EPS, there has been little fundamental change in the types of data or the way it is distributed.

Currently, display ready charts available from web servers are, and will be into the foreseeable future, the easiest way for forecasters to access ensemble forecast information. This is especially so for NHMSs with limited computing resources and bandwidth. Providers of EPS data should be encouraged to create fields in chart form for all regions of the globe.

Taking advantage of satellite radio and video (DVB) broadcast of data (e.g. RANET, EMWIN, RETIM) may be one way of helping smaller nations gain access to ensemble products.

The move towards the use of GRIB2 to exchange gridded EPS data is gradual but gaining momentum. In order to preserve bandwidth, splitting of global fields into geographical subsets should be encouraged and the adoption of advanced compression techniques, such as wavelet compression, pursued.

4.2 The status of ensemble prediction system and its application in region II (Asia) was reported by *Woo-Jin Lee*

The meeting was invited to take into account this information in the regional perspective.

4.2.1 There is a growing interest on Ensemble Prediction System (EPS) in region II. Four Members are running EPS for operation in the region. Three Members run EPS for both medium and long range, and one Member runs EPS mainly for the long-range prediction. The number of ensemble members in each EPS system run in the region has increased twice or more during the last few years. The standard verification scores for EPS are regularly evaluated at the producing Centres, but the scores have been only used for the domestic purpose. The EPS outputs are mostly used internally in the producing Centre, and a few Centres disseminate the limited volume of products to other Members by fax and/or Internet. Some of the EPS products from other regions are known to be used in the region through Internet, even though it is hard to monitor their usage in a quantitative manner. The needs and requirements for the education and training are high among Members for the interpretation of EPS products in operational environment. The GRIB Edition 1 format is temporarily used for the exchange of EPS products between Japan Meteorological Agency (JMA) and Korea Meteorological Administration (KMA), and between UK Met office and KMA through Internet. Some Members have to modify post-processing software to convert to the GRIB-Edition 2 format, which requires some time. Most of producing Centres in the region apply the breeding approach for generation of initial state perturbations. A few Centres produce ensemble tracks for tropical cyclones on an operational basis. There have been studies in the region to extend the EPS to regional scale.

4.2.2 User requirements

a) The producing centers are encouraged to provide their EPS products to the Members in the region. The instruction for the interpretation of the product and associated standard verification scores are recommended to be provided along with the EPS products so that users are able to develop experience with the limitation and the value of the EPS products.

b) Users need to develop the skill to visualize and to interpret EPS data in order to be able to use them. It will be useful to organize training workshops with case studies for users. For users to derive maximum benefits from EPS data, they should be trained on post-processing techniques such as calibrations, generation of application-specific forecast products and design of cost-loss models.

c) Since the users of ensemble prediction system have to be well aware of the value of probability forecasts for the risk management, the education on EPS needs to in part be focused on the interpretation of probabilistic forecasts for the high impact weather. In this regard, a joint training seminar for EPS and Disaster Prevention and Preparedness (DPP) would be useful for maximizing benefit of EPS to the end users faced with decision making with uncertainty.

d) Taking into account the constraints posed by communication bandwidth, data of EPS members to be made available to users may be limited to some important parameters, for example, (1) precipitation forecasts (in support of heavy rain forecasting) and (2) surface wind forecasts (in support of tropical cyclone forecasting) at reasonably good spatial and temporal resolutions (at least 1-deg resolution and 6-hourly intervals); and (3) forecast positions of tropical cyclones. Users can then generate their own probability forecasts or other EPS products specific to their operations.

e) The Members are encouraged to migrate from GRIB to GRIB-2 particularly for the ensemble prediction system outputs and long-range products.

f) It is desired to have a model intercomparison project on EPS for a given episode, to exchange expertise and experience, to identify common problems and possible solutions.

4.3 Toward an operational Limited Area Ensemble Prediction (LAEP) in Morocco *(Abdalah Mokssit)*

4.3.1 During the last 8 years Moroccan meteorological service has achieved progress in NWP with the implementation of an operational nested application based on a regional North Africa model: the ALADIN NorAf (28 km horizontal resolution), a Moroccan ALADIN model. The characteristics of ALADIN / Morocco are as follows:

- Horizontal resolution : **12 km**
- Vertical levels: **41**
- Horizontal extends : **2000km x 2000km (180 x 180 points)**
- Time step : semi-lagrangian two time level one : **480 seconds**
- Spectral discretization in limited area using the bi-périodicisation technique.
- Spectral coupling functions.
- Hydrostatic dynamics. Non hydrostatic is possible but not used into operations yet.
- Final forecast range: **72 hours.**
- Interval of results production: **3 hours** between 0H and 48H, **6 hours** between 48H and 72H.

The model is run twice a day for the 00H and 12H networks. One 72 hours run takes **15 minutes** on our computing platform (IBMS RS6000 SP). The assimilation OI is run. The 3DVAR is also run. An objective verification is also run based on observations.

4.3.2 Morroco runs also a meso-scale model (5 km) over four national regions thanks to the updated computing facilities (54 Gflops, 1 Terabytes disk storage, 10 Terabytes archive capacity).

4.3.3 During the last 3 years the need for extended range (day 7 to day 10) forecast (expressed by the policy makers) and also the lack of accuracy in the southeast regime has raised motivation to experiment with running an LAEP system. Two experiments were driven based on a simple perturbation technique using the different analysis (OI, 3 DVAR, analysis from the coupling model Arpege) starting from different past guesses. The aim of the experiment is the future implementation of an operational LAEP system in terms of:

- building the capacity to:
    - o running the LAEP routine, assessing the needed resources (computer time, storage,…);
    - o performing post processing of ensemble forecast: tubing, clustering, probabilistic products, spaghetti charts, etc..;
    - o performing some systematic verification comparing the deterministic scores with the LAEP scores;
    - o introducing the new products in preoperational forecast routine and looking for forecaster feedback;
- building the capacity to derive products from the advanced centers,
- initiating, as an intermediate advanced centre, the promotion and the use of the EPS product in the region (north Africa);.
- demonstrating the possible feasibility of LAEP in the framework of the ALADIN consortium.

4.4 Interface with the Public (forecast customers)

The Team considered the necessity and the difficulty of delivering information to the public, which takes into account the uncertainty inherent in deterministic forecasts. The EPS products can help to quantify that uncertainty and deliver more realistic forecasts. They also help to detect potential occurrence of extreme weather. The Team stressed that new products like confidence index, or probabilities for specific customers can improve the quality of the delivered information and the satisfaction of the customers. Products can be tailored to the different type of customers.

The Team felt it was important to communicate developments in EPS capabilities and products to the OPAG on PWS/Expert Team on Media Issues and in return consider its views and needs. The Team agreed that Dr Steven Tracton should act as liaison with this ET.

4.5 Other recommendations proposed by the Expert Team

- The Team discussed the availability of EPS products on GTS and Internet. It also considered the use of EPS products made by the forecasters. The Team made the following recommendations:

- The Team repeated that GRIB Edition 2 should be the format for dissemination of gridded EPS products. In order to assist the migration to GRIB 2, the Team requested Centres with GRIB 2 encoders/decoders to make their software freely available for implementation in NMCs.

- Producers of global EPS are encouraged to generate EPSgrams on a selected set of locations world-wide.

- The Team noted the benefit for forecasters of being able to generate the products interactively to adapt them for a given meteorological situation, but also the technical difficulty for offering this service. The Team recommended that EPS producers should consider this requirement in designing their new Web sites.

- The Team noted that EPS products can be especially valuable for high impact weather forecasting. NMHSs are strongly encouraged to adopt the use of EPS for that purpose.

5. REPORTING ON VERIFICATION MEASURES FOR EPS, AND SKILL OF AVAILABLE PRODUCTS - ENHANCING VERIFICATION OF EPS PRODUCTS

The Team reviewed the implementation of verification scores for EPS products and the exchange of results between producing centres. JMA made a proposal to operate an internet site with verification scores of medium-range EPS generated by producing Centres. JMA will seek CBS recognition as Lead-Centre for verification of Global medium-range EPS in 2004. All producing centres would be asked to pass their scores every month to JMA. The Team welcomed and agreed to this proposal, but with the idea that for the time being it will be experimental. It was recommended that CBS review the proposal and make a final recommendation on the project in its next session in 2004.

5.1 Lead centre for EPS verification

- JMA proposes to host an internet site that will gather and post verification results of EPS products following guidelines given by the expert team in Tokyo in 2001, with a few minor changes (see Appendix IV)
- The goal is to have an open website where the plotted results will be posted. At first, it is requested that the site would be password protected until every centre agrees on the data display.
- Tables with raw scores will be available on ftp. The aim is still to have a full exchange of verification data between producing centres, each participant therefore remains free to process the data independently for its own purpose. However, comparative verification results cannot be published without prior specific approval by participating centres.

- It is proposed to start the verification exchange with the 850 hPa temperature anomalies.

5.2 Proposed changes in the Attachment II-7 of the Manual on the Global Data Processing and Forecasting System (see Appendix IV)

- It is proposed to change the Attachment to exchange spread as the ratio to the ensemble mean (instead of the control).
- Reference to tables 5 and 6 (attachment II.9. in the Manual on the GDPS) is added
- Reliability tables will be done against analyses, except for precipitation, where the verification should be against observations using the same regions as per GDPS tables
- On request, ECMWF will provide climatology fields allowing anomaly verifications
- 850 hPa temperatures over extratropics will be added in the ensemble mean and spread verification; anomalies for 850hPa temperature probabilities will have +/-2K in addition to +/-4 and +/-8K

6. EDUCATION AND TRAINING ON THE USE OF ENSEMBLE PRODUCTS

The Team reviewed current material and education methods for training forecasters on interpretation and application of EPS products, and considered necessary enhancements.

6.1 ***Dr. William R. Bua*** described the training materials and capabilities of the Cooperative Program for Meteorological Education and Training (COMET) in numerical weather prediction (NWP) and ensemble forecast systems. First, the history of COMET and the NWP training efforts since 1998 was presented. This included the development of embedded NWP liaison positions funded by COMET at the National Centers for Environmental Prediction (NCEP).

Then, training modalities used by COMET were demonstrated. First, Dr. Bua presented the currently available training on NWP, which is in the form of a table or matrix (http://meted.ucar.edu/nwp/pcu2), as an example of web-based training on general NWP systems and specific NCEP-based forecast models. Next, examples of case studies applying NWP concepts were shown (http://meted.ucar.edu/nwp/pcu3/cases), including:

- A medium-range ensemble case connecting model-to-model run inconsistency and ensemble member uncertainty and
- A short-range ensemble case where the “true” atmospheric initial state was not captured by initial condition perturbations, and the ensemble forecast subsequently failed to predict the observed outcome.

Additionally, a “webcast” (web-based teletraining including narration by a subject-matter expert on ensemble prediction), and a “teletraining” on ensemble prediction systems (which includes interactive discussion and the ability to “draw” on the computer screen) were demonstrated.

Finally, content of the nearly complete COMET ensemble module was shown by Dr. Bua. A brief review of the content outline was shown, as well as some discussion of additional details contained in the module.

6.2 ***Mr Ken Mylne*** noted that the UK Met Office operates a training course on Probability Forecasting and Ensemble Prediction and that materials from this may be made available for adaptation to use in WMO training. The team noted that materials may also be available from a number of other centres.

6.3 **The Team considered the requirement related to training on EPS** and made the following recommendations:

- The Team recommends that workshops be organized to train trainers on the concepts and use of EPS. Computer Aided Learning (CAL) will be the prime training material for the trainers. CAL will then provide the principal tool for the trainers to use in their own countries.

- The Team recognized the existence and high value of the COMET CAL system and considered that it could be the basis for the development of training materials. The Team recommends that WMO contract one or more expert consultants to develop workshop materials to go alongside a CAL, and to work with a CAL producer, like COMET, to create or expand an existing CAL to meet WMO requirements.

- The Team recognised the need for assistance from various Centres to contribute to the development of training material and provide lecturers.

- Directors of NMHSs be informed of the benefit of EPS during one of the WMO meetings organized for them (e.g the Regional Management Group meeting).

- There is a risk that forecasters become overwhelmed with the addition of EPS products, Forecast office managers are encouraged to establish a suitable methodology for incorporating them into the forecast process.

- Implementation of coherent education and training activities remains critical for realising the benefits of EPS. EPS training as described in chapter 7 is necessary to help NMHSs make full use of EPS to improve their forecasts.

- The Team recommended sending a questionnaire on EPS to WMO Members to assess their interest and requirements on EPS which would help guide the training programme. The questionnaire should be preceded by some general explanations.

7. PREPARATION OF A WORKSHOP ON EPS

The Team developed an outline plan for a workshop on EPS. The Team considered the themes, subject of sessions, organizing committee and lecturers. The Computer Aided Learning tool should be an integral part of the WMO workshop on EPS programme and designed accordingly. The CAL tool will be used as follow-up to the workshop and used by the trainees to transmit EPS knowledge to their colleagues.

Workshop content:

7.1 The following categories of NMHS were identified:

a) EPS Producers
b) NWP producers/ Potential EPS producers
c) Having access to EPS products – Websites, GTS, satellite, etc…
d) No access

The training will be recommended primarily for NMHS having access to EPS products..

7.2 Objective

The objective of the workshop will be to train trainers on the concepts and use of EPS. Computer Aided Learning (CAL) will be the prime training material for the trainers. CAL will then provide the principal tool for the trainers to use in their own countries.

At the end of workshop, participants should:

- Be motivated in using EPS;
- Have a basic understanding in EPS, their applications, capabilities and limitations;
- Know how to incorporate the EPS in the forecast process;
- Know where and how to access EPS products and data;
- Be familiar with CAL content, and be able to use CAL for local training
- Know where to get further information/help

7.3 Issues

- Length, pace + introductions: ideally will be two weeks long, with at least one lecturer (resource person) covering the whole period;
- Availability/ Feasibility of WMO extension to the Cooperative Program for Meteorological Education and Training (COMET) CAL
- Languages? *(to be clarified by WMO)*
- Lecturers/ Resource persons: 3 lecturers per week should be the minimum
- Participant profile: Senior meteorologists with NWP knowledge and prepared to later train local forecasters; must be fluent in one of the languages of the workshop;
- Access to data/products is necessary during the workshop; one desk/laptop equipped with the WMO CAL per at most four participants;

7.4 Workshop content

Why are we doing it, sources of uncertainty, probabilities, how ensembles address issues, basic products, labs

Module 1 – Basic concepts and principles
- NWP basics
- Chaos theory
- Error sources – Initial Conditions and model error propagation – Linear/non-linear
- Scale and predictability
- Sub-grid processes
- Ensemble to address error sources

Module 2 – Strategies for constructing ensemble systems
- "Poor Person" Ensembles
- Initial conditions and model perturbations; relationship to data assimilation
- Multi-model ensembles
- Global and regional models

Module 3 – **Review of principles of probability**
- Introduction to probabilities
- Relation between probabilities and odds
- Probability from statistical methods
- Probability from ensembles
- Probability and decision making (Cost/ Loss model)
- Difference between point probability, area probability and average point probability

Module 4 – **Basic products**
- Stamp maps
- Spaghetti charts
- Ensemble mean and spread
- Probability charts
- PDFs/CDFs, stacked probabilities;
- Storm track and strike probability charts;
- Clusters/tubes
- EPSgrams and plumes

Module 5 – **Advanced products**
- Statistical post-processing
  - bias correction
  - calibrated probability products
  - probability dressing;
  - Kalman filtered
  - Bayesian post-processing
- EFI/Severe weather warnings
- Relative measure of predictability
- Circulation indices (blocking,…)
- Downscaling (statistical/dynamical)
- Downstream models and products for key sectors(e.g. energy, hydrology, agriculture, warning authorities, civil protection, etc.)

Module 6 – **Sources of ensemble data**

- Charts
- GTS/Internet/ftp/satellite
- GRIB and BUFR
- Technical requirements:
  - running EPS
  - post-processing EPS
  - expertise and support

Module 7 - **Skill and value of ensemble forecasts**

- Verification of probabilities
- Spread/skill relationships
- Rank histogram
- Reliability/Brier/ROC/Resolution
- Reference forecasts (climatology, persistence, statistical methods)
- Cost/loss value
- Sources of verification information
- Providing information on skill/ value to users
- Data needed (observations)

Module 8 – Forecast applications

- Improving deterministic forecasts
  - gain in predictability
  - confidence
  - alternative scenarios
  - capture of extreme events/low range events
- Probability forecasts
  - uncertainty ranges
  - risk analysis and decision making
  - shift in probability (forecast vs climatology)
- Communication of uncertainty to users

Module 9 – **Case studies**

- Exercises – locally adapted, real-time and/or historical
- Capabilities and limitations of ensembles
- Forecast process (methodology)
- High Impact Weather example
- Tropical Cyclone example
- Decision-making/Risk analysis

Module 10 – **Use the Computer Aided Learning (CAL)**

- CAL material to be used during the afternoon labs
- Relation between workshop modules and CAL
- Installation guide

<u>7.5</u> The Team noted that some of the Modules should have a higher priority than others. Given the fact that participants will come from different knowledge bases it will be necessary to adjust the pace and the level of the lectures and material accordingly.

8. CLOSURE OF THE MEETING

Before the closure, the Team thanked the two co-chairmen, Steve Tracton and Ken Mylne for having lead them well to achieve a very productive meeting.

The meeting of the Expert Team on Ensemble Prediction System was closed by the Chairman at 17.30 on 31 October 2003.

APPENDIX I

AGENDA

1. OPENING OF THE MEETING

2. ORGANIZATION OF THE MEETING

2.1 Adoption of the agenda

2.2 Other organizational questions

3. REVIEWING PROGRESS ON EPS AND ITS APPLICATIONS

4. AVAILABILITY OF EPS PRODUCTS ON INTERNET AND GTS

5. REPORTING ON VERIFICATION MEASURES FOR EPS, AND SKILL OF AVAILABLE PRODUCTS - ENHANCING VERIFICATION OF EPS PRODUCTS

6. EDUCATION AND TRAINING ON THE USE OF ENSEMBLE PRODUCTS

7. PREPARATION OF A WORKSHOP ON EPS

8. CLOSURE OF THE MEETING

APPENDIX II

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Please note, as of October 2003, the WMO website has moved to www.wmo.int and the WMO e-mail addresses have moved to the new domain « @wmo.int ». The new format of e-mail addresses is now made of: initial of first name followed by last name; i.e. for Dieter Schiessl : DSchiessl@wmo.int

Please update your bookmarks and address books.
In case of problems pertaining to World Weather Watch,
please write to e-mail box : wwwmail@wmo.int

APPENDIX III - STATUS OF RSMCs AND NMCs RELATIVE TO NUMERICAL MODELS *(2001 , 2002 or 2003 information)*

(last update 28/07/03)

GM = Global Model
LAM = Limited Area Model (resolution coarser or equal to 36 km
MSM = Meso Scale Model (resolution finer than 36 km)
Perturbation technique for ensemble prediction systems: SV = Singular Vectors, BGM = Breeding of Growing Modes, LAF = Lagged Average Forecasts, StoP=Stochastic Physics, OP=Observation Perturbations

REGION I

REGION I							**DISSEMINATION**			
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEV.***	***RANGE***	***Boundary***	***GTS***	***FAX***	***SAT.***	***SPECIAL***
PRETORIA	Geo. RSMC	GM (NCEP Anal.)	T126	L28	7 days		GTS	Fax		
		GM Ens. 16 members (BGM)	T62	L28	14days					
		GM (COLA)	T30	L28	8 month					
		LAM (ETA)	48 km	38	48 h	NCEP (USA)				
		MSM (MM5)								

REGION II

REGION II							**DISSEMINATION**			
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEV***	***RANGE***	***Boundary***	***GTS***	***FAX***	***SAT.***	***SPECIAL***
SEOUL	NMC	GM (GDAPS)	T213	L31	240 h					
		MSM (RDAPS)	30 km	43	48 h	GDAPS				
		MSM (RDAPS)	10 km	43	24 h	GDAPS				
		MSM (RDAPS)	5 km	43	24 h	GDAPS				
		Typhoon (KTM)	1/6 °	18	72 h	GDAPS				
		GM Ens. 17 members, BGM	T106	L21	10 days					
		GM Ens. 20 members, BGM	T106	L21	130 days					
		GM Ens. 20 members, BGM	T106	L21	7 months					
BEIJING	Geo. and Transport Model (T.M.) RSMC	GM (3 D-VAR)	T106	L19	10 days		GTS	Fax	SAT	
		LAM-(HLAFS)	0.5°	20	48 h	GM				
		LAM-(MTTP). Tropical	50 km	15	48h	GM				
		AGCM/OGCM	T106	30	30 days					
		GM Ens. 32 members SV	T106	L19	10 days					
		GM Ens. 12 members LAF over 3 days	T63	L16	1 month					

REGION II							DISSEMINATION			
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEV***	***RANGE***	***Boundary***	***GTS***	***FAX***	***SAT.***	***SPECIAL***
TOKYO	Geo.- T.M. and T.C. RSMC	GM (GSM0305) 3 D-VAR	T213	40	216 h		GTS	Fax		special
		GM Ens. 25 members BGM	T106	40	9 days					
		GM Ens. 26 members BGM (13 members and LAF on 2 days)	T106	40	34 days					
		GM Ens. 31 members, SV	T63	40	120/210 days					
		MSM (RSM0103) 4 D-VAR	20 km	40	51 h	GSM				
		MSM (MSM0103) 4 D-VAR	10 km	40	18 h	RSM				
		GM Coupled (AGCM/OGCM) Ens. 31 members, SV	T63	21	18 months					

REGION III

REGION III							DISSEMINATION			
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEV***	***RANGE***	***Boundary***	***GTS***	***FAX***	***SATELLITE***	***SPECIAL***
LIMA	NMC	LAM (ETA)	48 km	36	120 h	AVN				
		MSM (ETA)	25 km	36	48 h	AVN				
		CCM3 Coupled En. 12 members, perturbed SST			6 months	SST, USA				
INPE/CPTEC -SAO PAULO	Special Centre	GM CPTEC/COLA	T126	28	7 days					Special
		LAM (ETA)	40 km	38	60 h					
		GM Coupled, Ens. 25 members (Random perturbations)	T62	28	Six months					

REGION IV

REGION IV							DISSEMINATION			
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEV***	***RANGE***	***Boundary***	***GTS***	***FAX***	***SAT.***	***SPECIAL***
MONTREAL	Geo. and T.M. RSMC	GM (GEM) 3 D-VAR	0.9° (~ 100km)	28	240 h and 360 h		GTS			
		GM Ens. 16 members (Random perturbations and two models modifed 8 times)	T149 and 1.2 deg.	28	240 h					
		GM (GEM Regional)	Variable mesh 0.22° (~ 24 km) over North America	28	48 h					
		MSM (HIMAP)	10 km	35	30 h					
		GM Ens. 5 members (24 h time lagged)	T63	23	1 month					
		GM Ens. 12 members (24 h time lagged, two models)	T63 T32	23 10	100 days					
WASHINGTON	WMC/ Geo. and T.M. RSMC	GM (AVN) (3D-VAR)	T254	64	84 h		GTS		ISCS (WAFS)	Special
			T170	42	84 to 180 h					
			T126	28	180 to 384 h					
		LAM (RUC)	20 km	40	12 h	AVN				
		LAM (NGM)	85 km	16	48 h	AVN				
		MSM (HiRes) 3D-VAR (Meso-ETA) over Alaska	12 km	60	84 h	AVN				
		MSM ((HiRes) 3D-VAR (Meso-ETA) over Hawaii	10 km	28	48 h	AVN				
		Ens. 10 (SREF) (North America) (Breeding)	48 km	60	48 h					
		Ens. 20 members (Breeding)	T126 T62	28	84 hours 85 hours to 16 days					
		Ens. 20 members	T62	28	7 months					

REGION V

REGION V							DISSEMINATION			
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEV***	***RANGE***	***Boundary***	***GTS***	***FAX***	***SAT.***	***SPECIAL***
MELBOURNE	WMC, Geo. and T.M. RSMC	GM (GASP) OI-1D-VAR	T239	29	240 h		GTS	Fax	SAT	special
		LAM (LAPS)	0.375°	29	72 h	GASP				
		LAM (TLAPS)	0.375°	29	72 h	GASP				
		MSM (SE and SW MESO-LAPS) -	0.125°	29	36 h	LAPS				
		MSM (Sydney and Melbourne)	0.05°	29	36 h	LAPS				
		TCLAPS	0.15°	19	72 h	GASP				
		Ens. 32 members	T119	19	10 days					
		Ens. 10 members, coupled (ACOML)	T47	17	8 months					

REGION VI

REGION VI							DISSEMINATION			
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEV.***	***RANGE***	***Boundary***	***GTS***	***FAX***	***SAT.***	***SPECIAL***
ZURICH	NMC	full access to GM (ECMWF)								
		MSM (LM – COSMO consortium) non-hydrostatic, nudging	7 km	45	48 h	GME (Offenbach)				
ECMWF	RSMC for Medium-Range	GM	T511	60	240 h		GTS		MDD	special
		GM Ens.- 50 members SV+StoP	T255	40	240 h					special
		GM Ens.- 40 members (OP+StoP), coupled ocean-atmosphere	T95	40	6 months				MDD	special

REGION VI							DISSEMINATION			
CENTRE	***STATUS***	***MODELS***	***RESOL.***	***LEV.***	***RANGE***	***Boundary***	***GTS***	***FAX***	***SAT.***	***SPECIAL***
TOULOUSE	T.M. RSMC	GM (ARPEGE) (4 D-VAR)	Variable mesh T298C3.5 19km to 230 km	41	96 h				SAT-RETIM	special
		GM (ARPEGE-Tropiquee-Indian Ocean)	T358	41	72 h					
		MSM (ALADIN)	7.5 km	41	48 h	ARPEGE				
		MSM (ALADIN Trop. Cyclone- Indian Ocean))	31 km	41	72 h	ARPEGE				
		GM (ARPEGE-Climat) Ens. 10 members – time-lagged	T63	31	129 days					
BRACKNELL	Geo. and T.M. RSMC	GM (Unified Model) 3D-VAR non-hydrostatic	0.56 lat x 0.833 long.	38	120 h		GTS	Fax	SADIS (WAFS)	
		MSM 3D-VAR non-hydrostatic Some RADAR data assimlation	0.11°	38	36 h	GM				
		GM Ens. 9 members, 6 hours LAF	2.5°	19	4 months					
		GM Ens. 9 members, 6 hours LAF	2.5°	19	2 years					
MOSCOW	WMC, Geo. RSMC	GSM 3D-VAR	T169	31	240 h		GTS	Fax		
		LAM	75 km	30	48 h	GSM				
		MSM	10 km	15	36 h	LAM				
		GM Ens. 10 members	T40	15	1 month					

APPENDIX IV

Proposed modified Attachment II.7, Table F, Section III of the WMO Manual on GDPS

(Changes are under-lined)

Monthly exchanges:

ENSEMBLE MEAN

For verification of ensemble mean, the specifications in this table of the Attachment for variables, levels, areas and verifications should be used, <u>in addition 850hPa temperature should also be verified in the Extra-tropics</u>;

SPREAD

Ratio of standard deviation <u>of the ensemble</u> over RMS error of the Ensemble Mean averaged over the same regions and variables as used for the Ensemble Mean.

PROBABILITIES

<u>The reliability tables shall be exchanged in the same format as defined for the SVS long-range forecast (Table 5 or 6 in Attachment II.9).</u>
<u>Centres are encouraged to provide verification results at the maximum resolution in probability space (e.g. using the full membership of the ensemble)</u>,

List of parameters

PMSL ± 1, ± 2 standard deviation with respect to climatology (preferably each centre's own climatology)

Z500 with thresholds as for PMSL.

850 hPa wind speed with thresholds 10, 15, 25 m/s.

T850 anomalies with thresholds <u>± 2,</u>± 4, ± 8 degrees with respect to climatology (preferably each centre's own climatology)

Verified for areas defined for verification against Analysis.

Precipitation with thresholds 1, 5, 10, and 25 mm/24 hr every 24 hr verified over areas defined for deterministic forecast verification against observations (see current Attachment II.7, Table F of the Manual on the GDPS)
Observations for EPS verification should be based on the GCOS list of surface network (GSN).

Scores

<u>*(All of these will be derived from the reliability tables described above)*</u>

Brier Skill Score (with respect to climatology) *(see definition below*)*

Relative Economic Value (C/L) diagrams

Reliability Diagrams with frequency distribution

Note:

Annual and seasonal averages of Brier Skill Score at 24, 72, 120, 168 and 240 h for Z500 and T850 should be included in the yearly Technical Progress Report on the Global Data Processing system.

*The Brier score is most commonly used for assessing the accuracy of binary (two-category) probability forecasts. The Brier score is defined as:

$$PS = \frac{\sum \left(F_{ij} - O_{ij}\right)^2}{N}$$

where the observations O_{ij} are binary (0 or 1) and N is the verification sample size. The Brier score has a range from 0 to 1 and is negatively-oriented. Lower scores represent higher accuracy.

The Brier Skill Score is in the usual skill score format, and may be defined by:

$$BSS = \frac{PS_C - PS_F}{PS_C} \times 100 = \left[1 - \frac{\sum_{ij} \left(F_{ij} - O_{ij}\right)^2}{\sum_{ij} \left(C_{ij} - O_{ij}\right)^2}\right] \times 100$$

where the C refers to climatology and F refers to the forecast.