WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS
OPAG ON DATA PROCESSING AND FORECASTING SYSTEMS

REPORT OF THE

MEETING OF THE EXPERT TEAM ON ENSEMBLE PREDICTION SYSTEMS

TOKYO, 15-19 OCTOBER 2001

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Summary

Ten experts representing nine countries and ECMWF, and six observers from JMA participated in the meeting. Experts gave presentations on the status of operational EPS activities and related research in their respective Centres. Together, Medium Range Ensemble Forecasting and Short Range Ensemble Forecasting are viewed as integral in a "seamless suite" of products. These systems enable estimates in the forecast confidence of specific weather threats, first, in the context of the larger-scale circulation pattern and associated weather at medium range and, then, in the details of the weather system and sensible weather in the short range. The meeting noted that there is a growing interest in EPS and in response, the numbers of EPS producers and users have been increasing. The focus of targeted meteorological phenomena in use of EPS products now includes not only extra-tropical systems but also emphasis is being given to tropical phenomena and mesoscale features. Application of short-range regional model EPS to weather forecast is being used on a quasi-operational basis. Application of medium-range EPS to National "Early Warning System" are operational in many Centres.

The Team considered that the EPS products could be classified in three types of products:

- Text and graphical products on Internet;
- Gridded derived products such as probabilities of exceeding various thresholds, ensemble mean and spread; cyclone tracks;
- full model fields of ensemble members.

The Expert Team defined derived products for short-range and medium-range forecasting recommended for routine dissemination including direct model fields of the EPS to be made available to requesting WMO Members. The Team defined also a list of products for extended and long-range forecasting, but wished this list to be reviewed by other experts specialised in long-range prediction. The FM-92 GRIB Edition 2 format was considered by the Team to be the most practical code for exchange of gridded EPS data. Where GTS will not be able to handle the amount of EPS data, fields can be transmitted by other available means such as FTP services on INTERNET, dedicated lines or satellite distribution systems. Lat/long position of tropical cyclone tracks could be transmitted using BUFR code. In the EPS producer Web site, a catalog of EPS fields and products should be available. Documentation on the EPS system should be provided: time of availability of products, version number of EPS system, last modifications, perturbation method, etc. Verification scores should also be provided.

The Team arrived at a recommendation for a list of verification products to be exchanged between GDPS Centres producing EPS data. The list concerns short-range and medium-range EPS products. As a simple extension of current NWP scores defined in the Manual on GDPS, it was proposed that standard verification measures of the EPS be exchanged monthly. A subset of scores should be included in the annual GDPS Technical Progress Report. Performance measures recommended were:

- Ensemble mean verified in the same manner as deterministic NWP forecasts;
- Measures of spread (standard deviation) provided for the same parameters as the ensemble mean;
- Reliability tables for event probabilities.

From the reliability tables, key measures, which can be derived include: reliability diagrams and associated frequency distributions, Brier skill scores, Relative Operating Characteristics (ROC) and economic value diagrams. It was considered also desirable to verify precipitation against observations.

Finally, the Team agreed that implementation of coherent education and training was critical for realising the benefits of EPS. The Team was pleased to know that WMO was already programming an introduction to the Ensemble Prediction subject in its usual GDPS regional training seminars. The Team recommended that one or two week seminars entirely devoted to EPS should be organised. The production of guidance material on use of Ensemble Prediction products by forecasters, which could be a new chapter in the Guide on the Global Data Processing System, was also required.

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1. OPENING OF THE MEETING

1.1 At the kind invitation of the Japan Meteorological Agency (JMA), the meeting of the CBS Expert Team on Ensemble Prediction Systems, chaired by Dr Nobuo Sato (Japan), was held in the JMA Headquarters in Tokyo, 15-19 October 2001. Mr Koji Yamamoto, Permanent Representative of Japan with WMO and Director General of JMA opened the meeting and extended a warm welcomed to the participants. He noted that we have witnessed in the last decade development of Ensemble Prediction Systems to a flourishing activity. The methodology and utilization of EPS have developed rapidly and EPS products are now produced by many National Meteorological Services. He informed the meeting that the JMA started to develop EPS almost a decade ago and one-month EPS was made operational in 1996 then one-week EPS was made fully operational in March this year. He noted that JMA recently started to issue reliability measure A, B, C, which is attached to each one-week categorical forecast. He recognized that the capability of EPS is not yet fully exploited in terms of utilization both by the general public and specific users. He also hoped the application of EPS be extended to prediction of severe weather phenomena, which is bread and butter of every NMS. He wished the meeting success and that the discussions in this meeting will contribute to the further development and utilization of EPS by WMO members.

1.2 Mr Morrison Mlaki, Chief Data Processing System Division, on behalf of Professor G.O.P. Obasi, Secretary General of WMO, thanked Mr Yamamoto for his kind welcome, hospitality and the information he gave to the Team in his opening address. He thanked JMA for hosting the meeting and the excellent arrangements and facilities made available for the meeting. He expressed his appreciation to the chairman and members of the Team for their efforts in the work of the Team and the efforts they will devote during the week to assure relevant outcome and deliverables to meet CBS expectations. He noted that one deliverable expected of the Team was to review and report on operational use of EPS to forecast severe weather and extreme events as a response to protection of life and property and contribution to social economic development of communities. He further noted that other related issues to be considered focus on development of procedures and recommendations on standards which will facilitate meeting the objective of making widely available EPS products to Members for their beneficial use. In particular in their efforts in forecasting and issuing warnings of severe weather and extreme events and other social economic activities. He emphasised the need for the meeting to address and recommend solutions to the very important issues related to modalities for provision and contents for education and training of users of ensemble products.

2 ORGANIZATION OF THE MEETING

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

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

3. REPORT ON THE OPERATIONAL USE OF EPS, TO FORECAST SEVERE WEATHER AND EXTREME EVENTS

3.1 Experts gave presentations on the status of operational EPS activities and related research developments and future plans in their respective WMCs/RSMCs/NMHSs, for short-range and medium-range forecasting in general and in particular for severe weather and extreme events. Together, Medium Range Ensemble Forecasting and Short Range

Ensemble Forecasting are viewed as integral in a "seamless suite" of products. These systems enable estimates in the forecast confidence of specific weather threats, first, in the context of the larger-scale circulation pattern and associated weather at medium range and, then, in the details of the weather system and sensible weather in the short range. The meeting noted the following trends:

- Presentations observed that there is a growing interest in EPS and in response, the number of EPS producers and users has been increasing.

- The focus of targeted meteorological phenomena in use of EPS products now includes not only extra-tropical systems but also emphasis is being given to tropical phenomena and mesoscale features.

- Application of short-range regional model EPS to weather forecast is being used on a quasi-operational basis.

- Various application products from EPS are being developed and some of them are made available on the WMCs/RSMCs/NMHSs web sites (Confidence indices, probabilities, economic value estimates, calibrated site specific end products, severe weather related parameters).

- Initial objective assessment demonstrated that the Met Office (U.K.) experimental "Poor person Ensemble Prediction System" (PEPS) shows potential for short-range use in comparison with the operational ECMWF EPS. Experiments with higher resolution, more members and more weather parameters are proceeding. If PEPS becomes operational, UKMO indicated it would make available PEPS products to WMO Members.

- Application of medium-range EPS to National "Early Warning System" are operational and being further developed at some RSMCs /NMHSs.

- Increase in number of members of EPS and higher model resolution, more frequency of runs a day and relevant post processing are desirable for enhancing severe weather forecasting.

- As the amount of EPS grid fields will increase, the need for additional bandwidth in telecommunication and application software to extract information will also increase.

- Implementation of coherent education and training activities is critical for realising the benefits of EPS.

3.2 A summary of the presentations is given in the annex to this paragraph.

4. REVIEW AND ESTABLISH THE LIST OF EPS FIELDS AND PRODUCTS THAT SHOULD BE DISTRIBUTED.

4.1 The Team considered the list of products, which should be made available to NMCs, which do not have the capability to run EPS. It was recalled that CBS XII, taking into account the views of the ICT on DPFS, and the request of EC-LII regarding making ensemble prediction system products more widely available, urged those Members producing global ensemble products to make them available. The CBS stated that a basic list of EPS products to be distributed should at least include:

- Probability of precipitation;
- Ensemble mean at 500 hPa;

- Some indication of variability (e.g. spaghetti plots, spread).

Ranges to be covered are at least D4 (96 h) to D7 (168 h).

4.2 The Team agreed that this list was originally proposed in 1999; and since then EPS systems have been further developed and experience on the use of EPS has grown. The Team concluded that a new list of products to be made available was required. One could classify products in two levels:

(i) basic set of simple products which WMO members can all receive and use directly.
(ii) more complex set which NMCs could use to generate their own products – these would require some negotiation on exactly what was required because there is a vast range of products which could be possible.

There were also three types of products:

(i) Text and graphical products on Internet;
(ii) Gridded derived products such as probabilities of exceeding various thresholds, ensemble mean and spread;
(iii) full model fields of ensemble members.

The Expert Team defined derived products recommended for routine dissemination and direct model fields of the EPS to be made available to requesting WMO Members. The list of products is given below.

4.3 List of EPS products for distribution**:**

I. PRODUCTS FOR SHORT RANGE AND MEDIUM-RANGE:

1) GLOBAL PRODUCTS FOR ROUTINE DISSEMINATION

(Period for all fields: forecast D+0 to D+10 (12 hour intervals) at highest resolution possible)

- Probabilities of:

- Precipitation exceeding thresholds 1, 5, 10, 25 and 50 mm/24 hr
- 10m sustained wind and gusts exceeding thresholds 10, 15 and 25 m/s
- T850 anomalies with thresholds -4, -8, +4 and +8 degrees with respect to a reanalysis climatology specified by the producing Centre

- Ensemble Mean (EM) + spread (standard deviation) of Z500, PMSL, Z1000, vector wind at 850 and 250 hPa

- Tropical storm tracks (lat/long locations from EPS members)

2) MODEL FIELDS

Full set or subset of EPS members variables and levels for requesting WMO Members for specific applications.

II. PRODUCTS FOR EXTENDED RANGE AND LONG-RANGE:

The team discussed also the requirements for extended range and long-range products and defined a set of products which could be provided by GDPS centres to other NMCs for their applications. It found however that the expertise of the group was limited to appreciate fully the real requirements for long-range prediction and consider that the list proposed, if it was a minimum to be transmitted, may need to be reviewed by other experts specialised in long-range prediction.

Ensemble Means anomalies/Spread:

One week averages for first month, monthly means thereafter (all anomalies with respect to model climate) for:

- Tropical SST
- Standard ENSO Indices
- Precipitation, Z500, Z1000, T850 and surface temperature

Probabilities:

Terciles: above, below, normal (with respect to model climate) of:

- Precipitation
- Z500
- Z1000
- T850 and surface temperature

Model fields:

- Full set or subset of EPS members variables and levels for requesting WMO Members for specific applications.
- Relevant post processed fields from sequence of daily output (e.g., indices of monsoon onset, droughts, tropical storm activity, extratropical storm track activity (see extract of statement of requirements by the Inter-Commission Task Team on Regional Climate Centres, Geneva 30 April-3 May 2001, in annex to this paragraph).

5. PROVISION OF STATEMENT OF REQUIREMENTS TO THE ISS FOR THE DISSEMINATION OF EPS PRODUCTS

5.1 The FM-92 GRIB Edition 2 format was considered by the Team to be the most practical code for exchange of gridded EPS data.

5.2 The volume of set of products recommended for routine transmission above (see paragraph 4.3,I,1) will probably be about 50 megabytes/day of EPS products (about 7 MB per day per centre at 2.5x2.5 degree global grid). If divided into quadrants, the amount necessary to disseminate will be reduced, the whole globe being not required by every user. The fields, direct output of the model of one centre, may have a volume of several hundreds MB/day. Where GTS cannot handle this amount, EPS fields can be transmitted by other available means such as FTP services on INTERNET, dedicated lines, etc.. Satellite distribution should also be considered.

5.3 Text and graphical products (e.g. spaghetti diagrams, probabilities of weather elements) can generally be accessed on Internet.

5.4 Lat/long position of tropical cyclone tracks could be transmitted using BUFR code. However, some adjustment will be necessary for having the ensemble set of tracks identified and included in one single BUFR report. The ET requested the ET on Data Representation and Codes to finalize common sequences in BUFR Tables for that purpose.

6. DEVELOPMENT AND TEST OF PROCEDURES FOR EXCHANGE OF EPS GRIB/BUFR DATA

6.1 The Team agreed that the FM-92 GRIB Edition 2 format shall be used for the official exchange of EPS fields and GPV products. GRIB 2 software should be available for distribution during 2002. The EPS data producer should add an EPS version number with the products (e.g. octets 13,14 in GRIB 2). New-Zealand and Morocco were keen to receive products in GRIB 2 as soon as possible, when a GRIB 2 decoder will be available. ECMWF will produce operationally EPS data in GRIB2 in 2002. NCEP intends to produce operationally EPS data in GRIB2 during 2002.

6.2 WMO should maintain a WEB page with URLs for sources of EPS information. WMO Secretariat should be informed by Member States of web site URLs and any changes in order to maintain the list.

6.3 In the producer Web site, a catalog of EPS fields and products should be available. Documentation on the EPS system should be provided: time of availability of products, version number of EPS system, last modifications, perturbation method, etc.. Verification scores should also be provided.

7. PROPOSALS OF OVERALL EPS OUTPUT PRODUCTS - UPDATES TO APPENDIX II-6 OF THE MANUAL ON THE GDPS

The Team examined the functions and products listed in the GDPS Manual for GDPS Centres (WMCs, RSMCs and NMCs). The Manual did not mention Ensemble Prediction Systems. The Team recommended a set of updates to the Manual as listed in Annex to this paragraph, taking into account the coming of age of EPS. It was also recommended to add in the Appendix II-6 (paragraph 4. FORECASTS) of the Manual the list of EPS products defined in paragraph 4.3 of this report.

8. DEVELOPMENT OF STANDARD VERIFICATION MEASURES OF EPS

8.1 The Team had a long discussion to define the list of EPS verification products to be exchanged monthly, taking into account all the different opinions expressed, but finally arrived at a recommendation for a list of verification products to be exchanged as defined in Annex to this paragraph. It was recalled that this list was the set of verification products that should be exchanged, as much as possible, between GDPS Centres producing EPS data. The list concerns short-range and medium-range EPS products. As a simple extension of current NWP scores defined in the Manual on GDPS, it was proposed that standard verification measures of the EPS be exchanged monthly. A subset of scores should be included in the annual GDPS technical progress report. Performance measures recommended are:

- Ensemble mean verified in the same manner as deterministic NWP forecasts;
- Measures of spread (standard deviation) provided for the same parameters as the ensemble mean;
- Reliability tables for event probabilities.

8.2 Area definitions for verifications against analysis should be the same as those used for current standard NWP scores. Verifications against each centre 's own analysis should be exchanged. From the reliability tables, key measures, which can be derived include: reliability diagrams and associated frequency distributions, Brier skill scores, Relative Operating Characteristics (ROC) and economic value diagrams.

8.3 It was considered also desirable to verify precipitation against observations. The

GCOS Surface Network or an agreed upon subset will be used for this purpose.

8.4 Other measures of performance (Ranked Histograms, Continuous Ranked Probability Scores) or other parameters to be verified against observations (2m-temperature, 10m-wind) although useful, should probably not be considered at this early stage but will be reviewed in future.

9. EDUCATION AND TRAINING OF USERS OF ENSEMBLE PRODUCTS

9.1 The Team was informed that the WMO Executive Council (EC LIII) particularly welcomed that the Commission for Basic Systems (CBS), in collaboration with regional associations, put emphasis on training in severe weather forecasting and enhanced use of EPS products and definition of related regional requirements. The CBS had recommended four types of EPS training as follows:

- Regional WMO workshops to explain the EPS approach, its usefulness, and its limitations. It should concentrate on the products, which are available. These workshops would be mainly useful for those who intend to use EPS end products;

- Technical cooperation type of training for those who intend to make their own products and/or who will need more specific training about products or the methodology of the forecast. Training could be organized on individual request or through WMO voluntary cooperation arrangements;

- Workshops or seminars developed by Centres running EPS. These centres are encouraged to open them to a wide range of participants. Co-sponsorship with WMO should be considered.

- Universities engaged in the training in meteorology, should be encouraged by Members to include topics related to EPS in their programme**.**

9.2. To assure coordinated implementation of initial procedures for making available EPS products, the CBS endorsed the idea that the WMO Secretariat should plan for regional workshops with focus on EPS training under the appropriate programme of WMO. In parallel to the project of dissemination of ensemble products, training of forecasters to make the best use of these new products is necessary. CAL (Computer Aided Learning) modules should be developed. Roving seminars and training workshops should be organized.

9.3 The Team was pleased to know that WMO was already programming an introduction to the Ensemble Prediction subject in its usual GDPS regional training seminars. The Team recommended that one or two week seminars entirely devoted to EPS should be organized. If possible, these seminars should include practical sessions including case studies and products tailored to specific regions. The training should start with medium-range forecasting, with emphasis on severe weather prediction. It was pointed that targeted trainees should be selected persons who can make good use of products available operationally now, rather than short-range forecasters for whom suitable tools may not yet exist. It was suggested that it would be very profitable for the trainees to be addressed documentation to study before the training session. It was agreed that the training should comprise a tropical module and an extra-tropical module. The Team recommended that WMO should organize 1 to 2 of these regional training seminars per year.

9.4 The Team agreed that the training objectives on EPS should be:

- Motivate weather services in the benefits of EPS;
- Instruct on EPS concepts, principles, products and their applications;
- Training on availability, access, visualization and processing of EPS information;
- Provide participants with sufficient material to pass on this information within their services.

9.5 The Meeting agreed that trainers of WMO RMTC centres and other meteorological training institutions should be targeted also.

9.6 Compression of the EPS information is essential for its use. The team thus recommended to promote workshops and bilateral co-operation in order to implement visualisation and post-processing methods for those who intend to build their own products from EPS data.

9.7 The production of guidance material on use of Ensemble Prediction products by forecasters, which could be a new chapter in the Guide on the Global Data Processing System, is also required. The team recommended that a consultant contracted by WMO should gather material and write guidance on the methodology for the use of EPS products by forecasters for medium-range, and perhaps later for short range forecasting.

10. CLOSURE OF THE MEETING

The meeting of the Expert Team on Ensemble Prediction System was closed by the Chairman at 17.30 on 19 October 2001.

ANNEX TO PARAGRAPH 3.2

REPORTS OF EXPERTS ON THE EPS ACTIVITIES OF THEIR RESPECTIVE CENTRE

OPERATIONAL ENSEMBLE PREDICTION AT THE NATIONAL CENTERS FOR ENVIRONMENTAL PREDICTION (NCEP), U.S.A. (Steve Tracton)

BACKGROUND

1. The National Centers for Environmental Prediction (NCEP) now runs operationally twice per day 11-member ensembles with its Global Medium Range Forecast model for medium-range (3-14 days) predictions (MREF) and 10-member, multi-model ensembles with its Short Range Ensemble Forecast (SREF) system for short ranges (0-3 days) over North America and environs. Together, MREF and SREF can be viewed as integral in a "seamless suite" of products that enable estimates in the forecast confidence of specific weather threats, first, in the context of the requisite larger-scale circulation pattern at longer ranges and, then, in the details of the relevant weather system and associated sensible weather in the short range.

2. The current operational MREF configuration consists of a control plus 10 perturbed forecasts (11 members) run twice per day (00 and 12GMT). The control and perturbations are run with T126 resolution through 3.5 days and then extended to 16 days at T62. Perturbations to initial conditions are derived using the breeding of growing modes (BGM) approach. MREF products are available on the NCEP Web site (http.//SGI62.WWB.NOAA.GOV:8080/ens/enshome.html), which includes spaghetti diagrams of selected 500 hPa height contours, probability of precipitation for various threshold amounts, and relative Measure of Predictability charts. In addition to the Web sites, MREF data in GRIB format can be accessed via anonymous FTP. That data consists of each ensemble member at all forecast hours for selected levels and parameters, as well as mean/spread charts and probability of precipitation.

3. The SREF consists of 10 members run twice per day, 5 members each generated with the Eta and RSM regional models to 63 hours from 09 and 21GMT. Perturbations to initial conditions are generated with breeding as with MREF but in the context of the regional models. All forecasts are with 48 km versions of the two models. Products are available from the Web (http://lnx48.wwb.noaa.gov/SREF/SREF.html) and anonymous FTP. They cover a wide range of standard parameters and levels, including probabilities of precipitation, as well as for parameters specifically related to mesoscale features, e.g., Lifted Index and Convective Available Potential Energy (CAPE).

APPLICATIONS

4. The basic premise of ensemble prediction is that forecasting is stochastic. Recognizing, accepting, and exploiting this is possibly one of the most challenging aspects of ensemble prediction given the long history, psychology, and product suites predicated on "deterministic thinking". Growing pains are inevitable and understandable, but they can be minimized with appropriate educational vehicles and training. One major consideration in this regard is development and familiarity with ensemble based guidance. The second major consideration is how one conveys information to users on the nature and implications of the uncertainties in forecasts. At present, forecast product suites are largely deterministic. Ensembles provide a tool for forecasters to specify a degree of confidence and to assess the relative likelihood of alternative possibilities with regard to that prediction. The next step must be to modify the products issued to explicitly reflect that information. One can start with a semi-quantitative message or simple graphic expressing the confidence, e.g., low/high of the "best bet' single prediction. From there one could add explicit statements or graphics of the alternative scenarios and their relative likelihood and, then, proceed to full consideration of quantitative probability estimates. In the end, just how this is done will be user dependent – general public, weather sensitive businesses, emergency management, etc..

5. With regard to MREF, NCEP,s Hydrometeorological Prediction Center (HPC) forecasters issue a deterministic graphical forecast product based, for example, on consideration of whether a particular scenario is supported by a highly populated cluster. However, forecasters generally include discussion in the associated worded product. The role of the ensembles in their reasoning and especially, when significant weather is being considered, acknowledge the possibility of weather events that are less likely than suggested in the official forecast. Also, based on qualitative interpretation of ensembles, Climate Prediction Centre issues a THREATS assessment, which highlights over the days 3 to 14 any possible significant weather events and/or weather related impacts (e.g., east coast snow storms, drought, temperature extremes). In time, official forecast products will evolve to encompass more explicit and quantitative estimates of confidence, the relative likelihood of alternative outcomes, and probability fields. The exact nature and design will depend *crucially* on interaction between developers and users of these products. It is safe to say that ensemble based confidence estimates and probabilities show greater value over the long run of probabilistic versus deterministic prediction of extremes. That value, though, is highly dependent on proper interpretation and use of the probabilistic (in contrast to single value) forecasts. Thus, for example, one must consider issues related to conveying and using information of a low probability, but potentially significant weather events such as a severe blizzard or wide spread flooding rains.

6. SREF has been available routinely on a timely basis within NCEP only since June, 2001. The basic ideas on use of the MREF above apply equally well to SREF, except SREF is designed for regional models and shorter-term forecasts of smaller-scale features. Generally, the global system is intended to provide a broader-scale view at longer ranges of the possibilities, while the regional-model based system provides a more detailed picture as the event gets closer. Thus, for example, the MREF highlights prospects for impending weather scenarios in terms of the larger-scale circulation features and general aspects of associated sensible weather, while SREF focuses on the mesoscale details of systems and possibilities in the related temporal and spatial distribution of sensible weather elements.

7. SREF will be employed in much the same way as in generating the medium range predictions, i.e., as a tool in constructing the official deterministic graphic products with commentary on uncertainties and possible alternative scenarios left to the worded prognostic discussions accompanying the graphics. In addition to this general use of SREF, it will be a critical and necessary component in the HPC,s upcoming Winter Weather Experiment that begins November 1, 2001 and extends through early spring, 2002. The intent is to enhance the suite of products and services available from HPC to assist NWS field offices (WSOs) in delivering improved winter weather services to the public– especially to improve lead time and probability of detection in the prospects of winter storms and related temporal and spatial distributions of frozen versus non-frozen precipitation.

8. In two SREF case studies discussed, the bottom line is that in the face of the respective deterministic operational Eta forecasts to the contrary, the ensemble runs sent a distinct signal (“heads-up”) for the possibility of heavy snow in the Washington, DC region in the January 25-26th case and for the possibility of no snowstorm in the December 29-30th case. The key issue is whether these signals would have made a difference in the NWS operational (busted) forecasts. The question relates to the more general issue of whether and how to convey uncertainty in forecast products. The answer clearly depends upon the specific needs and requirements of users, which varies from the general interest of the “person on the street” to more sophisticated applications that can benefit from cost versus loss considerations as a function of user specific critical thresholds (“threshold of pain”), e.g., diverting aircraft from potentially affected airports. To fully exploit MREF and SREF, therefore, it is incumbent to educate both forecasters and users on the fundamental concepts and applications of ensemble prediction.

EPS AT CANADA-CMC (Louis Lefaivre)

HISTORY:

9. CMC EPS has been designed to produce medium-range (up to 10 days) global forecasts using a perturbation method based on data assimilation (Houtekamer et al 1997). Eight parallel data assimilation are run with perturbed observations and models (using different physical parameterisations). CMC EPS became operational in February 1998 with an 8 member ensemble at a resolution of T95 (~200 km). The number of members was doubled to 16 in August 1999 with the addition of the new model. In June 2201, the resolution of the members were increased to equivalent T149 (~150 km).

VERIFICATION:

10. The increased resolution EPS was run in parallel mode over a 3 month period (December 2000 - January 2001 - February 2001). During that period, the following verifications were performed:

- EPS mean of the geopotential 500 hPa RMS errors over Northern Hemisphere, as compared to the global deterministic CMC forecast (~100 km resolution) and to the spread in the ensemble. For the 3 month period, the higher resolution EPS RMS errors decreased between Day 1 to Day 8, while the spread in the ensemble increased at all lead times.
- Spread/skill relationship also shown an improvement until Day 7, according to a first order scheme proposed by Houtekamer (private communication).
- Probabilities of precipitation forecasts were verified over Canadian stations using Relative Operating Characteristics (ROC) curves. The area under the ROC curve showed improvement at all lead times until Day 8 for the 5 mm threshold. Results (not shown) were very similar for the 2 mm and the 10 mm thresholds. The 25 mm threshold probabilistic forecasts were not verified because of too little sample.

11. These verifications are proposed to be the basis of the standard verification measures for the EPS.

PLANS FOR CMC EPS:

(a) Analysis
The main EPS effort at CMC is concentrated on the development of an Ensemble Kalman filter (EKF) system (Houtekamer and Mitchell 2000), where a large number (~100 members) of perturbed data assimilation cycles will be running at the same time. The numerous trial fields thus produced will permit to calculate flow dependent model error statistics, thus eliminating the outdated Optimal Interpolation presently used in the EPS. The number of members in forecast mode can also be increased.

(b) Products
A confidence index (CI) for the medium range public forecast was tested using CMC EPS. This work was done in collaboration with a Météo-France trainee (Pithois et al 2001). Probability of precipitation (POP), based on perfect prog approach, can be issued for each individual member of the EPS. These POP were verified in cross validation mode over a 6-month period (June to December

2000) for 264 Canadian stations. The Brier scores thus obtained were then verified against variance terciles (spread in the ensemble). The spread/skill relationship shows a correct relationship for all lead times so that CI map can be displayed and used in plain language public forecasts. The tercile thresholds have to be refreshed every 90 day period. It is hoped to implement the 3 class CI (reliable, neutral, non-reliable) in the public forecasts to qualify the automatic forecast issued from the deterministic model.

EPS IN JAPAN METEOROLOGICAL AGENCY (Nobuo Sato)

12. Dr Nobuo Sato made a presentation on current status and development of EPS in JMA. JMA started to issue confidence index with three ranks to categorical forecasts up to a week ahead. The three ranks are in A, B, C: A for high confidence, B normal confidence and C low confidence (hit rate of categorical forecast is more than 70%, from 60% to 70%, and less than 60%, respectively). Dr Nobuo Sato stressed the fact that in East Asia the most significant severe weather events are generated mostly by typhoons and meso-scale convective systems along Baiu (Changma in Korea and Meiyu in China). One third of annual precipitation is brought by typhoons. Through the operational experience of EPS during the first summer season, application of EPS to typhoon track forecast was found to be feasible if the norm of the BGM perturbations to the south of 20N is increased.

13. The JMA mid-tem plan for NWP system upgrade was presented. It will emphasize EPS for typhoon track and meso-scale convective systems. The number of 9-day EPS members will be increased along with the increase in global model resolution (possibly TL499L60). With the same model, a 10 member EPS for 3.5 day typhoon track forecast from 00,06,12,18 UTC will be run. With regard to application of EPS to meso-scale convective systems (MCSs), the number of runs and model resolution will be increased from 4 times a day to 8 times a day and model resolution will be also increased from 10km with 40 levels to 5km mesh with 60 vertical levels. Lagged average forecast (LAF) will be adopted, because forecast performance falls off rapidly due to the inherent predictability of MCSs.

OPERATION OF ENSEMBLE PREDICTION SYSTEM AT KOREA METEOROLOGICAL ADMINISTRATION AT KOREA METEOROLOGICAL ADMINISTRATION (Woo Jin Lee)

14. The ensemble prediction system (EPS hereafter) was developed at Korea Meteorological Administration (KMA) based on the T106L21 version of global data assimilation and prediction system with 32 breeding vectors. The EPS runs once a day at 12 UTC for 10-day projection. An experimental EPS runs at 00 UTC with 16 breeding vectors. The ensemble mean forecast have higher accuracy of 5-10 percent in terms of RMSE errors than the conventional one for the medium range forecast because of the performance of the medium range system. Numerous products are generated including ensemble mean, standard deviation, and spaghetti plot, and provided to the forecasters in the form of web-based graphic. Basic products from EPS are internally used for short and medium-range forecasting at KMA, which can be accessed through Internet soon.

15. Centroid of ensemble or sub-cluster of ensemble is used at the moment for the interpretation of EPS product in the viewpoint of deterministic forecast. Collaborative research is going on with local university to refine the method in reference to Tube method. A probability of precipitation exceeding 5mm/12hours has been produced recently with the assumption that each ensemble member has equal likelihood of occurrence. Other elements such as temperature will be provided in probabilistic expression soon.

REGIONAL REQUIREMENTS

16. It is observed in the region (RAII) that there is a growing interest on EPS. The simple multi-ensemble approach in aspect of synopsis of multiple forecast charts are commonly used in operational forecasting centre. The EPS product in GPV format is at the moment rarely exchanged among NMCs in the region, except that few NMCs exchange GPV data with UKMO through the poor man's ensemble project. However, some EPS products such as probability of precipitation can be accessed through Internet (e.g. NCEP homepage), and partially used as a reference in some NMC.

17 High impact weather such as typhoons, heavy rainfall and strong wind is recognized as one of urgent area for improvement in forecasting skills. Recently super ensemble approach draws lot of attention among NMCs in the region to improve their track forecasts based on the multiple tracks accessed through GTS or Internet.

18. Many NMCs in the region ask for more detailed NWP products from more centres to reduce the uncertainty involved in numerical prediction. A multi-model ensemble approach may be also an efficient tool for the short-range weather forecasting including meso-scale weather phenomena. Considering the communication load and data volume, the multi-model ensemble in the regional domain is economical and easy to implement as a first step.

19. It is necessary to define standard format for exchange of GPV data and for the standardization of verification procedures. The end users in the region have very limited knowledge of how the EPS products are produced, how to use it in operational environment, how to access reliability of the product, and how to evaluate its value. Training seminars and workshops on the subject are urgently needed in the region.

TOWARDS IMPLEMENTATION OF SHORT RANGE ENSEMBLE PREDICTION SYSTEM IN MOROCCO (A.MOKSSIT)

20. In countries like Morocco the need for introducing a short range EPS came from the following question: how to improve the existing operational numerical weather prediction suite based on a limited area model ALADIN (16.5 km horizontal mesh, 31 levels) which runs twice a day on the computing facilities at Casablanca (54 Gflops with the New IBM RS6000). In fact the model even if it has improved considerably the quality of forecast presents some weakness in special situations (southwest wind) and over estimates convective rain.

21. The feasibility study of introduction of Short range EPS started by a cost/effective analysis that shows the importance of the introduction of probabilistic forecasts that can allow Decision Makers to manage the risk in case of extreme event. There are four principal components that contribute of the cost of the EPS :

- The construction of the initial perturbations.
- The resolution of the integrating model.
- The number of ensemble members.
- The length of the integration.

22. The EPS is undoubtedly computationally expensive. A crucial question is whether such an increase can be justified. What is really the value of the EPS? Contrary to the single deterministic forecasts, ensemble forecasts should be capable of estimating the risk of extreme weather more reliably.

23. How can this be quantified? To evaluate the socio-economic impact of the EPS, we consider a model used to estimate the potential economic value of the weather forecasts :

- A user can suffer a loss L if a meteorological event E occurs and no precautionary action is taken.
- The loss is avoided if precautionary action at cost C is taken.

Deterministic forecasts:

- Take action when E is forecast.
- Don't take action when E is not forecast.

It's a simple but unreliable criterion for deciding when to act.

Probability prediction:

- A user with small C/L should decide always to take precautionary action, except when the probability of E is sufficiently small
- A user with C/L close to unity should only take precautionary action when the probability of E is sufficiently high.

24. To start measuring the key elements of a feasibility study we have to run experiments with ALADIN coupled with ARPEGE comprising 13 members. We willl perturb the temperature using the previous FG (-3, -6, -9, -12 hours fcst verifying at the same time of the Initial conditions: 39 hours in total). The purpose is to check whether there is an ability e to run the EPS and also to check if this has any potential added value from Short Range EPS. The time of computing of the experiment was evaluated (13 min (anlysis+forecast)*13 members=169min) and the preliminary indication shows the ability to introduce a probabilistic solution for an southwesterly situation. The important work will come during a phase where strong collaboration with specialised centres will be needed.

USE OF EPS IN NEW ZEALAND TO FORECAST SEVERE WEATHER (Tony Simmers)

25. In December 2001 MetService will begin issuing a Severe Weather Outlook for days 3 to 6 based on a combination of the data received from the NCEP EPS and the deterministic models from NCEP, UKMO, and ECMWF.

26 The forecast is for the likelihood, expressed as one of three levels, that conditions will meet or exceed 100 mm in 24 hours, wind gusts over 60 kt, or 10 cm of snow in 24 hours. It will take the form of a chart showing areas where severe weather is expected.

27. The forecasters will subjectively assign the likelihood of an event, having looked at the EPS products, deterministic models, and factoring in their experience of the mesoscale aspects of typical synoptic systems.

OPERATIONAL USE OF EPS, TO FORECAST SEVERE WEATHER AND EXTREME EVENTS IN SWITZERLAND (P. Eckert)

INTRODUCTION AND OBJECTIVES

28 As a country not producing its own EPS, we mainly concentrated on postprocessing and verifification of the ECMWF EPS. Our main concerns first go to group properly the information that will be presented to the operational forecaster so that the relevant information can be extracted in a minimum of time. This includes the definition of a confidence index. There is also a need for downscaling the weather elements, especially when severe events are addressed. Probabilities can also be derived; they have to be both reliable and show resolution (values close to 0 or 100%).

STATIC CLUSTERING

29. Clustering of EPS members is usually done dynamically by grouping in some way all members of the ensemble. We suggest instead to use a fixed classification of meteorological situations and to fit the members of the ensemble to that classification. This

classification can be done in any way. We proposed since 1994 to classify weather patterns with the help of a neural network. The learning of 20 years of 500 hPa heights and 850 hPa temperature fields lead to the definition of 144 different weather types. Each member of the ensemble can then be attributed to one of this weather type so that the dispersion can be seen at one glance. The geometrical entropy of the distribution can also be computed as a measure of the spread of the ensemble. A linear combination of the entropy leads to the definition of a confidence index ranging from 0 (no confidence) to 10 (good confidence).

PROBABILITIES OF WEATHER ELEMENTS

30 Each unit of the classification can be provided with the probability of a weather element to be realised as for instance precipitation bigger than 5mm/24h or wind gusts bigger than 20m/s. This is done on a climatological basis by counting the amount of times the given event is realised in each unit. The EPS probabilities can then be determined by multiplying the frequency a unit is touched by the intrinsic weather element probability of this unit. It turns out that these probabilities are very reliable (good correspondence between forecasted probability and observed frequency) but that they miss resolution (they often do not differ a lot from climatology). Severe events are also too rare to be captured by this method. nyhow, for events like precipitation > 1 mm or relative sunshine < 25% the forecasts are significantly better than climatology up to day 6 or 7.

SEVERE EVENTS

31. As stated above, this type of post-processing is limited in the cases of severe events. One way out could be to improve the statistical post-processing, by targeting the learning of synoptic situations to a specific event on a specific place. This can for example be realised by so called supervised learning. On other way is to realise the downscaling by the means of a limited area model (LAM). The idea is to run the EPS up to day D, to realise a clustering at this stage, to choose one representative member of each cluster and to run a LAM from D+24 or D+48 using the chosen member for the initial condition and the lateral boundary conditions. This approach showed to be promising, but it is quite expensive in computer time.

RECOMMENDATIONS

- Show synthetic products for use of forecasters:
  - Spaghetti plots
  - Ensemble mean and spread
  - Few alternative forecasts (most probable, extremes)
  - Confidence index
  - Probability maps

- EPS meteograms

- Downscaling of weather parameters
  - Show probabilities, distributes probabilities to customers, generate probabilities into products.

- Upscaling of observations (verification)

For severe events, one can use the following strategies:

1. Direct Model Output (DMO) or DMO with a higher resolution model
2. DMO with respect to the model climate (EFI)
3. Statistical interpretation (as above)
4. Statistical interpretation targeted on the event (as proposed, supervised learning)

5. Mixtures of 1 and 3 or 4
6. LAM EPS (as described above)

Appendix

PROBABILITY OF PRECIPITATION in % QUANTITY IN mm/24h
RUN: Wed.26.Sep

GENEVE	>=0.1	>=1	>=5	>=10	>=20	>=50
Thu.27.Sep	0	0	0	0	0	0
Fri.28.Sep	0	0	0	0	0	0
Sat.29.Sep	57	44	13	4	4	0
Sun.30.Sep	57	41	25	19	7	1
Mon.01.Oct	58	33	13	11	5	0
Tue.02.Oct	39	21	7	4	2	0
Wed.03.Oct	37	24	13	7	3	0
Thu.04.Oct	40	29	14	9	5	0
Fri.05.Oct	27	17	8	6	2	0
Sat.06.Oct	28	21	11	6	3	0

POST-PROCESSING OF ECMWF EPS OUTPUT AT UKMO (Ken Mylne)

32. Two types of post-processing at the Met office were described:

(i) Calibrated site-specific ensemble probability forecasts
(ii) Early Warnings of severe weather

Calibrated site-specific products

33. Probabilities of temperature, precipitation and wind-speed are generated for local sites from the EPS. In the past these were produced with direct-model output interpolated from model grids to the local sites. This had a lot of bias problems and probabilities were generally over-confident, with insufficient ensemble spread. Recent developments have improved this in two stages.

34 The first stage was to apply a Kalman Filter MOS (KFMOS) system to improve local site interpolations from the model grids. The KFMOS relates observations to model analysis (or short-period forecasts) fields statistically, and derives regression relationships which can be used to derive forecast surface weather parameters from model fields. Relationships are derived from statistics accumulated over the past 60 days, updated daily, for each site. KFMOS provides several advantages:

- It corrects for local site-specific biases such as over-prediction of 10m wind-speed at night. (KFMOS will not correct biases due to model drift during the forecast, as it uses the same correction, based on analysis fields or very short-period forecasts, for all forecast lead-times. Use of correction by forecast time would damage the useful spread of the ensemble.)
- KFMOS is used to statistically derive Maximum and Minimum Temperatures, whereas previously temperatures were only available at 00 and 12 UTC.
- The KFMOS statistics applied to derive temperature and wind-speed each take several model parameters as input. For example the KFMOS for Maximum Temperature uses model 2m temperature, 10m wind-speed and wind-direction. Thus for a coastal site, for

example, it can make some allowance for whether the wind is coming from the land or the sea.

35. The second stage was to calibrate the probabilities generated, to correct the over-confidence. Calibration is based on Rank Histograms, which allow the ensemble members to be re-weighted to reflect how well the EPS covers the forecast uncertainty. This results in calibrated PDFs (probability density functions) with large peaks at the ends due to large weights from the outlier bins of the rank histograms. Since outlier bins represent occasions when the observation falls right outside the spread of the EPS, this probability needs to be redistributed outside the range of the ensemble. This is done by fitting a Weibul distribution function to the distribution of how far the observations lie beyond the extreme EPS member. This process widens the distribution and greatly reduces the large peaks, although it does not eliminate them completely.

36 Verification was shown which illustrates that the KFMOS greatly reduces the forecast biases, and that the calibration (applied after KFMOS) successfully corrects the over-confidence. Results are generally good, but less successful for precipitation. This system is now operational and can provide high-quality probability forecasts for any site for which observations are available. (Calibration is currently only available in the UK, but is planned to be extended to Europe and N. America.

Early Warnings of Severe Weather

37. This project aims to generate Early Warnings of severe weather in support of the UK National Severe Weather Warning Service (NSWWS). NSWWS Early Warnings should be issued up to 5 days in advance when the probability of an event “somewhere in the UK” is 60% or more. In addition to an overall UK probability, local probabilities are given for 12 UK regions. Warnings are issued for the following events:

- Severe Gales - gusts of 70 mph or more
- Heavy Snow - 2cm/hour or more for at least two hours
- Blizzards/drifting - snow with winds of 30 mph or more
- Heavy rain - at least 15mm within a 3-hour period

38. These events are very demanding for an NWP model, and proxy events had to be defined to represent these in the model output. A system for scanning the ensemble and estimating probabilities of each of these events was run in an operational trial during the autumn and winter of 2000/01. Alerts were issued to forecasters when forecast probabilities of severe weather exceeded 20% and recommendations to issue warnings at over 60%. Early Warnings from the system were verified against Flash Warnings which are issued for the same events at very short notice when forecasters have a high degree of confidence. Verification is difficult because of the small samples of severe weather, but some conclusions could be drawn.

39 Verification showed that the EPS forecasts performed much better at day 4 than at shorter lead-times – this may have been caused by a fault in the EPS at the time the experiments were run – this will only be known after the coming winter season. Forecasts were seriously over-forecasting severe weather in the operational system, but have been used to re-calibrate the system for future use. After re-calibration the verification shows potential for some useful probability information, but again this can only be tested with independent data over the coming winter.

PEPS Project

40 The PEPS (Poor Mans Ensemble Prediction System) project was started after the December 1999 storms in Europe which showed that there was still a serious risk that a major storm development could be missed by the best deterministic models. The idea is to combine output from different NWP centres’ models to form an ensemble which might be

used for short-range ensemble prediction, with particular interest in risk assessment for severe weather.

41. In the initial phase data were taken daily from those distributed freely on the GTS. Many of these fields are only distributed at low resolution (5x5° lat/long), and only selected parameters are available: H500 and PMSL. Data from the following NWP centres were taken: ECMWF, Met Office, Meteo-France, DWD, NCEP, JMA and BoM. In the case of ECMWF, both the High-resolution deterministic model and EPS Control runs were used; in addition to the operational Met Office forecasts, two additional runs using a lower resolution version of the model and started from Met Office and ECMWF analyses were also used. Six perturbed members of the ECMWF EPS were included to assess what benefits are available by incorporating some singular vector perturbations. Different configurations of the PEPS were formed by 15 different combinations of these models. Only combinations of models and model runs, which could be available on operational time-scales, were included. Data were collected over 126 days. PEPS forecasts were verified against the ECMWF operational analysis and results compared with the ECMWF EPS.

42. Brier Score results showed that the PEPS gave better probabilities over the northern hemisphere than the ECMWF EPS at 24, 48 and 72 hours – Brier skill at 24 hours was quite high, around 0.25, and was good for a range of PMSL thresholds from 970 to 1030mb. Results in the southern hemisphere were much less good – this is believed to be because (i) some of the models which do not have advanced data assimilation (3D or 4D Var) may have poorer analyses in the southern hemisphere and (ii) the EPS may agree better with the ECMWF analysis on data-sparse regions. Rank histograms showed that PEPS had better coverage of the observations than the EPS, but was probably over-spreading at 24h. Reliability diagrams were good at all lead-times but there was no significant difference from the EPS.

43. Thus, overall initial results from the basic system are very encouraging. The Met Office is now collecting forecast data directly from a much larger group of global NWP centres to assess the PEPS further. Data are being collected at 1.25° resolution for six fields (PMSL, H500, T850, 2m temp., 10m wind speed and precipitation) to allow a more comprehensive verification including more parameters of relevance to forecasters and forecast users. During the discussion, it was stressed that the current system is for research only, and is not operational. Operational implementation will depend on (i) the success of the system in research and (ii) the agreement of the centres supplying data.

OPERATIONAL USE OF EPS, TO FORECAST SEVERE WEATHER AND EXTREME EVENTS – ECMWF (Antonio Garcia-Mendez)

44. Severe weather can be defined as weather conditions threatening life and/or properties. These events are rare and are location dependent so their verification is difficult. On the other hand extreme weather is weather reaching the extremes of the climate frequency distribution. User needs are usually expressed for the very short range (6-24h). EPS techniques usually are best validated beyond 48h range. Their potential use is therefore mainly in terms or early warnings (pre-alert), the extension in terms of forecast range means that the False Alarms are likely to be more frequent than for very short range applications. On the other hand, at this range most severe weather have a limited predictability and it is important to demonstrate the value of probabilistic forecasts. Cases as the floods in South France in November 1999 with more than 600 mm accumulated over two days and the Christmas storm in December 1999 with wind speeds exceeding 150 km/h show clearly that the global EPS models do not generate 10m winds or rain rates that are a threat to lives or property. So there are have two options: upscaling the events definition or downscaling the model data.

45. An EPS climate has been derived consisting of 3 years (January 1997 to December 1999) with constant horizontal resolution (T_L159) on a monthly basis, valid at 12UTC for Europe Lat/Lon grid (0.5x0.5 degrees). The climate includes T_{2m}, Precip. (24, 120, 240h acc.), 10m-wind speed for 50 members (D5+D10) + Control (D0, D5+D10) so comprising around 10,000 events per month. The post-processing is fully non-parametric (archived values are all 100 percentiles + 1‰ and 999‰). A better definition of events worth plotting is for instance the number of EPS members forecasting values of 10m-wind speeds exceeding the 99% threshold in the "EPS Climate".

46. The EFI is a continuous ranked probability score for distance between distributions:

$$CRPS = \int_{-\infty}^{+\infty} [p_{EPS}(x < \boldsymbol{a}) - p_{C\mathrm{lim}}(x < \boldsymbol{a})]^2 d\boldsymbol{a}$$

By re-scaling and using the climate distribution, we can create a dimensionless, signed measure:

$$EFI = 3\left(\int_0^1 \left(p - p_{EPS}\left[x < x_{\mathrm{clim}}(p)\right]\right)^2 dp\right) \mathrm{sgn}\left(\int_0^1 [p - p_{EPS}\left[x < x_{c\mathrm{lim}}(p)\right]] dp\right)$$

The Extreme Forecast Index is:

- 0% when forecasting the climate distribution,
- 25% for a determinist forecast of the median,
- 100% for a deterministic forecast of an extremeThe proposal is to extend the products from physical parameters (e.g. amounts of precipitation) to the forecast of climatological quantiles (e.g. the forecast today is for a precipitation event, which frequency of occurrence in our February climatology is <1%). We need local climatologies to rescale the observed values. Some idea of extreme events can be found in the model direct output provided it is seen from a model perspective. In this approach calibration to observed extreme values would be left to the users.

47. Severe Weather Prediction test suite at ECMWF:

•March 2001
–Start of the routine running of the severe weather test suite, i.e. second run of EPS based on 00UTC
•June 2001
–Start of the routine running of the multi-analysis EPS from DWD, Meteo France, UKMO, NCEP analyses
•April 2001
–Runs of the 100 member EPS based on 12UTC
•August 2001
–Testing of targeted tropical singular vectors in the EPS
-Experiments with variable resolution (VAREPS)

ANNEX TO PARAGRAPH 4.3

Extract of statement of requirements by the Inter-Commission Task Team on Regional Climate Centres, Geneva 30 April-3 May 2001

3a. Forecast Products

Temporal resolution. **Monthly averages/accumulations/incidences** are preferred to seasonal values.

Spatial resolution. For the tropics and sub-tropics 2° x 2° target for squares/grid points, but 10° x 10° acceptable. Or catchment, river basins or other regions of comparable area.

Spatial coverage. Area of interest of user, but generally sub-regions of a continent.

Lead time. **0 - 6 months for products to be issued to end user, implies longer (0 - 7 months) for model and statistical inputs to regional or national centres**. Some requirements to 15 months. **3 months minimum** for warnings to end user of high amplitude and abnormal events, such as increase in tropical storm frequency or change in phase of ENSO.

Issue frequency. **Monthly** much preferred to three-monthly.

Output types. Grid point values, grid box area values or geographical contouring of probabilities **to remove discontinuities at boundaries**. Gridded fields for applications model initialisation.

Forecast Content.

- **For (land) surface temperature and total precipitation, calibrated ensemble outputs (from the single and multi-models) showing the full spectrum of distribution** in terms of probabilities of exceeding the full range of climatologically feasible values, expressed in absolute values or anomalies. ("Calibrated" implies the correction based on past performance of individual members for systematic errors eg in anomaly predictions). Alternatively or additionally, tercile or **decile** probability forecasts. These targets are implied also for outputs of the statistical/empirical models.
- As above for sunshine, solar radiation, cloudiness, temperature range and rainfall range.
- **Calibrated ensemble predictions of sea surface temperature in the Niño areas, tropical Atlantic, specified sectors of North Atlantic and Indian Oceans.**
- **Ensemble related predictions of surface pressure field indices including the SOI (eg Tahiti-Darwin pressure difference) and the NAO (Iceland -Azores difference).**
- Ensemble related predictions of the equatorial zonal wind average at heights of 30 and 50 hPa, as an indicator of the QBO.
- **For events such as tropical cyclones, wet (including heavy rain) and dry spells, hot and cold (including frost) spells, indications of whether the frequencies and severity will be above normal.**
- **Ensemble output related heating/cooling and growing degree-days using regionally supplied thresholds.**
- **Ensemble output related onset/duration of rainy and monsoon seasons.**
- Non-ensemble outputs of all the above variables/events where models are not operated in ensemble mode.
- Information **downscaled to higher spatial and/or temporal resolution** as far as achievable using statistical and/or dynamical methods once these have been validated.
- **General purpose consensus products relating to the variables listed above, based on model inputs, statistical/empirical inputs from physically based local, regional and international methods, downscaling schemes and recent climate and weather**

experience. Monthly updates especially in rainy season. Other characteristics (eg resolutions, lead times, output types including the statistical characteristics) as described earlier.

- Some users require short range to monthly forecasts together with the seasonal output, and all in the same probability format.
- **Tailored forecasts for different applications areas as determined regionally and nationally. The requirement for more detailed statistical inputs from various models, as described earlier, should allow for the likelihood of exceeding various applications related thresholds to be determined. (As stated in the introduction, tailored forecasts for the end-users are not the primary focus of this paper. However continuing dialogues with end-users are bound to result in changes to the input needs of their suppliers.**

<u>Confidence level.</u>

- **An indication (text statement) of the confidence in each forecast for example based on model ensemble characteristics, uncertainties in initial conditions, model uncertainties, and degree of consensus**.
- **An alert, to accompany forecasts, of significant changes in models or practices used to generate the forecasts**. Examples are changes to analysis schemes for surface wind stress and sea surface temperature changes in assimilation techniques and model resolution.
- Regions where probabilities are close to climatology level reflect either a lack of predictability demonstrated for the region, or no clear forcing on the climate for the particular forecast period, even though predictability on the average has been demonstrated for the region. It may be useful to distinguish between the two in map format.

<u>Verification and reliability.</u>

- **With each statistical and NWP model output (single forecast and ensembles), and each consensus forecast, a time series of verification data describing the model and consensus performance. Such data to include outputs from the WMO Standardised Verification Scheme for Long Range Forecasts including ROC catering for flexible event definitions.**
- **Reliability data for 2° x 2° boxes,** or other natural geographical regions, **in the tropics/sub tropics to demonstrate success in predicting exceedence of predefined thresholds, in the form of hit rates and skill scores.**
- **Verification to discriminate between seasons and lead times, and phase of major events such as ENSO.**
- Verification based skill masks to be applied to forecasts for areas where there is little skill, to be developed using criteria agreed with users.

<u>Documentation</u>

- **Text descriptions of statistical and numerical models including scope and limitations.**
- **Text descriptions of run processes.**
- **Text description of consensus procedures.**
- **Notifications of intention to upgrade or change models and procedures.**

ANNEX TO PARAGRAPH 7
Modifications to the GDPS Manual are indicated with a strikethrough or underlined.

PART I

1. PURPOSE OF THE GDPS
The main purpose of the Global Data-processing System (GDPS) shall be to prepare and make available to Members in the most cost-effective way meteorological analyses and forecast products. The design, functions, organizational structure and operations of the GDPS shall be in accordance with Members' needs and their ability to contribute to and benefit from the system.

2. FUNCTIONS OF THE GDPS

2.1 The real-time functions of the GDPS shall include:
(a) Pre-processing of data, e.g. retrieval, quality control, decoding, sorting of data stored in a database for use in preparing output products;
(b) Preparation of analyses of the three-dimensional structure of the atmosphere with up-to-global coverage;
(c) Preparation of forecast products (fields of basic and derived atmospheric parameters) with up-to-global coverage ~~for one to 10 days ahead~~;
<u>(d) Preparation of Ensemble Prediction Products;</u>
(e) Preparation of specialized products such as limited area very fine-mesh short-, medium-, extended-, and long-range forecasts, tailored products for marine, aviation, environmental quality monitoring, and other purposes;
(f) Monitoring of observational data quality.
(g) Post-processing of NWP data using workstation and PC based systems with a view to producing tailored value added products and generation of weather and climate forecasts directly from model output.

2.2 The non-real-time functions of the GDPS shall include:
(a) Preparation of special products for climate-related diagnosis (i.e. 10-day or 30-day means, summaries, frequencies and anomalies) on a global or regional scale;
(b) Intercomparison of analysis and forecast products, monitoring of observational data quality, verification of the accuracy of prepared forecast fields, diagnostic studies and NWP model development;
(c) Long-term storage of GOS data and GDPS products, as well as verification results for operational and research use;
(d) Maintenance of a continuously updated catalogue of data and products stored in the system;
(e) Exchange between GDPS centres of ad hoc information via distributed data bases;
(f) Conduct of workshops and seminars on the preparation and use of GDPS output products.

3. ORGANIZATION OF THE GDPS
The GDPS shall be organized as a three-level system of <u>World Meteorological Centres</u> (WMCs),<u>Regional Specialized Meteorological Centres</u> (RSMCs) and National Meteorological Centres (NMCs), which carry out GDPS functions at the global, regional and national levels, respectively. The GDPS shall also support other WMO Programmes and relevant programmes of other international organizations in accordance with policy decisions of the Organization.

4. FUNCTIONS OF GDPS CENTRES

4.1 The general functions of GDPS centres shall be as follows:

4.1.1 World Meteorological Centres (WMCs)
These shall consist of centres applying sophisticated high-resolution global NWP models (including Ensemble Prediction Systems) and preparing for distribution to Members and other GDPS centres the following products:

(a) Global (hemispheric) analysis products;

(b) Short-, medium-, extended- and long-range forecasts and products with a global coverage, but presented separately, if required, for:

(i) The tropical belt;

(ii) The middle and high latitudes or any other geographical area according to Members' requirements;

(c) Climate-related diagnostic products, particularly for tropical regions.

WMCs shall also carry out verification and intercomparison of products, support the inclusion of research results into operational models and their supporting systems, and provide training courses on the use of WMC products.

PART II
1. Functions of WMCs, RSMCs and NMCs

1.1 GDPS products and services
Each Member or group of Members(s) responsible for a GDPS Centre should ensure that its centre performs the relevant category of the following functions:

1.1.1 Real-time products and services for middle latitudes and subtropical areas
For middle latitudes and subtropical areas, the GDPS should provide the following products derived from deterministic and Ensemble NWP systems and services in real time:

(a) Surface and upper-air analyses;

(b) Prognoses one to three days in advance, including:

(i) Surface and upper-air prognoses of pressure (geopotential), temperature, humidity and wind in map or other form;

(ii) Diagnostic interpretation of numerical weather prediction (NWP) products to give:

- Areal distribution of cloudiness;
- Precipitation location, occurrence, amount and type;
- Sequences at specific locations (time diagrams), at the surface and aloft, of temperature, pressure, wind, humidity, etc., subject to agreement between Members where appropriate;
- Vorticity advection, temperature/thickness advection, vertical motion, stability indices, moisture distribution, and other derived parameters as agreed by Members;
- Jet-stream location and tropopause/layer of maximum wind;
- Numerical products providing sea-state or storm-surge forecasts;

(c) Prognoses four to ten days in advance, including:

(i) Surface and upper-air prognoses of pressure (geopotential), temperature, humidity and wind;

(ii) Outlooks of temperature, precipitation, humidity and wind in map or other form;

(d) Extended- and long-range forecasts of averaged weather parameters as appropriate, including sea-surface temperature, temperature extremes and precipitation;

(e) Interpretation of numerical products, using relations derived by statistical or statistical/ dynamical methods to produce maps or spot forecasts of probability of precipitation or precipitation type, maximum and minimum temperature, probability of thunderstorm occurrence, etc.;

(f) Sea-state and storm-surge forecasts using models driven by winds from global NWP models;

(g) Environmental quality monitoring and prediction products;

(h) Independent real-time quality control of the Level II and Level III data defined in Note (3) to paragraph 1.5.2.

1.1.2 Real-time products and services for tropical areas

For tropical areas, the GDPS should provide the following products derived from deterministic and Ensemble NWP systems and services in real time:

(a) Surface and upper-air analyses;

(b) Prognoses one to three days in advance, including:

(i) Surface and upper-air prognoses, particularly of wind and humidity in map or other form;

(ii) Diagnostic interpretation of NWP products to give:

• Areal distribution of cloudiness;

• Precipitation location/occurrence/amounts;

• Time sequence of weather parameters at specific locations, subject to agreement between Members, where appropriate;

• Vorticity, divergence, velocity potential, vertical motion, stability indices, moisture distribution and other derived parameters as agreed by Members;

• Jet stream and layer of maximum wind locations;

• Numerical products providing sea-state or storm-surge forecasts;

(iii) The use of special NWP nested models or diagnostic interpretation of fine-mesh global models to give:

• Tropical storm positions and tracks;

• Tropical depression and easterly wave positions and movement;

(c) Prognoses four to ~~five~~ ten days in advance, including:

(i) Surface and upper-air prognoses, particularly of wind and humidity;

(ii) Outlooks of precipitation, wind, cloudiness and wet and dry periods;

(iii) Life cycle of tropical storms;

(d) Extended- and long-range forecasts of averaged weather parameters, as appropriate, including sea-surface temperature, temperature range and precipitation;

(e) Interpretation of numerical products, using relations derived by statistical/dynamical methods to produce maps or at specific location of forecast probability of cloudiness, temperature range, precipitation, thunderstorm occurrence, tropical cyclone tracks and intensities, etc.;

(f) Environmental quality monitoring and prediction products;

(g) Sea-state and storm-surge forecasts using models driven by winds from global NWP models;

(h) Independent real-time quality control of the Level II and Level III data defined in Note (3) to paragraph 1.5.2.

1.1.3 Non-real-time products and services

The GDPS should also provide the following products and services in non-real time:

(a) Long-range weather and climate monitoring products when operationally useful;

(b) Climate-related diagnoses (10- or 30-day mean charts, summaries, anomalies, etc.) particularly for the tropical/subtropical belt;

(c) Intercomparison of products, verification and diagnostic studies, as well as NWP model development;

(d) Access to data, products and intercomparison results using internationally-accepted formats and media;

(e) Provision of continuously updated catalogues of data and products;

(f) Regional and global analyses (circulated by Members or research institutions) of the atmosphere and oceans, including means and anomalies of surface and upper-air pressure, temperature, wind and humidity, ocean currents, sea-surface temperature, and ocean surface layer temperature; derived indices, including blocking and teleconnection indices;

(g) Satellite remote sensing products distributed by Members; including outgoing long-wave radiation, sea-surface elevation, normalized vegetation indices;

(h) Monthly and annual means or totals for each year of a decade (e.g. 1971–1980, etc.) and the corresponding decadal (10-year) averages of pressure (station level and mean sea level), temperature and precipitation, principally from CLIMAT reporting stations;

(i) Climatological standard normals (for the periods 1931–1960, 1961–1990, etc.) of selected elements, principally from CLIMAT reporting stations;

(j) Guidelines on the operational use of GDPS centre products; and

(k) Carrying out periodic monitoring of the operation of the WWW.

1.2 Functions of Members responsible for GDPS centres

1.2.1 Interpretation at NMCs

National Meteorological Centres (NMCs) should be able to use, interpret and interact fully with GDPS products in order to reap the benefits of the WWW system. Appropriate guidance on the methods for the interpretation of the GDPS output to end-user products should be made available to Members, as well as methods for the verification and intercomparison of forecasts.

1.2.2 Accessibility of products

GDPS products should be accessible through a system of World Meteorological Centres (WMCs) and Regional Specialized Meteorological Centres (RSMCs)* with functions and responsibilities as defined in the Manual and according to agreements among Members when appropriate.

* The present structure of the GDPS is given in Appendix I-1.

1.2.3 Data Management

The WWW Data Management function shall be used to coordinate the real-time storage, quality control, monitoring and handling of GDPS data and products.

1.3 WMC responsibilities

1.3.1 Output products

Each WMC applying sophisticated high-resolution global NWP models <u>including Ensemble Prediction Systems</u> should prepare for distribution to Members and other GDPS centres the following products, based on the list in paragraphs 1.1 to 1.1.3 above:

(a) Global (hemispheric) analysis products;

(b) Short-, medium-, extended- and long-range weather forecasts <u>based on deterministic and ensemble NWP systems</u> with global coverage presented separately, if required, for:

(i) The tropical belt;

(ii) The middle and high latitudes or any other geographical area according to Members’ requirements;

(c) Climate-related diagnostic products, particularly for tropical regions;

(d) Environmental quality monitoring, analyses, forecasts and prediction products.

1.3.1.1 Global model products required to meet the needs of all WMO Programmes should be made available to national and regional centres at the highest possible resolution given technological and other constraints.

1.3.2 Use of products

WMCs should also carry out verification and intercomparison of products and make results available to all Members concerned, support the inclusion of research results into operational models and their supporting systems and provide training courses on the use of WMC products.

1.3.3 The functions of a WMC should also include the following non-real-time activities:

(a) Carrying out the development of research in support of large- and planetary-scale analyses and forecasting;

(b) Exchanging technical information with other centres;

(c) Providing opportunities for training personnel in data processing;

(d) Managing non-real-time data involving:

(i) Collection and quality control of data not available from the GOS in real-time, via mail or other means;

(ii) Storage and retrieval of all basic observational data and processed information needed for large- and planetary-scale research and applications;

(iii) Making non-real-time data available to Members or research institutes upon request;

(e) Continuously updating and providing, on request, catalogues of available products.

APPENDIX II-6
4. FORECASTS

Surface (including synoptic features)
925 hpa
850 hpa
700 hpa
500 hpa
400 hpa parameters: p/h, t, w and r, as appropriate and applicable
300 hpa
250 hpa
200 hpa
150 hpa
100 hpa
70, 50, 30, 20 10 hpa
Jet-stream location and tropopause/layer of maximum wind
Significant Weather
Relative topography, thickness 500/1000 Hpa

Note: The above list includes products which are required as part of the ICAO world area forecast system in accordance with requirements determined by ICAO.

Freezing level
Vorticity
Vertical motion
Areal distribution of cloudiness
Precipitation location, occurrence, amount and type
Sequences at specific locations (time diagrams) at the surface and aloft of t, p, w and r
Vorticity advection, temperature/thickness advection, vertical motion, stability indices, moisture distribution and other derived parameters
Tropical storm positions and intensities
River stage, discharge and ice phenomena
Tropical depression and easterly wave positions and movement
Four-to-10-day outlook in middle latitudes and subtropical areas or four- to five-day outlook in the tropics for t, w, r and precipitation
Forecasts of probability of precipitation and temperature extremes for middle latitudes and subtropical areas or forecasts of cloudiness, temperature range and precipitation probability for tropical areas
State of sea
Storm surge
Sea-surface temperature
Thermoclines
Sea ice
Superstructure icing

Three-dimensional trajectories with particle locations at synoptic hours for EER
Time integrated pollutant concentration within the 500 m layer above ground in three time periods up to 72 hours for eer
Total deposition up to 72 hours
Ensemble prediction system products:
(Period for all fields: forecast D+0 to D+10 (12 hour intervals) at highest resolution possible)

Probabilities of:

- Precipitation exceeding thresholds 1, 5, 10, 25 and 50 mm/24 hr
- 10m sustained wind and gusts exceeding thresholds 10, 15 and 25 m/s
- T850 anomalies with thresholds -4, -8, +4 and +8 degrees with respect to a reanalysis climatology specified by the producing Centre

Ensemble Mean (EM) + spread (standard deviation) of Z500, PMSL, Z1000, vector wind at 850 and 250 hPa
Tropical storm tracks (lat/long locations from EPS members)
Model fields:

- Full set or subset of EPS members variables and levels for requesting WMO Members for specific applications.

Extended range forecasts (levels and parameters as appropriate five, 10, 15 or 30 day) and applicable mean values
Long-range forecasts (monthly, three-month or 90-day, seasonal to multi-seasonal outlook
Ensemble prediction system products for extended-range and long-range:

Ensemble Means anomalies/Spread:
One week averages for first month, monthly means thereafter (all anomalies with respect to model climate) for:

- Tropical SST
- Standard ENSO Indices
- Precipitation, Z500, Z1000, T850 and surface temperature

Probabilities:
Terciles: above, below, normal (with respect to model climate) of:

- Precipitation
- Z500
- Z1000
- T850 and surface temperature

Model fields:

- Full set or subset of EPS members variables and levels for requesting WMO Members for specific applications.
- Relevant post processed fields from sequence of daily output (e.g., indices of monsoon onset, droughts, tropical storm activity, extratropical storm track activity)

ANNEX TO PARAGRAPH 8.1

EXCHANGE OF SCORES

Monthly exchanges:

ENSEMBLE MEAN

For verification of ensemble mean follow the specifications in the current Attachment II.7, Table F of the Manual on the GDPS for (Variables, levels, areas and verifications) (see copy below):

ANNEX 1 TO RECOMMENDATION 3 (CBS-Ext.(98))

PROPOSED AMENDMENTS TO ATTACHMENT II.7, TABLE F OF THE *MANUAL ON THE GLOBAL DATA-PROCESSING SYSTEM* (WMO-No. 485)

Factors and methods used in standardized verification of NWP products

I – Verification against analysis

Area	Northern hemisphere extratropics (90°N – 20°N) (all inclusive) Tropics (20°N – 20°S) (all inclusive) Southern hemisphere extratropics (20°S – 90°S) (all inclusive)
Grid	Verification analysis is the centre's on a latitude–longitude grid 2.5° ¥ 2.5°; origin (0°, 0°)
Variables	Mean sea-level pressure, geopotential height, temperature, winds
Levels	Extratropics: Mean sea-level, 500 hPa, 250 hPa Tropics: 850 hPa, 250 hPa
Time	24 h, 48 h, 72 h, 96 h, 120 h, 144 h, 168 h, 192 h, 216 h, 240 h ...
Statistics	Mean error, root-mean-square error (rmse), anomaly correlation, S_1 skill score, root-mean-square vector wind error ($rmse_v$)

The following definitions should be used:

mean error

$$M_{f,v} = \frac{\sum_{i=1}^{n} (x_f - x_v)_i \cos\varphi_i}{\sum_{i=1}^{n} \cos\varphi_i}$$

rms error

$$rmse = \sqrt{\frac{\sum_{i=1}^{n} (x_f - x_v)_i^2 \cos\varphi_i}{\sum_{i=1}^{n} \cos\varphi_i}}$$

correlation coefficient between observed and forecast anomalies

$$r = \frac{\sum_{i=1}^{n} (x_f - x_c - M_{f,c})_i (x_v - x_c - M_{v,c})_i \cos\varphi_i}{\sqrt{\sum_{i=1}^{n} (x_f - x_c - M_{f,c})_i^2 \cos\varphi_i \cdot \sum_{i=1}^{n} (x_v - x_c - M_{v,c})_i^2 \cos\varphi_i}}$$

rms vector wind error

$$rmse_v = \sqrt{\frac{\sum_{i=1}^{n} (\vec{V}_f - \vec{V}_v)_i^2 \cos\varphi_i}{\sum_{i=1}^{n} \cos\varphi_i}}$$

S_1 skill score (for mean sea-level pressure and geopotential height only)

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

where: x_f = the forecast value of the parameter in question;

x_v = the corresponding verifying value (analysed);

n = the number of grid points in the verification area;

$\cos \varphi_i$ = cosinus of latitude of grid point i;

x_c = the climatological value of the parameter;

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

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

$\vec{V}_f$ = the forecast wind vector;

$\vec{V}_v$ = the verifying (analysed) wind vector.

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

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

where the differentiation is approximated by differences on a 2.5° × 2.5° latitude/longitude grid.

NOTES:

(1) Values for these statistics should be computed daily (0000 UTC and 1200 UTC separately) for each specified area. Monthly averages should then be computed from the daily values of all forecasts verifying within the relevant month. For those centres not running forecasts from either 0000 or 1200 UTC, tables may alternatively be provided for 0600 UTC and 1800 UTC and should be labelled as such.

(2) The number of runs (daily statistics) forming the monthly means should be exchanged in the monthly report.

(3) Annual averages of daily verification are inlcuded in the yearly *Technical Progress Report on the Global Data-processing System*. These statistics are for the 24, 72 and 120 h forecast and include the rms vector wind error at 850 hPa (tropics area only) and 250 hPa (all three areas) as well as the rms error of geopotential heights at 500 hPa (northern and southern hemispheres).

(4) To the extent possible, horizontal and vertical interpolations from model to verifying grids should not involve multiple steps or explicit smoothing.

II – Verification against observations

Network The seven networks used in verification against radiosondes consist of radiosondes stations lying within the following geographical area:

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

Stations The list of radiosonde stations to be used in each network is updated annually by the lead centre for radiosondes. The chosen stations must be available to all the centres and provide quality data on a regular basis. Consultation with all centres (usually by electronic mail) is desirable before establishing the final list. This list is published in the monthly WWW *Operational Netwsletter*, as appropriate.

Variables Geopotential height, temperature, winds

Levels 850 hPa, 500 hPa, 250 hPa

Time 24 h, 48 h, 72 h, 96 h, 120 h, 144 h, 168 h, 192 h, 216 h, 240 h ...

Statistics Mean error, root-mean-square error (rmse), trend correlation, root-mean-square vector wind error ($rmse_v$)

The following definitions should be used:

mean error $$M_{f,v} = \frac{1}{n}\sum_{i=1}^{n}(x_f - x_v)_i$$

rms error $$rmse = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_f - x_v)_i^2}$$

correlation coefficient between observed and forecast trends

$$r = \frac{\sum_{i=1}^{n}(x_f - x_{f_o} - M_{f,f_o})_i (x_v - x_{v_o} - M_{v,v_o})_i}{\sqrt{\sum_{i=1}^{n}(x_f - x_{f_o} - M_{f,f_o})_i^2} \cdot \sqrt{\sum_{i=1}^{n}(x_v - x_{v_o} - M_{v,v_o})_i^2}}$$

rms vector wind error $$rmse_v = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\vec{V}_f - \vec{V}_v)_i^2}$$

where: x_f = the forecast value of the parameter in question;

x_v = the corresponding verifying value (observed);

x_{f_o}, x_{v_o} = same as above, but for the initial time;

n = the number of observations in the verification area;

M_{f,f_o} = the mean value over the verification area of the forecast trends;

M_{v,v_o} = the mean value over the verification area of the observed trends;

$\vec{V}_f$ = the forecast wind vector;

$\vec{V}_v$ = the verifying (observed) wind vector.

NOTES:

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

(2) Values for these statistics should be computed daily (0000 UTC and 1200 UTC separately) for each specified network. Monthly averages should then be computed from the daily values of all forecasts verifying within the relevant month. For those centres not running forecasts from either 0000 or 1200 UTC, tables may alternatively be provided for other base times and should be labelled as such.

(3) The number of runs (daily statistics) forming the monthly means should be exchanged in the monthly report, as well as the average number of observation points used in the computations.

SPREAD

Ratio of standard deviation over RMS error of the Control averaged over the same regions and variables as used for the ensemble mean.

PROBABILITIES

The following Table should be exchanged:

Reliability table
(N members ensemble)

	O	**NO**
F=N, NF=0	H_N	F_N
F³ N-1, NF£1	H_{N-1}	F_{N-1}
F³ N-2, NF£2	H_{N-2}	F_{N-2}
F³ 1, NF£N-1	H_1	F_1
F³ 0, NF£N	H_0	F_0

List of parameters

PMSL ± 1, ± 2 standard deviation with respect to center's own climatology

Z500 with thresholds as for PMSL.

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

T850 anomalies with thresholds ± 4, ± 8 degrees with respect to a centre specified 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

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.

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. REPORT ON THE OPERATIONAL USE OF EPS, TO FORECAST SEVERE WEATHER AND EXTREME EVENTS

4. REVIEW AND ESTABLISH THE LIST OF EPS FIELDS AND PRODUCTS THAT SHOULD BE DISTRIBUTED

5. PROVISION OF STATEMENT OF REQUIREMENTS TO THE ISS FOR THE DISSEMINATION OF EPS PRODUCTS

6. DEVELOPMENT AND TEST OF PROCEDURES FOR EXCHANGE OF EPS GRIB/BUFR DATA

7. PROPOSALS OF OVERALL EPS OUTPUT PRODUCTS - UPDATES TO APPENDIX II-6 OF THE MANUAL ON THE GDPS

8. DEVELOPMENT OF STANDARD VERIFICATION MEASURES FOR EPS

9. EDUCATION AND TRAINING OF USERS OF ENSEMBLE PRODUCTS

10. CLOSURE OF THE MEETING

APPENDIX II

MEETING OF THE CBS EXPERT TEAM ON ENSEMBLE PREDICTION SYSTEMS
(Tokyo, Japan, 15-19 October 2001)

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