WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

OPAG ON
DATA PROCESSING AND FORECASTING SYSTEM

IMPLEMENTATION-COORDINATION TEAM ON
DATA PROCESSING AND FORECASTING SYSTEMS

GENEVA, SWITZERLAND, 22-26 NOVEMBER 2004

FINAL REPORT

Report of Meeting of the Implementation and Coordination Team on Data Processing and Forecasting Systems

1. OPENING OF THE MEETING (Agenda item 1)

1.1 The Meeting of the Implementation/Coordination Team on Data Processing and Forecasting System chaired by, Ms Angèle Simard, Chair of OPAG on DPFS, was held at the WMO Headquarters in Geneva, Switzerland from 22 to 26 November 2004. Ms Simard declared the meeting open and invited Mr Dieter Schiessl to address the meeting.

1.2 On behalf of Mr Michel Jarraud, Secretary General of WMO, Mr Dieter Schiessl, Director World Weather Watch Department, welcomed the participants. Mr Schiessl noted that the twelfth session of the Commission for Basic Systems in December 2000 established the Team within the Open Programme Area Group on Data Processing and Forecasting Systems and CBS Ext.2002 adjusted the tasks of the related expert teams.

1.3 Mr Schiessl recalled that the major tasks of the Implementation Coordination Team on DPFS include to identify new emerging requirements with input required from RAs, determine how to fulfil emerging requirements, identify needs for workshops/training, and consider proposals for future work from related expert teams and make recommendations to CBS as well as providing feedback to the teams concerned. He invited the meeting to take into account work in progress in relevant Expert Teams of the OPAG and directives and conclusions of EC-LVI specifically those that relate to the CBS-Ext.2002 report on the efforts that are in progress to further develop the World Weather Watch aspects of the infrastructure for forecasting at all time ranges, and related operational requirements, standards and procedures.

1.4 Mr Schiessl noted that the meeting was expected to develop proposals and recommendations on increasing the operational use of Ensemble Prediction Systems and available NWP products for forecasting high impact and severe weather events; developing further the Global Producing Centres for Long-Range Forecasting and the infrastructure for verification of these forecast products; to develop the scope and capabilities of the Emergency Response Activities to meet new requirements from WMO Members in responding to emergencies with large scale dispersion of pollutants in the air and in water.

1.5 Mr Schiessl urged the Meeting to respond to requirements expressed by Congress and EC and contribute to the development of the WMO Quality Management Framework (QMF) in particular by developing forecasting standards relating to “Weather Forecasting Techniques considered as a sequence of Standard Processes” and implications of Quality Management on the forecasting process. The outcome of this meeting, including its view of the future work programme for DPFS will provide input to the CBS XIII, to be held next February.

2. ORGANIZATION OF THE MEETING (Agenda item 2)

2.1 Adoption of the agenda (Agenda item 2.1)

2.1.1 The Meeting adopted the agenda given in Appendix I.

2.2 Working arrangements for the meeting (Agenda item 2.2)

2.2.1 The Meeting worked in one committee and established subgroups that considered specific problems. It agreed on its working hours, other mechanism and work schedule. The list of participants is given in Appendix II.

3. FORECASTING STANDARDS

3.1 The Meeting was informed of the statements of the WMO constituent bodies relevant to the question of forecasting standards. The last Executive Council asked CBS to give consideration to the development of guidance and support systems for forecasting. In that respect, it was noted with satisfaction that CBS had started work on the development of WMO standards or recommended practices for weather forecasting as requested by Cg-XIV.

3.2 The meeting noted with appreciation a recent report by J. Coiffier, a WMO consultant, entitled: "Weather Forecasting Technique considered as a Sequence of Standard Processes from the Forecaster's Point of View". The meeting made several recommendations based on this report.

3.2.1 The Meeting noted that there are many factors which determine the actual forecasting processes and procedures, including forecast range, geographical and climatological context, organization of the forecast office, users, technical environment (capabilities and equipment) of the forecasting system. There exist several references (e.g. Guides, web sites), which describe forecasting practices. The report summarized the tasks of weather forecasting and these were revised during the meeting as follows:

- Evaluating the present meteorological situation
- Examining the quality and relevance of the analysis
- Identifying the key elements of the meteorological situation, according to the accepted conceptual models and / or guidance / tools
- Examining the various guidance products and choosing the most likely scenario
- Describing the evolution of the atmosphere corresponding to the chosen scenario
- Deducing the consequences for smaller scale and specific areas
- Describing of the expected weather in terms of weather elements (including automated production techniques when applicable)
- Deciding on the opportunity / necessity to issue / end warnings
- Distributing the various products to users
- Evaluating according to performance measurements / Verifying forecasts

The Meeting further agreed that these recommended practices be added to Section 3 (Analysis and Forecasting Practices) of the Manual on GDPFS – WMO No 485.

3.2.2 As well, the report suggests that a cascading process from medium-range to nowcasting could be used as a framework to describe and build a forecasting process. Additional emphasis needs to be placed on objective performance measurement.

3.2.3 These aspects could form the basis for the development of WMO standards or recommended practices for weather forecasting.

3.3 The paper entitled : "The development of standard and/or recommended practices and procedures in the field of weather forecast production technologies" (by A.I. Bedristsky, president of WMO) was reviewed. The paper emphasized the importance of establishing standards and/or recommended practices, considering the current stage of development of meteorological science and information and computer technology.

3.4 The Meeting was informed of the recent WMO Workshop on Quality Management (26-28 October 2004).

3.4.1 In relation to DPFS, the Workshop recommended that the consideration of quality assurance aspects related to forecasting and warning products and services should be addressed in connection with the standing task of CBS, to develop standards or recommended practices on weather forecasting and the use of forecasting systems.

3.4.2 Participants who are in the process of implementing ISO 9001 certification or have already done so, noted that ISO 9001 is about defining a process, documenting, maintaining and updating on a regular basis; it is about continuous improvement of the process, not about the content of the process *per se*. It is also worth noting that NMHSs who went through the certification process have experienced no problems with the relevant WMO technical regulations in the process of acquiring their certification.

3.4.3 The Meeting agreed that the ultimate goal of a quality management framework (QMF) is to establish the functional basis to ensure ongoing improvements of the forecasts' reliability and accuracy, and to build and maintain the confidence of customers and users. It agreed on forecast standards, procedures and processes and/or recommended practices for the short-range forecasting as per annex to this paragraph. The NMHSs should be encouraged to use these recommended practices, evaluate their applicability, and make necessary adjustments according to their needs and capabilities.

3.4.4 A condensed and revised version of the WMO Consultant report was prepared. This revised version entitled: "A Summary of Recommended Practices for Weather Forecasting" is annexed to this paragraph, for review by CBS.

3.4.x The Meeting noted that the Guide on the GDPFS has not been revised recently and would benefit from review and updating.

3.4.5 The Meeting recommended that some guidance material be provided to help NMHSs develop their own performance measurement systems. It was the opinion of the participants that this would be best achieved through the work of a WMO consultant as noted in section 11.

4. ENSEMBLE FORECASTING SYSTEMS PRODUCTS AND APPLICATIONS

4.1 The Meeting noted with appreciation the report of the Chairman of the CBS/DPFS Expert Team on Ensemble Prediction Systems (ET-EPS), Mr. Ken Mylne, on its meeting (27-31 October 2003) and on the progress made.

4.2 Most advanced centres are now operating or developing Ensemble Prediction Systems (EPS) for use on short, medium and/or long-range. Most operational EPS use global models for medium-range predictions. A small number of regional ensembles focussing on short-range forecasts are in quasi-operational mode and many more are under development.

4.3 The uncertainty in initial state and/or numerical model is reflected in the EPS. Various approaches are used to account for uncertainty due to observational and/or to model errors. Several approaches are used to deal with initial condition errors, including singular vectors, bred vectors and variants of the ensemble Kalman filter. The use of multiple models, or multiple parameterisation schemes, is a simple and pragmatic approach, which has been demonstrated to have significant positive benefit in accounting for model errors. Much research is now focussing on methods with a better grounding in theory through randomly perturbing the model within the forecast run. The surface boundary condition (i.e. soil moisture, SST) is another source of uncertainty.

4.4 The so-called poor person's ensemble (PEPS) is a combination of various model outputs, which are produced from different initial analyses and/or from different model configurations. Research in the Poor person's ensemble at the UK Met Office has demonstrated that this approach can provide reliable probability forecasts at relatively low cost. A regional PEPS for Europe is under development at DWD (German Weather Service).

4.5 The ensemble approach to dealing with uncertainty is applied from short to long-range prediction. Even though the underlying science are different, the decision making strategy and evaluation techniques are similar, and EPS provides a framework for developing seamless forecasts from short to long range, recognizing that the level of detail increases as the forecasts approach the short-range.

4.6 Methods of post-processing ensembles for downscaling and bias correction are becoming well-established. The statistical interpretation approach (e.g. Kalman filtering) is applied to EPS products to remove site-specific biases, and calibration methods for correction of ensemble spread are also available. Methods such as best-member ensemble dressing or Bayesian Model Averaging (BMA) are increasingly used to improve the quality of probability forecasts. BMA can be applied to weight the members of multi-model ensembles.

4.7 Following a request from CBS, the expert team on EPS developed an outline plan for a workshop on EPS. It recommended that workshops be organized to train trainers on the concept and use of EPS. It examined the use of Computer Aided Learning (CAL) material as a means to provide the principal tool for the trainers to use in their own countries. The Expert team recognized the existence and high value of the USA COMET CAL system and considered that it could be the basis for the development of training material.

4.7.1 Training materials for forecasters are under development, and some information and guidelines can be found on the Internet (e.g., http://meted.ucar.edu/nwp/pcu1/ensemble/), which include use of probability concepts and interpretation of various probability diagrams provided by EPS, and the concerns on bias of EPS and relevant calibration.

4.7.2 Two training workshops are being organized by WMO in 2005: for RAs III/IV in Brasilia (January), and for RAs II/V, tentatively in China (April). The provisional programme for the Brasilia workshop is shown in the annex to this paragraph.

4.7.3 Examples in the COMET modules are all USA-based. In order to make the modules more appropriate for the use by NMHSs, the COMET developers have offered to generate some case studies for regions outside the USA, in particular in regions appropriate to the forthcoming training workshops.

4.7.4 It was noted that while COMET modules are very useful for the training on EPS, they are presently only available in the English language. The translation of the EPS modules into the French language is being considered by Canada. There is a need to translate the materials so that they become more widely accessible and beneficial to more NMHSs.

4.7.5 The Training Workshops place a high demand on the subject experts who have agreed to provide the lectures and the case studies. It should be recognized that the development resources needed to prepare the workshops are considerable, especially of suitable materials for a particular region, and when it is for the first time.

4.8 A WMO framework for the verification of EPS is being implemented and standardized following the recommendations of the CBS. The exchange of reliability tables has been established with the support of JMA who provide a data server and web pages. The Meeting expressed its gratitude to JMA for offering to assume the Lead Centre role and services for EPS verification and congratulates JMA for the work of implementing a web site. Producing centres of EPS products are encouraged to provide verification results as per the agreed content and format.

4.8.1 It was noted that while the ET had developed the standards for EPS verification, and that they have been incorporated into the Manual for GDPFS, it currently references the specifications for the standard verification system of Long-range forecasts (SVSLRF). At the recent meeting of the ETs on LRF (Infrastructure and Verification, 16-19 November 2004), modifications to the SVSLRF are being made. The ET for EPS should review the Standard Verification System for EPS, drawing from the SVSLRF.

4.8.2 The JMA presented the status of its activities of the experimental lead centre for the exchange of EPS verification scores.

4.8.3 The JMA has set up two Internet sites and has run them on an experimental basis since January 2004: a FTP site (ftp://ftpepsv.kishou.go.jp/) for gathering the statistics of EPS verification and a web site (http://epsv.kishou.go.jp/EPSproducer/) for verifying the skill of EPS. Both sites are password protected and accessible only to the registered producing centres during the development phase.

4.8.4 The Meeting agreed with the proposal that the Manual on GDPFS should be modified to make the responsibility of the Lead Centre for EPS Verification clear. The JMA is ready to take operational responsibility of this Lead Centre. The President of CBS is requested to designate RSMC Tokyo as the Lead Centre for verification of EPS. The proposed amendments to the Manual on the GDPFS at Attachment II-7 are noted in the annex to this paragraph.

4.9 THORPEX

4.9.1 The meeting was informed of THORPEX activities by the chair of the expert team who attended the second meeting of the THORPEX Implementation Plan (TIP), held in Beijing in September 2004. The Cg-XIV established THORPEX as an international research programme to accelerate the improvements in the accuracy of 1-day to 2-week high-impact weather forecasts. A key part of the TIP is the establishment of TIGGE (THORPEX Interactive Grand Global Ensemble). TIGGE will be a multi-model global ensemble system formed by bringing together ensemble forecasts from a number of NWP centres in a common format. TIGGE is intended to be used for research and will not be on an operational time schedule. The latest version of the THORPEX science plans is available at http://www.mmm.ucar.edu/uswrp/programs/thorpex.html and the Implementation Plan ("TIP") at http://www.wmo.int/thorpex/ .

4.9.2 The Meeting expressed interest on TIGGE. A first step toward the establishment of TIGGE may be built on the collaborative multi-model ensemble project formed by the USA (through NCEP) and Canada (MSC). This collaboration is on a more operational basis than TIGGE, and is now expanding with the inclusion of the UK (Met Office). Discussions with other centres including ECMWF are underway.

4.9.3 The Meeting also expressed interest in the observation targeting activities of THORPEX.

4.9.4 The Meeting considered arrangements to improve the linkages and communications between DPFS and the developments in THORPEX and this is further discussed under section 11.1.

4.10 The meeting recommended that all Tropical Cyclone (TC) RSMCs transmit their TC observations in BUFR format for acquisition by NWP Centres, and especially global EPS producers, to improve their data assimilation and initialization by facilitating insertion of data on TCs. It should be noted that the performance of EPS for Tropical Cyclone needs further attention.

4.11 The Meeting wished to remind all NMHSs that a number of EPS products are available on several major GDPFS centres web sites. Links to these web sites are available at http://www.wmo.int/web/www/DPS/EPS-HOME/eps-home.htm on the WMO web site.

5. SEVERE WEATHER AND EXTREME EVENTS FORECASTING

5.1 The Chairperson of the OPAG on DPFS reported with pleasure on the recent Workshop on Severe and Extreme Events Forecasting held in Toulouse, 26-29 October 2004. She noted that the Workshop was well represented and included all the WMO Regions, as well as subject experts and the DPFS Rapporteur for Severe Weather.

5.2 The CBS-Management Group suggested a demonstration project on forecasting of severe weather, involving EPS, NWP models, nowcasting, interpolation techniques and involving, through voluntary participation, global NWP model producer(s), RSMC(s), developing NMS(s) and disaster management and civil protection authorities. The scope of the project is to test the usefulness of the products currently available from NWP centres or products that could be made available from current systems, in improving severe weather forecasting services in countries where sophisticated model outputs are not currently used. Such a demonstration project would use a cascading (forecasting) approach to provide greater lead-time for severe weather and would at the same time contribute to capacity building and improving links with disaster management authorities. The Workshop developed further details of the proposed demonstration project and national resources required.

5.3 It was noted that the Workshop developed a general definition for “Severe Weather”, which is based on impacts:

> “a hazardous meteorological or hydro-meteorological phenomenon, of varying but short duration (minutes, hours, days to a couple of weeks) and of varying geographical extent, with risk of causing major damage, serious social disruption and loss of human life, requiring measures for minimizing loss, mitigation and avoidance, and requiring detailed information about the phenomenon (location, area or region affected, time, duration, intensity and evolution) to be distributed as soon as possible to the responsible authorities and to the public.”

5.4 The Meeting agreed that reference to extreme weather events in the Workshop’s report was confusing as the workshop did not define what was meant by extreme weather events and this is often associated with climate extremes. The ICT agreed that the word “Extreme” can be removed without change to the considerations developed.

5.5 The Workshop discussed the necessary cascading process with the information required at various steps for severe weather forecasting. It was agreed that a sequence of processes was necessary for the forecasting of severe weather and that sub-processes could also be defined. For example EPS based guidance could be used to identify several days in advance potential areas for severe weather. Then higher resolution models would be used to refine the forecasts in the shorter range. Finally in the very short term (few hours), nowcasting techniques or extrapolation techniques could be used to provide more up-to-date information. In case of severe weather, it is necessary to provide the users (Disaster Management and Civil Protection Authorities (DMCPA), for example) with meteorological information which is easy to understand and meets their needs.

5.6 The Workshop defined the broad goals for the proposed demonstration project and the roles of the participating centres. It agreed on a three-level approach involving a Global NWP producer(s), a Regional Specialised Meteorological Centre and one or two NMC(s). The goals of the project need to be clearly stated. The demonstration project goals were reviewed by the Meeting as follows:

- to improve the ability of NMCs to forecast severe weather events
- to improve the lead time of alerting of these events
- to improve interaction of NMCs with DMCPA before and during events
- to identify gaps and areas for improvements

5.6.1 In addition, the demonstration project will allow the assessment of the value of probabilistic forecasts and the skill of EPS products, and enhance the capacity of NMCs (training, capacity building). The general terms for the demonstration project, including goals, the roles of the participating centres, and the criteria for participation are annexed to this paragraph.

5.6.2 It was envisaged that 2 types of project could be developed, one that is aimed at improving forecasting the severe weather which is associated with Tropical Cyclones, and another project focusing on improving heavy precipitation/strong wind forecasts (not associated with Tropical Cyclones). The terms of these two possible demonstration projects *are* annexed to this paragraph.

5.6.3 The Meeting supported the two demonstration projects and noted that such projects can be used to further evaluate the recommended practices for forecasting standards and recommended practices for performance measures, to provide a means for capacity building in the use of post-processed products and to define most useful products, and to strengthen the links between NMHSs and Disaster management and Civil Protection Authorities.

5.6.4 It also noted that the skill of EPS products in the Tropics is not well known and that there is a need to improve the model skills in the Tropics.

5.6.5 The Meeting agreed with the Workshop's emphasis that this project could only succeed if there are clear commitments from all participants to fulfil their roles as well as to participate in the evaluation of the project (lessons learned, identify gaps, and make recommendations). The project will build on existing capabilities and be developed with a view to ensure sustainability. Performance measures will need to be established prior to the start of the project. A process will be established to ensure that all severe weather events are documented. It is recommended that at the end of the project, there will be an in depth analysis, including the feedback from all parties including disaster management and civil protection agencies involved. It was proposed that project duration should be of one year to ensure that sufficient severe weather events are analyzed.

5.7 The Meeting noted with appreciation the report of the Rapporteur on Application of NWP to Severe Weather Forecasting, Ms Corinne Mithieux. The aim of the paper was to try to classify severe weather events, and to give some ideas about the current possibilities of the NWP models to forecast them in order to support the issuing of advisories and warnings as early as possible to the responsible authorities and to the public. The paper addresses the three categories of severe weather for which CBS requested to give priority.

5.7.1 Severe weather forecasting implies a hierarchy of several forecast processes, which differ according to the considered range. Because of the methods and tools currently used, it seems logical to divide the whole forecasting procedure into three main processes: medium-range forecasting, short- and very-short-range, and nowcasting.

5.7.2 The cases of extratropical storms over ocean or over land, and large-scale heavy precipitation and high intensity precipitation over small area for short duration (heavy rainfall or snowstorm) concern large scale meteorological systems which are generally well forecast by operational models. The models are generally able to describe correctly the state and the behaviour of synoptic scale weather systems up to three days. But if NWP models can produce realistic lifecycle of extratropical cyclones leading to strong wind or/and heavy precipitations, the reality in the details (the precise location of the low and the chronology, the strongest expected gusts and/or accumulation of precipitation over 24 or 48 hours) often differ from the numerical simulation. Nevertheless, for these kinds of event, an early warning (or advisory) can be useful for the authorities because they can mobilize important means which cannot be managed by local authorities.

5.7.3 For the case of active convective events with associated phenomena (heavy precipitation, hail, lightning, gusts, tornadoes), these are more associated with small scale rapidly developing vortices. There are certain large-scale severe events which can certainly be forecast quantitatively by global NWP and EPS systems. On the other hand, one cannot expect a NWP model to be able to well simulate those scales close to the truncation scale. In this respect one should distinguish between the truncation scale of a model and the smallest physical feature it can accurately resolve. For example, it appears that a mesoscale convective complex with a scale of 10 km cannot be well simulated with a grid spacing of more than about one kilometre.

5.7.4 Currently, NWP gives important information about the synoptic environment favourable for the development of severe thunderstorms but is unable to give with accuracy the right location and intensity of the most intense phenomena. Although NWP systems explicitly compute precipitation fields, forecasters know they cannot rely totally on this information to prepare final forecasts. Convection oriented diagnostic fields, also provide valuable help for identifying the most exposed areas but cannot correctly give intensity information and exact locations of extreme events. Nevertheless numerical models provide relevant information about the synoptic environment favourable to the development of severe thunderstorms. Low tropopause anomalies, wet-bulb potential temperature and wind convergence in the lowest layers, wind shear, helicity, convective available potential energy (CAPE), and other stability indices indicate regions where intense thunderstorms are likely to occur. The National Meteorological Services which implemented nowcasting systems based on satellite images, radar networks, lightning detection systems are able to detect the location of growing convective cells and to try to extrapolate their displacement one or two hours ahead and to calculate estimated water accumulation at the surface.

5.7.5 Significant evolution in NWP systems is planned to be achieved for the end of the decade. It is envisaged to replace or complement the current operational models by a new generation of atmospheric models, which will be non-hydrostatic with horizontal resolution of 1-3 km. Almost all the Eumetnet Short Range Numerical Weather Prediction (SRNWP) consortia (HIRLAM, COSMO, ALADIN, ALADIN-LACE, and UKMO) envisage such developments. For example, Météo-France, within the ALADIN consortium, has started to develop such a high-resolution model, called AROME, foreseen to become operational by 2008.

5.7.6 It is desirable that producing centres of NWP and diagnostic products could provide relevant products that assist in the tasks of forecasting severe weather in NMHS that otherwise have no NWP based guidance of their own. These NMHSs often have limited bandwidth to access or receive such products. It would be useful if each Regional Association could develop a short (minimum) list of products with consultation between the producing centre(s) and the relevant NMHSs. The proposed demonstration project on severe weather forecasting could provide the experience necessary to understand the requirements for products more clearly.

5.7.7 The meeting noted progress made on the application of NWP to severe weather. In recent years, there has been several success stories related to the implementation of LAMs in several countries e.g., in the following NMCs: Vietnam, Hong Kong/China, Mongolia, Saudi Arabia, Thailand, and several countries that are part of the Aladin consortium. These implementations were very important for the NMCs in terms of capacity building. Several of these were accomplished through bilateral agreements as it requires support from a more advanced GDPFS centre e.g. to provide a model and NWP expertise. It also requires significant investment from the NMHSs who must provide human resource investment in order for this implementation to be worthwhile and sustainable.

5.7.8 The Meeting noted that it is also important for NMCs to work on case studies to gain in depth understanding of severe weather events in order to build conceptual models and learn from past experience. It also indicated that stability indices deduced from raw model outputs have proven extremely useful in severe weather forecasting. It is important to note that model outputs, even from high resolution LAMs, could be wrong at times. It is very important to follow the evolution of the atmospheric fields in the first hour outputs of the model to see if there are any divergences between model solution and actual evolution of the atmosphere.

5.7.9 The Meeting came up with the following recommendations/conclusions:

- The demonstration project is supported strongly in that it will be an excellent way to apply the cascading approach in three levels:
  - Global NWP centres to provide available NWP products, including in the form of probabilities.
  - Regional centres provide some coordination for the definition of episode, interpretation for the guidance, collection of feedbacks, and training for facilitating the demonstration by targeted user NMCs
  - NMCs to provide severe warning and evaluation of the project.
- The demonstration project will also provide means to evaluate limitation of the value of current EPS, diagnostic products, nowcasting techniques and direction for improvement.
- Encourage NMCs to request, from the global producing centres, products related to severe weather (e.g. vertical indices).
- Encourage the availability of more NWP outputs be available on GTS and/or Internet, so that comparison between model outputs and conceptual models could be done.
- Make available on GTS and/or Internet some consensus approach products from multi-model EPS such as poor person ensemble prediction systems (PEPS).
- Encourage forecasters to use observations, e.g. comparison between radar outputs/satellite images, to verify NWP outputs.
- Encourage the use of EPS outputs to measure uncertainty.

It also recognized the need to come up with a minimum list of products to be provided to NMHSs that have low bandwidth. It is recommended that the regional rapporteurs on the GDPFS review the minimum list of NWP products on the GTS within their own association, in coordination with the Rapporteur on the Application of NWP to severe weather forecasting.

6. LONG-RANGE FORECASTING (INFRASTRUCTURE AND VERIFICATION) *(Agenda item 6)*

6.1 The meeting noted with appreciation the work of the CBS/DPFS Expert Team on Infrastructure for Long-range Forecasting, chaired by Dr Chung-Kyu Park. The report of the Joint Meeting was presented by Mr Terry Hart. It focused on the recent meetings of the Teams and related progress made. The meeting noted that significant progress has been made in Long Range Forecasting over the last few years. Global Producing Centres (GPCs) are offering global forecasts products and services under a regular schedule and are producing the SVSLRF.

6.2 The Meeting reviewed and endorsed the following proposals and recommendations of the Meeting of the Teams on LRF (Infrastructure and Verification) that:

- It is now time to formally designate the GPCs. This will allow institutions outside of the WWW system that have demonstrated capabilities in LRF production and services on an operational scale to be officially recognized as such. It will facilitate international cooperation and exchange of products within WMO and those institutions. It will also contribute to a more credible program in LRF, under the auspices of the WMO.
- For this purpose a formal minimum list of products to be made available by GPCs is required based on a statement of user requirements that was endorsed at the CBS-Ext.(02) as contained in Appendix V of its report. This list given in the Annex to this paragraph is recommended for adoption for inclusion in Appendix II-6 in the Manual on the GDPFS and should be used as a minimum requirement for designation purpose.
- This list should be reviewed on a regular basis to include additional products from the list endorsed by CBS.Ext.(02) as capabilities of centres increase.

6.3 The Meeting recommended that the procedures for broadening the functions of existing RSMCs and for designation of new RSMCs should be applied to the designation of Global Producing Centres. In order to be officially recognized as a GPC, organizations must as a minimum adhere to:

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

GPCs are further committed to participate in development and research programmes, and to training of users (RCCs and/or NMHSs) on LRF products. CBS will monitor scientific progress with a view to improving LRF products and services.

6.4 The Meeting reviewed the data needs for LRF and suggested updates to the Statement of Guidance (SOG) for inclusion in the rolling requirements review process conducted by the CBS/OPAG on IOS as given in the annex to this paragraph and invited the CBS/OPAG on IOS to include them in the rolling requirements.

6.5 The Meeting noted the scientific benefits of the development of multi-model ensembles for long-range forecasting and the significant progress made in APEC Climate Network (APCN), European and IRI systems. The meeting noted that investigations into methods for combining output from individual models into a multi-model forecast have been conducted.

6.5.1 It noted preliminary results from an investigation conducted by IRI that:

- Dynamical models are over-confident in their probability distributions, and dynamical predictions benefit in reliability from combining several models together by simple averaging;
- Further improved reliability of seasonal climate forecasts can be achieved by recalibrating the forecasts;
- Given the small sample sizes that typically are available for seasonal climate forecasts, best results may be achievable through simple combination schemes after recalibration of forecasts from individual models.

6.5.2 The Meeting encouraged the further development of such systems, including further research into the best means of combining individual model output.

RECOMMENDATIONS AND FUTURE WORK

6.6 The ICT reviewed and endorsed the recommendations:

- That GPCs conduct studies to assess the optimum ensemble size.
- That CCI provide guidance on the use of climatological normals as a basis for forecasting LRF anomalies, in consideration of both climatological shifts as well as availability of hindcast data sets.
- That WCRP Working Group on Seasonal to Interannual Predictions and CAS Working Group on Numerical Experimentation consider conducting intercomparison studies on the relative performance of Tier-1 and Tier-2 LRF models and make available the results to GPCs.

6.7 The ICT recommended that the ETs on ILRF and SVSLRF be both maintained with adjusted terms of reference. The future work of the ET on Infrastructure of LRF should include, in addition to the current terms of reference:

- To develop user interpretation guidance to facilitate the correct use of LRF anomaly forecast;
- To further develop the infrastructure needed for provision and exchange of LRF Multi-Model Ensembles.

6.8 The meeting noted with appreciation the report of the chairman of the CBS/DPFS Expert Team on System for Verification of Long-range Forecasts, Mr Terry Hart, that covered the progress made in implementation since the last session of CBS and in particular progress in implementation of the Lead Centre jointly developed and operated by Melbourne and Montreal.

6.9 The report noted that the SVSLRF was being implemented in APCN, IRI, CMC, JMA, ECMWF and Met Office (UK). It was noted that JMA had the most comprehensive system. All centres were congratulated for their achievements in implementing the SVSLRF.

6.10 The Meeting was impressed with the work carried out by the co-lead centres, and the progress made since the meeting in December 2003 and congratulated the personnel in Montreal and Melbourne for their accomplishment. The web site is planned to be made operational in the first half of 2005.

6.11 The meeting agreed on the recommendations on the role and responsibilities of the Lead Centre that would contribute to the further development of the activities of the Lead Centre Web site with links to the GPCs, and the development and provision of relevant software. The role and responsibilities of the Lead Centre are given in the proposed amendment to draft Appendix II.8 to the Manual on GDPFS.

6.12 The Lead Centre will develop and maintain the SVSLRF web site. This web site will be hosted at the WMC Melbourne. RSMC Montreal will take the responsibility for preparing the verification datasets. These will be updated on the SVSLRF web site on a yearly basis provided that new data is made available. The choice of the verification datasets will be revised as new datasets become available and as recommended by the SVSLRF expert team.

6.13 The Lead Centre will develop and provide specifications defining the format of the data to be sent to the Lead Centre for graphics preparation. There is no need to specify standards for graphics to be sent to the SVSLRF web site because all graphics will be generated by the Lead Centre. The Lead Centre will ensure that clear and concise information explaining the verification scores, graphics and data is available and maintained up-to-date on the SVSLRF web site. Also, links to the participating GPCs will be listed on the SVSLRF web site. The Lead Centre will consult with the GPCs to make sure that the verification data is correctly displayed before making their verification results available on the SVSLRF web site.

6.14 The Lead Centre at Montreal will provide and maintain software to calculate the verification scores. The software code will be available on the SVSLRF web site. Once the SVSLRF web site is operational, the Lead Centre will provide progress reports every two years to CBS, prior to its meetings. The SVSLRF web site is password protected initially.

6.15 The meeting discussed the recommendations from the Joint Team meeting based on the report of the meeting of the Lead Centres on Long-Range Forecast Verification held at the Canadian Meteorological Centre (CMC) in Montreal, Canada, 1-5 December 2003. Some changes are proposed to Appendix II.8 to the Manual on GDPFS based on these recommendations and some issues were identified as requiring further work by the Team. These issues relate to:

- Clarification on whether or not verification should be carried out on post-processed output
- Development of more information on error bars and significance levels to be made available in the documentation, and consideration of the best means of displaying such information
- Calculation of the area under ROC curves (use of fitted curves or not)
- Responsibility for display of real time monitoring information
- Need for more guidance on the prescription of the cross-validation procedure and its appropriateness for individual dynamical models
- Specification of ENSO years

6.16 The Meeting agreed with the recommendation that Attachments II.8 and II.9 in the Manual on GDPFS be revised and unified as Attachment II.8. The proposed updates are given in Appendix III to this report (provided separately).

6.17 The meeting also agreed that where possible the verification datasets be confined to one per parameter and the choice of datasets be periodically revised. It endorsed the recommendations of the Team on change to the verification data set for 2-metre temperature (draft Appendix II.9 to the Manual on GDPFS) for future calculations.

6.18 The meeting noted that other areas for clarification, addition and correction had been made in the draft revised and consolidated documentation.

6.19 The Meeting also agreed that the WMO Secretariat send a letter to GPCs to invite them to submit their verification results to the SVSLRF web site once the latter is ready. Information also should be sent to RCCs and NMHSs on the role of the Lead Centre.

6.20 The Meeting also recommended that the WMO Secretariat request RCCs and NMHSs for feedback one year after the launch of the SVSLRF web site and noted that the Lead Centre had offered to develop a questionnaire.

6.21 It is recommended that long-range forecast verification and its importance be discussed and the Lead Centre activity be publicised at the Workshop of Global Producers of Seasonal to Inter-Annual Forecasts planned in 2005.

6.22 On terminology, the meeting suggested that the term "Lead Centre" refer to both co-lead centres (Melbourne and Montreal) together as the functions are being distributed between the two. The web site is being jointly developed and maintained by the two co-lead centres and is designated as the "SVSLRF web site".

6.23 The Meeting noted that information on significance levels is required as part of SVSLRF. GPCs could consider how to use this information in the products they make available such as through masking areas of low skill.

6.24 The meeting also noted that the list of fields to be required in the formal designation of GPCs contained MSLP and upper level fields not included in the SVS. The SVS was deliberately confined to a small number of fields of most direct relevance to end users. SVS statistics for these fields is not required for publication on the Lead Centre site. However GPCs may decide to apply SVSLRF to these extra fields and make information available.

6.25 The Meeting recommended that the expert team on SVSLRF continue its work for the next period. Areas that may need future consideration to augment the SVSLRF are:

- Development of scores to measure skill in the ensemble spread
- Assessment of multi-model ensembles
- Standardising methods for defining terciles, etc.
- Verification of extremes (such as the outlying quintiles)
- Standardising of hindcast period
- Standardising verification data sets
- Ongoing coordination and support of Lead Centre role
- Clarification of issues arising from the broader use of SVSLRF

6.26 The ICT also reiterated the need to ensure that links to the research and climate product user community (through CAS, CLIVAR/WGSIP and CCl (CLIPS)) are maintained.

7. EMERGENCY RESPONSE ACTIVITIES

7.1 The Representative of RSMC Montréal, Mr René Servranckx, reported on behalf of the Chairman of the CBS Emergency Response Activities Coordination Group on the progress that has been made. The ERA-CG is a standing expert group within the OPAG on DPFS consisting of members representing each of the RSMCs, RTH Offenbach, NMHSs, the IAEA, the CTBTO, and the ICAO. The ERA-CG last met at the WMO in Geneva, 22-26 March 2004.

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

7.3 While the primary focus of these RSMCs with specialization in Atmospheric Transport Model Products for Emergency Response is to provide global coverage specialized products to support nuclear emergency response, these Centres have from time to time also provided support for other kinds of emergency response incidents based on atmospheric transport modelling technologies, e.g., smoke dispersion in wild-land fires, volcanic ash and gases in the atmosphere, airborne diseases, etc.

7.4 Advances in numerical modeling, technologies for product exchange and access and distribution methods continue to be realized, which represent a continual improvement of these specialized services. Faxing remains the official product transmission method but all RMSCs have implemented web-based technologies to exchange information and products. Some RSMCs also have identical (mirror) but independent password protected web pages. As an example, RSMCs Washington, Montreal and Melbourne use ftp to exchange their products in order to make them available in a congruent system. The key advantage is that the three Centres' web sites have identical content while being completely independent from one another. Therefore, even when one server is down, congruency allows accessibility to the RSMC products in a fail-safe manner.

7.5 The regularly performed operational notification tests between the IAEA Emergency Response Centre (ERC) and the RTH Offenbach has been extended to include the RSMCs once every quarter. The scope of the test now includes the requesting of RSMC products by the IAEA, testing the link between RTH Offenbach and the RSMCs and testing the delivery of products. In addition, a test of the full arrangements, including the transmission of messages on the GTS, participation of NMHSs and IAEA Contact Points is to be done every other year. Exercises and regular testing continue to be important to assure operational readiness.

7.6 It is important that potential NMHS users be aware of the specialized services and arrangements. It is encouraged that the ERA programme be promoted to the NMHSs through the Regional Associations, for example, via the Regional Rapporteurs for DPFS. Some capacity building has taken place through dedicated and joint training events, bilateral arrangements and through exercises, where all NMHSs have been encouraged to participate. It was also noted that the WMO Technical Note No. 778 (Documentation on RSMC support for EER targeted for meteorologists at NMSs) is the technical reference to the ERA programme. It contains background, definitions, regulatory materials for the operational standards, procedures and forms, important scientific notes, and annexes that describe each of the RSMCs modeling systems and products. It is important that this document continues to serve as the definitive information reference on the ERA for all Members.

7.7 From the perspective of the scientific and technological underpinnings of the ERA, there continues to be good exchange and collaboration among the Centres.

7.7.1 Many national governments are investing and cooperating in science and technology and reviewing operational arrangements to enhance the level of security measures, including in the areas of environmental monitoring and numerical modeling and simulations for detection, assessment and prediction of atmospheric transport of hazardous materials.

7.7.2 The “ensemble” approach for predicting the atmospheric transport and dispersion of tracers (ATM) is being explored for emergency response applications. There are promising developments on this front, some of which have been incorporated in the HYSPLIT dispersion code used at RSMC Washington. Examples of ATM ensemble products include Ensemble Trajectory Plot, Member Number Plot, Probability Exceed Plot, Concentration Probability Plot, and other applications. These products, or some variation, could be adopted as supplemental products to be issued by the RSMCs, depending upon customer requirements, which have yet to be clarified for any ensemble products. In addition, the adoption of any new products would have to be done in conjunction with updated distribution and product exchange procedures. While the requirements for these new products have been expressed by the IAEA, there remain technical questions to be resolved before operational implementation could be planned.

7.8 ERA Cooperation with other international organizations includes those with the Comprehensive Nuclear-Test-Ban Treaty Organization and the International Civil Aviation Organization.

7.8.1 The relationship with the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) has developed considerably in the last few years, highlighted by the developments of the atmospheric transport modeling application to Treaty Verification. The excellent level of participation at the highly automated numerical simulations experiment organized by the CTBTO's provisional secretariat is an indicator of the desire by many meteorological centres to participate in an advancing area of technology that has many potential important applications. Meteorological data acquired through the International Monitoring System (IMS) are made available to WMO Members. Meteorological information and forecasts were demonstrated to be necessary for the Treaty's On-Site Inspection regime. As a proof of concept, the Meteorological Service of Canada produced an automated set of meteorological products (maps and bulletins) in support of the On-Site Inspection Exercise that was held in Kazakhstan (October 2002). The future CTBTO-WMO operational response system is being developed through experimentation (e.g. first one in 2003) and discussions. The CTBTO proposes to conduct and encourages participation in the 2nd CTBTO-WMO experiment in early 2005 and as well in the Final System-Wide Performance Test (SPT) required by its Preparatory Commission in 2005.

7.8.2 In the context of air navigation and air traffic control operations, benefits have been realized from the specialized atmospheric transport modeling of airborne volcanic ash, a technology from which the specialized products are essential for its 9 designated Volcanic Ash Advisory Centres to support the operations of ICAO's International Airways Volcano Watch programme. In addition, a study is being prepared by an expert at CTBTO, to assess the potential usefulness of the Treaty's Verification monitoring data for the early detection of explosive volcanoes, which could serve as an early indication of the possible presence of airborne volcanic ash.

7.9 The main focus of the future of the ERA programme is its expansion of scope and capabilities as noted in the WMO 6th Long Term Plan.

7.9.1 At its March 2004 meeting, the ERA-CG reviewed relevant aspects of the WMO 6 LTP and CBS Ext.(02) as well as Congress XIV and EC-LVI conclusions and decisions on the way forward in activities related to non-nuclear environmental emergencies, including to consider expanding and enhancing the emergency response capabilities of NHMSs through new methodologies, and the development of emergency response arrangements related to volcanic eruptions, wildland fires, airborne diseases and chemical accidents. It was also stressed that the work should include the provision of technical guidance, training and coordination with the national emergency management organizations. It was also important to maintain coordination with other relevant international organizations.

7.9.2 In the domain of international chemicals management, the WMO is participating at the Preparatory Committee for the Development of a Strategic Approach to International Chemical Management (SAICM), led by UNEP, at its First Session in November 2003, and its Second Session in October 2004. The expectation was that until such time as when UNEP would establish an operational emergency coordination unit, WMO Members would continue to develop the appropriate environmental prediction tools and make them and/or the products available to NMHSs to prepare and strengthen their operational capability to advise national authorities if the need arises. These tools should be developed under the WWW / ERA programme in collaboration with other programme areas.

7.9.3 It should be noted that many National Meteorological Centres already have a national responsibility to provide information in support of chemical accident emergency response and/or marine environmental emergencies. Also, the RSMCs designated for nuclear and radiological emergencies are already involved in the provision of some support services for non-nuclear emergencies. For example, RSMC Obninsk, for oil fires in Iraq during military operations. Wildland fires are placing increasing demand on meteorological services for specialized fire weather services, for the dispersion of smoke plumes. In this connection it was emphasized that because many of the problems are regional in nature and because some of the required products and expertise may not be available at NMHSs own resources, there is clearly a potential role for RSMC's to meet the needs in relation to regional NWP, specialized dispersion forecasts, remote sensing data and possibly other needs targeted at requirements of fire weather forecasting. Application of well-developed smoke dispersion forecasting models was considered of special value because, under suitable conditions, concentrated smoke plumes might travel hundreds of kilometres posing threats to physical and psychological health. Skill development is needed for forecasters to enable them to provide the kind of specialized information for fire weather forecasting. It was suggested that this could be addressed through strengthening the capacity of RMTCs to provide suitable training in the required skills.

7.9.4 The ERA-CG considers that the ERA program should, in the longer term, include all environmental emergency support activities covering both the atmospheric and fresh water environments, as well as radiological, chemical and biological issues. Initially, it was felt that it should concentrate its efforts on consolidating and improving its current services related to already existing arrangements in the nuclear, radiological and volcanic ash areas. Now however, with the potential increase in scope of activities and interests, WMO has conducted a survey among NMHSs regarding available capabilities, gaps in capabilities (needs) in nuclear and non-nuclear emergency response services. The results will be compiled, examined and presented at a Workshop on Development of Scope and Capabilities for ERA in December 2004. The concept of helping countries that need support should remain a valid preoccupation for the ERA-CG. Also, the characteristic of being trans-boundary or not, should not be considered a major limiting factor in the context of the activities of the ERA CG.

8. IMPACT OF CHANGES OF GOS ON GDPFS

8.1 The Meeting was informed by the Rapporteur on this subject, Mr Kevin Cooley, on experiments, which were conducted at NCEP in late 2003 and early 2004 to assess the relative contribution of various satellite observational data sources to the performance of the NCEP Global Forecast System (GFS) model. These experiments were supported by the NCEP Environmental Modelling Center (EMC) and the Joint Center for Satellite Data Assimilation (JCSDA). The JCSDA a collaborative organization sponsored by NOAA, NASA and the DOD in the United States. Doctors Stephen Lord, Tom Zapotocny and James Jung were the principal researchers.

8.2 The experiments, conducted using the operational version of the GFS with one forecast run per day, were of the data denial type. A control run using all available satellite and conventional observations was run. Then runs without each subject observational data type were executed to assess the degradation of performance resulting from the removal of the data type. Measuring this degradation in model performance provided a basis to assess the individual contribution of each observational data source. The experiments were conducted during a winter period (January – February 2003) and a summer period (August – September 2004) for both the northern and southern hemispheres.

8.3 The results of these experiments yielded the following conclusions. The overall contribution to hurricane track forecast performance by satellite observational data sources is 10-15%. While the contribution of TRMM data to hurricane track forecast performance is less than this (5%), this satellite data source is still valuable. The relative contribution to GFS model performance in the northern hemisphere generated by AMSU data is as significant as all conventional observational data. AMSU data yields a one-half to three-quarters of a day improvement in model performance for temperature relative to HIRS data. AMSU data contributes more than HIRS data for wind vector field performance in the model. In the tropics, overall model performance weakness at day one for wind vector performance masks any difference in the contribution of AMSU and HIRS data. Even though this is the case, HIRS and AMSU data are nearly equally valuable for humidity field for the first day of the forecast.

8.4 Given the dominant impacts of AMSU data, investments in time and resources in the use of AMSU data will yield performance improvements in global model performance for temperature, wind vector and humidity.

8.5 The Meeting noted that these findings are consistent with sensitivity studies conducted by other centres, as presented at the third WMO workshop on impact of various observing systems on NWP held at Alpbach, Austria, 9-12 March 2004.

9. REGIONAL PERSPECTIVES

9.1 The nominated rapporteurs on the GDPFS aspects of each WMO Regional Association reported on the GDPFS implementation and performance in their respective regions. The rapporteurs also expressed requirements specific to their respective Region for improving the GDPFS for supporting applications, especially forecasting.

9.1.1 In Regional Association I it was reported that some NMHSs have made progress in NWP through interpretation of NWP products from advanced centres and running of LAMs. However it was noted that many NMHSs still lack the necessary human resources and computing capacity to run LAMs. In order to build capacity for the RSMCs and NMHSs in Region I, to use/run NWP models and EPS products it is recommended that:

- Training be done for the region in form of training seminars or workshops on NWP modelling and interpretation of products
- Capacity building of form of training seminars or workshops on the use and interpretation of EPS products particularly those affected by Tropical Cyclones and those in the subtropics where EPS has already demonstrated skill
- Capacity building in the development of techniques for severe weather forecasting

9.1.2 In Regional Association II (Asia), several emerging areas are noted, including the EPS based forecasting, exchange of severe weather information, preparation for non-nuclear environmental hazards, technical transfer of NWP system in PC cluster, and application of Grid Point Value (GPV) data, with the understanding that the severe weather forecasting associated with tropical cyclone have been improved through the coordination of regional bodies such as Typhoon Committee.

The DPFS functions that require priority support include arrangements and/or resources to:

- Facilitate more GPV data from lead centres to be disseminated at NMHSs through GTS or Internet
- Encourage capacity building on application of EPS products on weather forecasting particularly at longer lead time
- Encourage exchange of verification results for both EPS, and deterministic models to improve quality of dynamic prediction outputs
- Identify a list of useful NWP products focusing on severe weather considering the limited bandwidth and local characteristic
- Facilitate dissemination of trajectory and/ or density (or intensity) for high impact weather systems and air-borne pollutants to target NMHSs, while supporting research and training

programs coordinated by regional bodies such as Asian THORPEX committee and Typhoon Committee
- Encourage regional exchange of asynoptic observations including ATOVS satellite radiances, radar reflectivity and Doppler winds, and windprofiler soundings
- Promote bilateral or regional collaboration for the technical transfer of NWP system in PC clusters, as demonstrated by Mongolian Meteorological Service
- Promote collaboration among various disciplines in NMHSs to enhance the capacity building toward mitigation of natural disasters associated with severe weather, including meteorology, hydrology, coastal engineering, disaster management, and other applied fields at downstream end of cascading process from the medium-range EPS to the nowcasting

9.1.3.1 The RA III expressed a growing interest on EPS and the need for a workshop on the use of EPS products. It also needs to have access to EPS products including medium-range guidance for the forecasting of severe weather, and long-range products similar to those developed for other regions.

9.1.3.2 Noting the importance of upper air observations for specifying initial conditions and for the verification of models, some silent upper air stations in the RA III could rapidly be re-activated (in particular in middle and high latitude), provided that the necessary consumables are obtained by means of some sort of bilateral or multilateral cooperation since infrastructure and staff are still available.

9.1.3.3 In RA III, the ECMWF has provided access to certain products of great interest. Nevertheless, the Ibero-American NMHSs have also requested the ECMWF and WMC Washington regarding the possibility of receiving early advisory of potential warning situations as soon as possible related to Severe and Extreme Events Forecasting (droughts, floods, etc). This request could be considered as a candidate for the demonstration project on severe weather forecasting.

9.1.4 In RA IV, the list of the recommendations is as follows:
- Review the NWP products on GTS, including diversifying the NWP source and include EPS products.
- Request for formal feedback mechanisms on NWP between user NMCs and provider RSMCs.
- Request for RA IV NMCs support to run local area models (LAM) for their area of responsibility.
- Request for training material (mainly the CAL) be available in Spanish.
- The working group recommended that it would meet every two years (instead of every four years) and that these meetings would coincide with the Hurricane Committee.

9.1.5 In RA V the issues of concern are identified are as follows:
- There is general lack of skill for forecasting of severe weather in the tropics by NWP and EPS except for Tropical Cyclones. There is therefore a need to encourage further research in this area, especially from researchers who actually lived in the Tropics.
- Need for training in verification of forecasts.
- Need for more training on interpretation and use of EPS products for developing countries.
- Use of EPS for Tropical Cyclone track prediction is a developing area that is of particular relevance for RA V. Need for advanced GDPFS centres to make available EPS products on TC in this region.

10. NEEDS FOR TRAINING

10.1 The Meeting reviewed the training requirements as expressed by Expert Teams or Workshops in DPFS.

10.1.1 The following aspects related to training have been identified through the Regional Associations:

- Training courses focused on the explanation of the various products which could be made available from the various systems (EPS, deterministic models, nowcasting tools) and their limitations;
- Workshops gathering modellers and forecasters to study particular cases and propose some methodology aiming to better identify severe weather events, using all the available information in connection with conceptual models, as part of a demonstration project.
- To develop proposals for training of experts from developing countries of the Region in interpretation of NWP products;
- To develop proposals for a regional workshop on the use of EPS products in close collaboration with the Rapporteur on PWS;
- To develop proposals for a regional workshop for training of forecasters in severe weather forecasting and public weather service in close collaboration with the rapporteur on the GDPS.

10.1.2 Training requirements were identified from the Workshop of GPCs (April 2003) as follows:

- Training on hindcast.
- Global producers should organize training and capacity building activities directed to RCCs and NMHS.
- Users need support and training to empower them to make best use of GPC data, whether for downscaling or direct use.

10.1.3 Training aspects were identified by the ET on EPS (October 2003):

10.1.3.1 Since the users of ensemble prediction system have to be well aware of the value of probability forecasts for the risk management, the education on EPS needs to in part be focused on the interpretation of probabilistic forecasts for the high impact weather. The needs and requirements for the education and training are high among Members for the interpretation of EPS products in operational environment. As well, at a suitable future time following the training of weather forecasters, a joint training seminar for EPS and Disaster Prevention and Preparedness (DPP) would be useful for maximizing benefit of EPS to the end users faced with decision making with uncertainty.

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

10.1.4 At the Workshop on Severe and Extreme Events Forecasting (October 2004) training was envisaged through the demonstration projects where participating developing countries would be able to benefit from organised training events and capacity building activities.

10.2 Training courses envisaged by the WMO Secretariat In 2005 include:

- Training workshop on EPS for RA III and RA IV Spanish speaking countries, Brasilia, 24-29 January 2005, 6 days (confirmed).

- Training workshop on EPS for RA II and RA V countries in China, 25-30 April 2005 (tentative)
- Regional training seminar on PWS and GDPFS to better support natural disaster prevention (RA I English speaking countries) (tentative)
- Regional Training Seminar of GDPFS (RA I French speaking, tentative)
- Training on operational LAM NWP implementation for six most advanced countries of RA I and ACMAD, but without operational NWP in Africa (Casablanca, Morocco, tentative in 2005)

10.3 The Meeting recommended that training envisioned for RA I be expanded to include some aspects of severe weather and that this kind of training be provided in other Regional Associations. It also recommended that training workshop on EPS be organized for RA RA VI and I.

10.4 Training workshops place a high demand on the subject experts who have agreed to provide the lectures and the case studies. It should be recognized that the development resources needed to prepare the workshops are considerable, especially of suitable materials for a particular region, and when it is for the first time.

11. FUTURE WORK PROGRAMME

11.1 The Meeting considered the implications for DPFS of the THORPEX research programme and the arrangements to improve the linkages and communications between DPFS and the developments in THORPEX. The Meeting recommended that a representative from THORPEX attend the meeting of the ICT for DPFS, and as well that a representative of the ICT DPFS, its Chairperson or its delegate, participate in the most appropriate working group of THORPEX at this time.

11.2 The ICT discussed and developed recommendations for the future work programme of the OPAG and the relevant team. The revised Terms of Reference proposed for the teams are shown in ***annex to this paragraph***.

11.2.1 The Team recommended a new expert team that will focus on the expansion of the ERA to non-nuclear ERA activities. It recognized that the Coordination Group for nuclear ERA is well established and involves international organizations that may not have an interest in non-nuclear ERA activities. Other international organizations would be interested to participate in non-nuclear ERA activities. If one expert group is retained for the entire mandate of both nuclear and non-nuclear ERA, it would become too large and inefficient to well represent, resolve and retain all issues and interests. Terms of reference for the CG and a separate expert team have been developed and are contained in the above noted Terms of Reference for the expert teams for the OPAG on DPFS (annex to paragraph 11.2). .

11.2.2 There is a need to maintain the Expert Teams on EPS, on the Infrastructure for Long-range Forecasting, and on the Standardized Verification System for Long-Range Forecasts. These Teams have made significant progress over the years but there are still some important issues to be addressed, and some additional work to be conducted. The revised terms of reference for each of these Teams are contained in the above noted Terms of Reference for the Expert Teams for the OPAG on DPFS (annex to paragraph 11.2). .

11.2.3 The Team further supported the need for the Rapporteurs on the Impact of Changes to GOS on NWP, and on the Application of NWP to Severe Weather Forecasting. Their respective terms of reference have been revised to include aspects discussed during the meeting and are contained in the above noted Terms of Reference for the expert teams for the OPAG on DPFS (annex to paragraph 11.2).

11.2.4 The Team supported the proposal for the demonstration project (s) developed at the Workshop on Severe and Extreme Events Forecasting. It recommended that, conditional to the approval from CBS, WMO circulate the proposal to the NMHSs to seek voluntary participation. Criteria have been established to help in the selection of participants. It is further recommended that the Chairperson of the OPAG on DPFS, in consultation with the Rapporteur on the Application of NWP to Severe Weather Forecasting, will select participating centres based on the criteria developed during the workshop. Two demonstration projects are envisaged, one that is aimed at improving severe weather forecasting associated with Tropical Cyclones, and another demonstration project focusing on improving heavy precipitation/strong wind forecasts (not associated with Tropical Cyclones). Once the participating centres are determined, it is proposed that a WMO consultant further develop details of the demonstration project in collaboration with participating centres.

11.2.5 Once the demonstration project is completed, an expert team should be established to analyse the results of the project and to make recommendations on broader implementation of the proposed approach. Such a team would not likely be established until 2 years from now.

11.2.6 The Team also recommended that a WMO consultant be tasked to review existing material with respect to performance measures with a view to further develop recommended practices to be added to the Guide on the GDPFS to help NMHSs to develop their own performance measurement systems.

11.2.7 The Team supported the need to hold a second workshop of Global Producers of Seasonal to Inter-Annual forecasts as recommended by the first workshop. This workshop should take place in 2005 and be informed of the role and progress of the Lead Centre on SVSLRF, and on progress made by the Expert Team on Infrastructure for Long-Range Forecasts.

12. CLOSURE OF THE MEETING

12.1 The meeting was closed at 16.00 hours on Friday 26 November 2004

Annex to paragraph 3.4.3

Forecast standards, procedures and processes and/or recommended practices

Statements of WMO constituent bodies

Congress was of the view that the establishment of a WMO Standard and/or recommended practices for weather forecasting techniques would assist in producing more reliable forecasts, using optimally the current levels of meteorological science and technology. CBS has been requested to study the matter with a view to taking appropriate steps to develop recommendations.

Executive Council noted with satisfaction that CBS has started work on the development of WMO standards or recommended practices for weather forecasting as requested by Cg-XIV.

Objective

The ultimate objective of defining recommended practices for short-range weather forecasting is the improvement of weather forecasts.

By defining the various steps that compose the short-range forecast process, the recommended practices facilitate the task of identifying the specific step(s) that need to be adjusted and/or improved.

Factors to consider

It is not easy to define standards and/or recommended practices. The way the forecaster works depend on several factors:

- The forecast range (medium-range, short-range, nowcasting) and the size of the domain to be covered (globe, regional domain, small country, city)
- The geographical context and related climatology (mid-latitudes, tropical or equatorial areas, isolated islands)
- The potential risk associated with the expected weather at various ranges
- The organization of the forecast service (multipurpose forecasters or specialized forecasters for each type of applications)
- The end-user who receives the forecasts (civil defence, aviation, marine, hydrologic and water management service, road administration, medias, public)
- The technical environment (available external and/or internal NWP products, in situ observations, satellite and radar images, lightning detection network, efficient visualization workstation adapted to the forecaster, Web access)

It is also worth noting that the skill of numerical models have improved significantly over the years and will continue to improve to the point that some centres are automating routine forecasts to allow forecasters to focus on high impact weather or areas where they can add significant value.

The products or forecasts that can be automated are those for which the forecasters add little or no value. Any forecast, produced either by a forecaster or automatically, has to be verified to assess the quality of the forecasts and their improvements over the years as models or techniques continue to improve. This also contributes to identify deficiencies in the models and areas for future improvements.

Relevant information

- Guidelines for Education and Training of Personnel in Meteorology – WMO TD No 258.
- Guide on Global Data-processing System – WMO No 305
- Guide on the automation of data-processing centres – WMO No 636
- Guide to practices for meteorological offices serving aviation – WMO No 732
- Guide to marine meteorological services –WMO No 471
- Guide to public weather services practices – WMO No 834
- Guide to hydrological practices – WMO No 168
- Manual of GDPS –WMO No 485

From a general point of view, it can be said that the aim of a National Meteorological Centre is to perform a clear analysis of the present weather, to provide weather forecasts, to evaluate the level of risk associated with the expected important meteorological phenomena and to issue as soon as possible pertinent warning to the concerned user.

Recommended practices

The following steps are Recommended Practices for the weather analysis and forecast process for the short-range forecasting process:

- Evaluating the present meteorological situation
- Examining the quality and relevance of the analysis
- Identifying the key elements of the meteorological situation, according to the accepted conceptual models and / or guidance / tools
- Examining the various guidance and choosing of the most likely scenario
- Describing the evolution if the atmosphere corresponding to the chosen scenario
- Deducing the consequences for smaller scale and specific areas
- Describing of the expected weather in terms of weather elements (including automated production techniques when applicable)
- Deciding on about the opportunity / necessity to issue / end special warning
- Distributing the various products to users
- Evaluating according to performance measurements / Verifying forecasts

It is noted that these steps will need to be adjusted by the NMHSs depending on various factors previously described. Also, these recommended practices would need to be examined and / or refined for nowcasting forecasts and medium range forecasts and beyond. However a performance measurement system is judged essential to ensure that products are of good quality, to assess improvements, identify deficiencies and area for improvements.

The need for training and education should be fulfilled by following the guidelines for education and training and in particular the components that relate to Meteorologist.

Quality management

The workshop on quality management recommended that the consideration of QC aspects related to forecasting and warning products and services be addressed in connection with the standing tasks of CBS. The recommended practices defined above are the first steps of this process.

It should be noted that the term ISO refers to a set of quality management standards which are process standards, not product quality standards.

The group agreed on these recommended practices and encouraged NMHSs to apply them and report on their experiences.

References:

Development of standard and/or recommended practices and procedures in the field of weather forecast production technologies (A.I. Bedritsky, president of WMO)

Weather forecasting technique considered as a sequence of standard processes from the forecaster's point of view. (J. Coiffier -12 September 2004)

Forecasting standards: Implications of Quality Management on the Forecasting Process. Extract of the Report of the Workshop on Quality Management (Kuala Lumpur 26-28 October 2004).

Annex to paragraph 3.4.4

(Intended as CBS contribution to the establishment of a WMO standards and /or recommended practices for weather forecasting techniques)

A Summary of Recommended Practices for Weather Forecasting
(November 2004)

This document provides a first step towards the development of weather forecasting technique considered as a sequence of standard processes. The NMHSs are encouraged to use the recommended practices, evaluate their applicability and make the necessary adjustments according to their needs and capacities.

1 - Introduction

1.1 - Weather forecasting is not *a purely mechanical linear process,* for which standard practices and procedures can be directly applied. Forecaster's job is based on theoretical background and lab work which needs several years of study but mainly day-to-day practice inside a weather forecasting service having a specific technical environment. The work of the forecasters has evolved significantly over the years to take advantage of both scientific and technological improvements. The skill of numerical models has improved so much that some centres are automating routine forecasts to allow forecasters to focus on high impact weather or areas where they can add significant value. So it is not easy to determine a standard way to achieve weather forecasts.

1.2 - The way the forecaster currently works depends in fact on several factors.

- the forecast range (medium-range, short-range, very short-range, nowcasting) and the size of the domain to be covered (large portion of the globe, regional domain, small country, city);
- the geographical context and related climatology (midlatitudes, tropical or equatorial areas, isolated islands);
- the potential risk associated with the expected weather at various ranges;
- the organization of the forecast service (multipurpose forecasters or specialized forecasters for each type of applications);
- the end-user who receives the forecasts (civil defence, aviation, marine, hydrologic and water management service, road administration, medias, public)
- the technical environment (available external and/or internal NWP products, in situ observations, satellite and radar images, lightning detection network, efficient visualization workstation adapted to the forecaster, Web access);

2 – General Overview of Analysis and Forecasting at NMCs

2.1 - The *Manual on GDPS* (WMO N° 485, Volume I - Global aspects, 1991 and Volume II – Regional aspects, 1992, both of them being regularly updated) explains the organization and functions of the

Global Data-Processing and Forecasting System (GDPFS) and describes the various aspects of data processing, including responsibilities of the Centres, agreed standards about analysis and forecasting practices, preparation of charts, exchange of products.

2.2 - Nevertheless, the various tasks to be performed in a Meteorological Centre, following the technical regulations described in the Manual on GDPFS greatly varies according to its level of responsibility of the Centre (WMC, RSMC, NMC or simple Forecast Office), to its specialization (medium-range, tropical cyclone forecasting, emergency response, severe weather,…) and to its internal organization with respect to the needs to elaborate products for specific meteorological activities (aviation, marine, media …) or for other end-users (civil security, transportation, …).

2.3 - From a very general point of view, it can be said that the aim of a National Meteorological Centre is to perform a clear analysis of the present weather, to provide weather forecasts, to evaluate the level of risk associated with the expected important meteorological phenomena and to issue as soon as possible pertinent warnings toward the concerned people. These general commitments have to be fulfilled for the country and for its responsibility areas and covering the forecasting ranges according to the WMO classification. Of course the forecasts should gain in detail and accuracy for geographical location when the forecast range diminishes.

2.4 - Broadly speaking, weather analysis and forecasting should be considered as the succession of the following tasks:

- to clearly understand the recent evolution and the actual situation of the atmosphere at all time scales (weather analysis);

- to obtain the pertinent information from at least one numerical model and to assess the future evolution of the atmosphere in order to determine the most likely scenario (synoptic weather forecasting); when available, automated tools provide a first guess, that forecasters may or may not follow;

- to deduce finally the consequences of the expected synoptic situation in terms of weather elements (weather elements forecasting) and to evaluate the risk of the occurrence of hazardous phenomena (risk assessment);

- to prepare the meteorological information (including possible warnings) to be directed toward the various internal or external users.

2.5 - For the more advanced Centres, extensive use of artificial intelligence, statistical methods, specialized post-processing allow the total or partial automation of several of these processes. Automation allows forecasters to concentrate more on severe or high impact weather situations. Those products or forecasts that can be automated are those for which the forecasters add little or no value.

3 - Training the Forecasters

3.1 - It is relatively simple to specify training standards in mathematics, physics and theoretical meteorology, according to the curricula proposed in TD N° 258. It can be more difficult to precisely define standard processes to achieve the various tasks associated with operational weather forecasting while still exploiting the scientific expertise of the forecaster. Several attempts have been made to define a methodology for consistent preparation of weather forecasts. (Indeed, such definition of procedures may be required where an NMHS seeks accreditation for certain quality management standards). Some attempts have been made (e.g. New Zealand Met. Service) to define “the competencies" for each element of work the forecaster has to complete (local temperature forecasting, for instance) but the generalization of such initiatives requires a huge amount of work. During recent years the methods of working of forecasters have changed dramatically thanks to the continuous progress in NWP and meteorological imagery techniques, making it difficult to keep any process definitions up to date.

3.2 - An effective way of training is to let the beginner work alongside a more experienced forecaster over several weeks until he/she feels able to do the job alone. It is also important to provide training on a regular basis to ensure skills are updated with improvement in science and technology. In addition to this "on the job training" several attempts have been made by experienced forecasters to define a methodology for consistent preparation of weather forecasts. Today's forecaster can be overwhelmed by a huge amount of information and has to try to detect the essential characteristics of the atmosphere in order to prepare a synthesis as quickly as possible.

4 - The tasks to be performed in the context of weather forecasting

4.1 It is clearly beneficial to establish some standards to identify the basic methodology of weather forecasting and the tasks a forecaster has to perform operationally.

4.2 Weather analysis and forecasting process for short-range purpose implies the following steps.

The following outlines the steps for short-range forecasting. They may need some refinement for nowcasting or for medium range and beyond. Examples are taken mainly from the mid-latitudes – more detail on analysis and forecasting in the tropics are presented in chapter 5 of the Guide on GDPFS.

- Step 1: Evaluating the present meteorological situation

Weather analysis needs a clear understanding of the actual situation and the recent past at the synoptic scale. Animation of model analyses and satellite images during the last 24 hours is an efficient way to asses the dynamical behaviour of the atmosphere. It has been recognized that, at least for the middle latitudes, the dynamical forcings can be identified preferably in the low layers and at the tropopause level. So, fields such as Mean Sea Level Pressure (MSLP) and 850 hPa wet bulb potential temperature are very informative about the low layers while wind and geopotential height at level 1.5 PVU (the level where the Potential Vorticity reaches 1.5 PV Units, which is currently called the *dynamic tropopause level*) provide useful information to detect upper troposphere anomalies. Infrared (IR) satellite imagery allows to assess atmospheric humidity and tops of the clouds while Water vapour (WV) imagery enables to recognize some important characteristic features of the dynamic tropopause.

- Step 2: Examining the quality and relevance of the analysis

The various observations at the surface and at upper levels, especially in the sensitive regions of the atmosphere (eg. baroclinic zones) have to be scrutinized and compared with the model analysis as soon as it becomes available, as well as with satellite images, in order to evaluate the quality and relevance of the analysis. Every disagreement can reveal a failure in the analysed initial state, which is a reason to reduce the confidence in the results of the corresponding forecast. The comparison with other analyses coming from other Centres can also help to validate the confidence or not.

- Step 3: Identifying the key elements of the meteorological situation, according to the accepted conceptual models and / or guidance / tools

The inspection of the analysed fields at low levels and in the upper troposphere, jointly with satellite IR and WV images, complemented by appropriate cross-sections, allows a well trained forecaster to detect the key meteorological features associated with the conceptual models (jet streams, tropopause anomalies, frontal discontinuities, baroclinic zones… for the midlatitudes; squall lines, African easterly waves, tropical cyclones … for tropical areas). At the end of this step, it is very useful to try to synthesize the results of this analysis work on a graphic document.

- Step 4: Examining the various guidance products and choosing the most likely scenario

The assessment of numerical model output is difficult to standardize because a number of reasons can induce erroneous forecasts (eg. lack of observations in the initial state, weakness of model physics, …). When several models are available, examination of the succession of the most meaningful model fields (already mentioned for the synoptic analysis purpose) coming from the various available models has to be performed to asses the evolution of the atmospheric circulation. It is important to check whether the most recent forecast agrees with the previous one for the same model as well as to compare the various models coming from different Centres. It is also important to compare model forecasts with latest observations once the forecast enters the validity period to assess whether it is on track. Such comparison of this set of forecasts (a "poor man ensemble") allows, when the scenarios agree, to increase the confidence in the model solution. Where Ensemble Prediction Systems are available, some tools or post-processing will provide information on probability of certain events to occur, which could provide very valuable information for decision-makers. When there is an important divergence between the various scenarios, the forecaster's task becomes much more difficult because it is necessary to make a choice. Unfortunately it is not possible to formulate a clear rule to make this choice as rationally as possible. The rejection of an a priori valuable observation in the model analysis could be responsible for an erroneous forecast; the similarity of the model behaviour during successive forecasts could incite to increase the confidence in the model. Anyway there is no definitive rule and the choice essentially rests on the forecaster's experience.

- Step 5: Describing the evolution of the atmosphere corresponding to the chosen scenario.

By applying the knowledge about the lifecycle of the conceptual models identified during the analysis step or in the framework of the chosen forecast scenario, the forecaster determines what are the main characteristics of the evolution of the atmosphere at the synoptic scale. This mental exercise, which takes place within the forecaster's brain, has to be carefully formalized in order to become usable by other people. This can be achieved by short written guidance describing the forecast evolution and by performing for successive forecast ranges (every 12 hours for instance) synoptic graphical products similar to the ones corresponding to the analysis. The written guidance should contain the reasons for the choice of the adopted scenario and give additional details in order to complement the graphic document. It is important to point out that, when the meteorological situation is likely to be favourable to the occurrence of severe weather, in-depth analysis of this event has to be performed with a high degree of priority.

- Step 6: Deducing the consequences for smaller scales and specific areas

An accurate description of the weather requires the forecaster to translate the synoptic scale forecast, elaborated during the preceding step, into smaller-scale phenomena. These may include effects such as diurnal variation, orographic or coastal effects. It is to be noted that as model resolution increases, some of these effects are better forecast by the model. The availability of model fields such as vertical velocities, accumulated precipitation or stability indices can be very helpful to achieve this task. Conceptual models are also useful but they can be subject to adaptations according to local conditions. The details at the scale of a country or parts of a country can be summarized in written technical bulletins or synthesized on a graphic (SIGWXs established for general aviation are good examples of documents fulfilling this purpose). In case of an expected severe weather event it becomes essential to take particular care to give a detailed account of its evolution. Modeldiagnostics and prognostics of phenomena may also be useful e.g versions of thunderstorm forecast decision trees that produce output on the possibility and severity of thunderstorms.

- Step 7: Describing of the expected weather in terms of weather elements (including automated production techniques when applicable)

With the help of the guidance and documents obtained after completion of steps 5 and 6, and local model output (eg. model's synthetic tephigrams, statistical interpretation, meteograms) the forecaster should be able to depict the expected weather at selected points by giving numerical values of the meteorological parameters characterizing the weather (temperature, wind speed and direction, precipitation) and specifying the possible occurrence of various meteors (fog, snow, thunderstorm, hail, …). A good knowledge of the characteristics and performance of objective weather guidance from dynamical/statistical interpretation tools (such as Perfect Prog. Method, Model Output Statistics, Kalman Filter …) is also needed. Such depiction of the weather elements should be done for all the important places of the area of responsibility and if possible for different times of the day in order to describe the diurnal cycle. High resolution models are able to provide detailed information/ weather elements at chosen points in time and faces. Some centres have developed tools that allow the forecasters to modify weather elements as needed.

Step 8: Deciding on the opportunity / necessity to issue / end warnings.

The risk assessment for severe weather events has to be a continuous concern for the forecaster, especially during steps 5 and 6 of the weather forecasting procedure. When severe weather is expected to threaten a region, this task has to be completed with the highest priority. The decision to issue or end a severe weather warning will result from the comparison of specific forecast weather elements (temperature, wind speed, precipitation) with agreed thresholds, adopted in cooperation with the civil security services. But it is important to note that it is not possible to define standard thresholds for each category of severe weather phenomena: the attempts to achieve such a normalization, even inside the same country, shows that the values or the thresholds depend on the level of protection against the possible damage. Moreover, the decision to issue warnings does not only depend purely on the expected value of meteorological parameters, but also on the expected impact. For example, forecasting snowfall during a period when important traffic jam is foreseeable may justify the issue of warnings even if the expected snow accumulation does not exceed the agreed threshold. For all these reasons it is not possible to establish standard rules to decide whether severe weather warnings should be issued.

- Step 9: Distributing the various products to users

This step consists of preparing forecast products for the users (eg. civil protection, hydrological service, aviation, marine). Products should be designed to meet the agreed requirements of users, and in some cases it may be appropriate to provide "raw" information such as radar imagery, satellite imagery or NWP output. Detailed inspection of the atmospheric model output as well as guidance products described in previous steps, results of other models (eg. wave model for marine forecasts) are necessary to perform these specialized forecasts. The workload necessary to elaborate special bulletins, forecasts in tabular form, graphics for the media or other clients strongly depends on the degree of involvement of the Meteorological Centre in the preparation of customized products, on their level of automation

- Step 10: Evaluating according to performance measurements / Verifying forecasts

Performance measurement is essential to ensure that products are of good quality, to identify deficiencies and facilitate continuous improvement.

5 - A cascading procedure from medium-range forecasting to nowcasting

5.1 - Normally, forecasters focus their attention on short-range forecasting. Nevertheless, medium-range forecasting can also provide users with effective products up to at least 7 days. Such forecasts may provide various possibilities for the synoptic evolution, which will be then treated in the framework of short-range forecasting.

5.2 - The number of Centres running Ensemble Prediction Systems for medium-range purpose increases regularly. They use various techniques (singular vectors, breeding, perturbed physics, …) and provide the forecaster with a set of possible evolutions of the atmosphere. This kind of forecast enables the forecaster to assess, for each meteorological parameter, a finite sample of its probability density function (PDF) instead of the single deterministic value given by a simple model. It becomes possible to obtain everywhere the mean value and standard deviation of meteorological parameters, or to compute probabilistic forecasts. Users who are able to evaluate a cost-loss ratio can take advantage of probabilistic forecasts to manage, in an optimal way, an activity that depends on weather conditions.

5.3 - A large variety of products can be generated from EPS: mean value and standard deviation, clusters resulting from an automatic classification, probability of occurrence of weather events (eg. warm or cold anomalies, rainfall accumulation, high winds and others). The products consist either of charts or the presentation of probabilistic time-series at specific locations (eg. EPSgrams are a useful tool to assess the spread of the ensemble for the main weather elements (temperature, wind speed, precipitation, cloudiness) at a given location.

5.4 - Within the framework of weather forecasting considered as a continuous process, medium-range products coming from EPS provide forecasters with different evolutions at the synoptic scale. The existence of solutions favourable to the development of severe weather within the ensemble can provide useful guidance to the possible issue of early warnings for the following days. The Extreme Forecast Index (EFI) developed at ECMWF gives an example of a specific product useful to alert forecasters to the possibility of extreme solutions.

5.5 –The forecaster's work for very short-range and nowcasting purposes is very much dependant on observations, radar and satellite information, and model output. Nowcasting involves extrapolating the latest observations, such as radar observations of precipitation, forward in time, sometimes with the aid of wind fields from numerical models, and is often automated. In very short-range forecasting the forecaster can monitor whether the actual behaviour of the atmosphere agrees with the forecast one. This process needs to compare the model fields (or model synthetic images) with real satellite images or radar echoes. When the actual evolution differs from the model one, the forecaster should be able to adjust the forecast and to amend the products delivered toward the end-user. This task becomes particularly critical when a severe weather event is taking place.

5.6 – In some of the larger NMCs which have access to EPS, global models, limited area models and nowcasting tools such as radar networks the cascade process from medium-range forecasting to nowcasting can be performed in the same NMC. In other countries access to products required for parts of the cascade may be obtained through cooperation between the centres of the GDPFS.

5.7 - If short-range weather forecasting appears as a rather well defined process, the links with medium-range forecasting on one side, and with very short-range forecasting on the other side, are not straightforward. A good way to define the products to be exchanged in the framework of such a cooperation would be to organize a demonstration project involving several Centres. This would allow demonstration of the provision of products from producer centres to user centres, and also feedback back up to the producer centre on how the information has been applied. This feedback process should be activated every time a severe weather event is forecast in order to assess the efficiency of the cascade process.

Appendix – Further information on forecast processes and training

A.1 - Relevant information about all the knowledge and practice necessary to perform meteorological forecasting can be found in the documentation elaborated by various meteorological training schools and this subject has justified the elaboration of a very comprehensive document prepared by a panel of experts for WMO : *Guidelines for Education and Training of Personnel in Meteorology - WMO TD N° 258*.

A.2 - According to the document TD N°258, WMO classifies meteorological personnel into two categories:

- Meteorologists, who acquired at the university an appropriate knowledge on mathematics, physics and chemistry and completed a degree specialized in meteorology;

- Meteorological Technicians, who acquired scientific background at the secondary or postsecondary school and completed a specialization in meteorology;

A.3 - In many countries it is possible to acquire, at the appropriate level, the fundamentals of meteorology and to complement this scientific background by some practice of weather forecasting through lab work. Nevertheless, when a new forecaster enters a weather forecasting office, he/she has to be trained on a forecaster desk (on the job training) to apply knowledge/methodology in a real environment and to acquire the skills to perform the various tasks in due time.

A.4 - Volume I of the TD N° 258 is devoted to meteorology .Part A covers three major items: the new classification of personnel (as mentioned above), the revised core curricula in meteorology and job-specialized required competencies. It gives details of three packages: the Basic Instruction Package for Meteorologists (BIP-M), the Basic Instruction Package for Meteorological Technicians (BIP-MT) and the Continuing Education and Training (CET). Part B gives examples of BIP and job-competency requirements in the main branches of activities (in particular, weather analysis and forecasting, climate monitoring, agrometeorology, aeronautical meteorology, marine meteorology, environmental meteorology).

A.5 - Important information about the various tasks the forecaster has to carry out in a forecast office are also described with many details in the various Guides which have been prepared by specialists, edited by WMO and regularly updated.

A.6 - The Guide dealing with general weather forecasting is:

- the *Guide on the Global Data-processing System* (WMO N° 305, edited and regularly updated since 1993). It contains brief descriptions of many methods and techniques used in data processing but also interpretation techniques for weather analysis and forecasting in both middle and tropical latitudes. It includes non-real-time tasks as well as quality-control procedures.

A.7 - Other Guides dedicated to specific applications of weather forecasting describe how the products elaborated in the framework of general forecasting should be adapted to fit as well as possible the special needs of the end-users. It also indicates the specialised training required for personnel in charge of preparing these forecasts. These are:

- the *Guide to practices for meteorological offices serving aviation* (WMO N° 732, second edition, 2003); the chapters 5 and 7 are particularly relevant with respect to specific aeronautical tasks and corresponding training;

- the *Guide to marine meteorological services* (WMO N° 471, third edition, 2001); the chapter 1 provides guidance on the various marine meteorological services, preparation of weather bulletins for shipping and coastal storm warnings, and chapter 7 gives information on training in marine meteorology.

- the *Guide to public weather services practices* (N° 834, second edition 1999); many examples explain how to present weather products for the public; chapter 8 considers coordination problems within the meteorological service and with various partners, while chapter 9 points out the need to develop awareness of meteorological phenomena among the public. This excellent document is complemented by a set of 4 CD-ROMs giving helpful advice on preparation of weather bulletins with many exercises to train the personnel.

- the *Guide to hydrological practices* (N° 168, fifth edition 1994, which contains 770 pages and is available on a CD-ROM). This comprehensive guide consists of 59 chapters covering the entire field of operational hydrology, as it is currently perceived, with its applications to water management. It describes with many details the various aspects of hydrological phenomena and the corresponding forecasting methods (Part B, chapters 41 to 46).

A.8 - Numerous NMHSs or national organizations have taken advantage of recent developments in NWP and dynamic meteorology to define methodologies for preparing weather forecasts. Several attractive training materials based on Computed Aided Learning (CAL) and New Information Technologies have been developed and are now available. The information about these products can easily be found on the Web and a few references are given below :

- COMET: http://comet.ucar.edu/modules/index.htm; a very comprehensive set of modules covering meteorological phenomena and weather prediction techniques;

- EUROMET: http://euromet.meteo.fr/; a course on NWP and satellite meteorology, developed by a consortium of meteorological services and universities;

- SATREP: http://www.knmi.nl/satrep/startpage.html; a methodology devoted to the interpretation of meteorological information by the forecaster, developed by ZAMG, FMI, KNMI and Eumetsat;

- ANASYG-PRESYG: http://www.meteorologie.eu.org/anasyg; a Computed Aided Learning focussed on synoptic meteorology from the point of view of the forecaster;

- ASMET: http://www.comet.ucar.edu/modules/ASMETI.htm; a Computed Aided Learning focussed on forecaster's work in Africa, developed by EAMAC (Niger) and Eumetsat;

A.9 – Despite these developments, further work is required to produce specialised training material devoted to forecasters working in tropical areas. During the meeting organized by the Bureau of Meteorology (Australia) in January 2001 in Darwin, it was recognized that: "*While there has been much progress in recent years in understanding the large-scale dynamics of the tropical atmosphere on intraseasonal and longer time scales, there has been rather less focus on the morphology and dynamics of tropical weather systems that are of importance in day-to-day weather forecasting, perhaps with the exception of tropical cyclones, but including monsoonal weather. Forecasters in* *tropical regions have few conceptual models at their disposal and there is a notable lack of useful theory that they can call upon*".

A.10 - There are also many Organisations or Training Schools associated with NMHSs which regularly organize training courses and provide training materials for operational weather forecasting. Only a few are listed below with their Web address:

- COMET/UCAR (USA): http://www.comet.ucar.edu/modules/index.htm
- The Met-Office College (UK): http://www.met-office.gov.uk/training
- Ecole Nationale de la Météorologie (France): http://www.enm.meteo.fr

A.11 - Several organizations and professional bodies provide accreditation or certification for meteorologists. Examples include the American Meteorological Society in the USA, the Canadian Meteorological and Oceanographic Society in Canada and the Royal Meteorological Society in the UK.

Annex to paragraph 4.7.2

RA III/IV TRAINING WORKSHOP ON ENSEMBLE PREDICTION SYSTEMS

(Brasilia, 24-29 January 2005)

PROVISIONAL AGENDA

DAY 1

Ensemble basics concepts and principles Lecturer: ECMWF expert

- Chaos theory
- Error sources: initial conditions error and model error propagation
- Scale and predictability - Sub-grid processes

Construction of ensembles

- "Poor Person" Ensemble
- Initial conditions and model perturbations; relationship to data assimilation
- Multi-model ensembles
- Global and regional ensemble systems

Basic products 1

- Stamp maps
- Spaghetti charts
- Ensemble mean and spread
- Clusters/tubes
- EPSgrams and plumes

DAY 2

Review of principles of probability

- Introduction to probabilities
- Relation between probabilities and odds
- Probability from statistical methods
- Probability from ensembles
- Probability and decision making (Cost/ Loss model)
- Difference between point probability, area probability and average point probability

Basic products 2

- Probability charts
- PDFs/CDFs, stacked probabilities;
- Storm track and strike probability charts;

Advanced products

- Statistical post-processing
  - bias correction
  - calibrated probability products
  - probability dressing;
  - Kalman filtered
  - Bayesian post-processing
- EFI/Severe weather warnings

- Relative measure of predictability
- Circulation indices (blocking,…)
- Downscaling (statistical/dynamical)
- Downstream models and products for key sectors(e.g. energy, hydrology, agriculture, warning authorities, civil protection, etc.)

DAY 3

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

Presentation of Regional Experiences with EPS and/or EPS products
Case study no1 *Leaders*
- *Exercises – locally adapted, real-time and/or historical*
- Capabilities and limitations of ensembles
- Forecast process (methodology)

DAY 4

Sources of ensemble data
- Charts
- GTS/Internet/ftp/satellite
- GRIB and BUFR products
- Technical requirements:
  - running EPS
  - post-processing EPS
  - expertise and support

Use of the Computer Aided Learning (CAL)
- CAL material to be used during the afternoon labs
- Relation between workshop modules and CAL
- Installation guide

Case study no2
- *Exercises – locally adapted, real-time and/or historical*
- Access to products
- Capabilities and limitations of ensembles
- Forecast process (methodology)
- High Impact Weather example

DAY 5

Skill and value of ensemble forecasts
- Verification of probabilities
- Spread/skill relationships

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

Cases studies no3

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

DAY 6

Cases studies no4

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

Closing session

- Discussion – ***Panel:*** *All Lecturers*
- Recommendations – Wrap up
- Closing

Annex to paragraph 4.8.4

Amendments to the Manual on the Global Data-Processing System (WMO-No.485)
Modifications to the Attachment II-7 of the Manual on GDPS are indicated with an underlined.

(proposed changes in *italics*)

STATISTICAL VERIFICATION OF NUMERICAL WEATHER PREDICTION

23 The accuracy of forecasts of numerical weather prediction models should be monitored by objective verification procedures.
(*a*) Centres operating global, hemispheric or near-hemispheric models and regional models covering appropriate areas should compile verification statistics using the standard procedures described in Table F. The results, together with any relevant information such as improvements that have been made to their NWP systems, should be exchanged monthly between participating centres. Such information may enable centres to identify deficiencies or problems and make improvements in their NWP systems;
(*b*) Centres receiving GDPS products over the GTS may wish to verify appropriate areas using the standardized measures listed in Table F and send the results to the producing centres.

24. *The statistics of EPS verification should be exchanged. A lead centre for EPS verification should take responsibility for gathering the statistics of EPS verification and for deriving probabilistic scores such as the Brier score, the reliability score, ROC area and the economic value from the exchanged reliability table. The lead centre should make the verification scores available on a Web site, which is open to the NMHSs, promptly.*

Annex to paragraph 5.6.1

SEVERE WEATHER FORECASTING DEMONSTRATION PROJECTS

Goals:

- To improve the ability of NMCs to forecast severe/extreme weather events
- To improve the lead time of the alerting of these events
- To improve interaction with disaster management and civil protection agencies before and during event
- To identify gap and areas for improvements

Sub goals:

- To evaluate the value of probabilistic forecasts and the skill of EPS products
- To enhance capacity of NMCs (training, capacity building, etc..)

Three – level approach:

1) Global NWP Centres: producers of products;
2) Regional Centres with human and technical capability to run NWP models over a limited area, to interprate products from global NWP centres;
3) NMCs with sufficient capacity to benefit from project.

Roles of each centre:

1) Global NWP Centres:

- Commitment to provide NWP products over area covered by the project for duration of project(s): deterministic model, EPS output such as extreme weather index, probability precipitation/wind exceeding a certain threshold.

2) Regional Centres:

- Interpret information received from global NWP centres, develop diagnostics products/guidance material on potential of severe weather based on EPS products (timeframe 3-5 days ahead of time); make the information available to participating NMC(s);
- As it gets closer to event, run mesoscale model to refine products, confirm potential for severe/extreme weather, provide more detailed information (36-48H);
- Establish communications between regional centre and participating NMC;
- Evaluation of approach from regional centre perspective;
- Provide feedback to participating global NWP centres.

3) NMCs:

- Liaise with disaster management and civil protection agencies;
- Establish contacts with above agencies prior and during event;
- Interpret information received from Regional Centres and assess diagnostics products against available information and make adjustments as required;
- Apply nowcasting techniques;
- Issue alert, advisory, warning as appropriate;
- Evaluation of cascade approach from a forecaster perspective;
- Provide feedback to regional centre on usefulness and skill of product;

- Get feedback from users.

Criteria for participation

The project will only succeed if participating NMCs agree to meet certain pre-determined criteria. Participating centres must meet the requirements listed below.

1) Global NWP centres:
   - Commit to provide agreed upon information during duration of project;
   - Consider feedback from users as appropriate;
   - Provide a contact person for the project.

2) Regional centres:
   - Ability to interpret, use and evaluate products from Global NWP centres;
   - Ability to run limited area model over region considered;
   - Provision of training to participating NMCs as required;
   - Provide a lead person for the duration of project.

4) NMCs
   - Minimum communication bandwidth of 64kbps;
   - Operational and real-time access to satellite data and some observations from ground stations;
   - Adequate telecommunication system to receive/transmit information;
   - Appropriate workstation that meet data processing standards;
   - Provisions of senior forecaster for the duration of the project that must meet WMO standard training for meteorologist: meteorologist who acquired at the university an appropriate knowledge of mathematics, physics, and chemistry and completed a degree specialized in meteorology;
   - Provision of a lead person for duration of project;
   - Commitment to establish liaison with disaster management and civil protection agencies within their country.

Potential participants will have to demonstrate that they meet the above criteria.

More general criteria:

- Regional centres and NMCs would be from same region, and be able to communicate in same language;

- Must be in area where severe weather is encountered;

- Ability and commitment to participate in the evaluation of the experiment: criteria, indicators, and etc..;

- The project must be sustainable: use of existing capacity, on-going commitment of participating centres, on-going assessment of usefulness and skill.

Annex to paragraph *5.6.2*

DEMONSTRATION PROJECT ON TROPICAL CYCLONES

Specific objectives:

In addition to broad objectives described under chapter 3.7 of the report:

- To bring the available technology and tools, including EPS, to the forecasters in developing countries for the improvement of intensity forecasting. Capacity building should not be overlooked.
- To evaluate the usefulness of EPS in various aspects of intensity forecasting associated with tropical cyclone in terms of lead-time, quantitative measure of probabilistic information from both forecasters and users point of view.
- To evaluate EPS guidance against deterministic guidance including high-resolution NWP products on varying lead-time (medium to very short range).
- To promote the usefulness and value of EPS guidance particularly in the form of probabilistic guidance for the disaster mitigation from heavy rain, storm surge and strong wind from tropical cyclone, and to evaluate the effectiveness of information at three level of cascading stage including the linkage between meteorological office and disaster management authorities at national level.
- to identify limitation of the value of current EPS products particularly over Tropics, and direction for improvement.

Potential products:

In addition to existing information from Tropical cyclones program:

- Deterministic grid output (3-5 days in advance);
- Probabilistic information on track and intensity, including precipitation and wind higher than a certain threshold, EPSgram (grid point information on temperature, precipitation, wind) (3-5 days in advance);
- Some regional model output (24-72 hour in advance).

Deliverables:

At the end of the demonstration project, the expected outcome would be:

- Evaluation on the utility of EPS guidance in improving severe weather associated with tropical cyclone: timing, lead-time, location, scale of impact, and effectiveness to alarm disaster management authorities for preventive and/ or counter measures;
- Better tool to forecast intensity of tropical cyclones based on NWP guidance including EPS products;
- Identification of gaps and areas for improvement (i.e. additional products required, training needs, infrastructure enhancement such as telecommunication requirements to access the modern NWP products). This could be used in future steps e.g. to develop a proposal to enhance capabilities of NMCs in collaboration with disaster management sector.

Cascade process:

- One or more global EPS centres would provide the probability distribution of TC tracks and strength of TC intensity in terms of rain, wind, temperature, central pressure, EPSgrams along with conventional form of NWP guidance for 3-5 days in advance through Internet or other communication means available for the target country;
- The products would be provided to the RSMC for Tropical cyclones who would interpret the information;
- High resolution limited area models may provide detailed synoptic conditions and possible some mesoscale signatures on the distribution of rainfall and wind structure, and their interaction with topography or with large-scale circulation;
- The various downscaling process will be activated to infer detailed scenarios for expected disasters associated with storm surge, floods, strong wind, and severe thunderstorms. The exchange of information among partners is requested (such as oceanographers for storm surge, hydrologist for floods, and disaster managers for evacuation, civil engineers for protection of property, etc.);
- When the threat is imminent such as TC landfall, the observation can be compared with the model guidance and corrections are made to fit with the latest observation in nowcasting range.

Three levels and roles:

- Global NWP centres provide available NWP products particularly in the form of probability;
- Regional centres provide some coordination for the definition of episode, interpretation for the guidance, collection of feedbacks, and training for facilitating the demonstration by targeted user NMCs;
- NMCs provide severe warning, evaluation of the project (the WWRP reference on the standard form for verification is desired). They are also responsible to communicate with disaster management sector, particularly for hydrology group and DMCPA component. They are requested to comment on further improvement to be carried out by advanced centres.

Duration:

- A whole year to sample on extreme storm events (classified as tropical storm or stronger in Pacific region for instance).

Evaluation of demonstration:

- To measure the accuracy of meteorological products using WMO standards;
- To measure the process itself, survey is recommended after each storm event towards both forecasters and end users at national level.

Preconditioning:

- The infrastructure for the communication and/or verifying ground network should be available for the participating NMC;
- The targeted user NMC have an appropriate capability for the evaluation of the cascading process and the usefulness of the processed information;
- The committed NMCs and/ or intermediate RSMCs have to identify the forecast problem (i.e., how to use the given NWP guidance on what sort of severe weather in tropical cyclone), and the way of verifying the process for all three level of cascading.

Special recommendation to CBS/WMO:

- Global NWP centres are identified as willing to provide as much EPS products as available to target user NMCs;
- Approach regional bodies such as regional association or tropical cyclone community to find appropriate regional centres that coordinate the interpretation of NWP guidance, train target user NMCs and collect feedbacks from the users;
- The participating NMCs should be identified as highly motivated to use the latest available NWP products for their forecasting process, while being committed to evaluate the accuracy of the information, the usefulness of the information provided and the effectiveness for the disaster mitigation, from a meteorological service perspective.

Downscaling details:

- The uncertainty of meteorological information based on EPS could be further processed for refining the assessment of the risk associated with ~~for the~~ storm surge and flood, which could be handled with a coordinated effort with the hydrology community and the coastal engineering community.

Remarks:

- A tropical cyclone may hit a single country and/ or several countries on its passage. In case several NMCs may be involved in any single event, associated NMCs may participate on the demonstration. The targeted NMC may not necessarily be limited to a single country.
- Many global NWP centres including ECMWF have a plan to enhance the resolution of their EPS, which could provide additional opportunity and motivation to participate on demonstration project.
- In a sense the tropical cyclone program is well established at regional level. Some agreement or harmonization have to be developed to make the demonstration successful from the planning stage to the implementation stage. Some institutional arrangement between CBS and tropical cyclone community has to be made.
- The linkages between NMCs and disaster management and civil protection agencies need to be strengthened, as it is very weak in some countries.
- Performance measures need to be developed to verify the usefulness and the skill of the projects. There may benefits to use the scheme developed by WWRP for the demonstration project during the Sydney Olympics. The scheme should evaluate the performance from both a forecaster perspective and user point of view.

DEMONSTRATION PROJECT TO IMPROVE FORECASTS OF HEAVY RAIN AND STRONG WINDS

Objectives:

In addition to the broad objectives described under chapter 3.7 of the report

- To bring the available technology and tools, including EPS, to the forecasters in developing countries for the improvement of severe weather forecasting related to heavy rain and strong winds;
- To evaluate the usefulness of EPS in various aspects of heavy rain and strong wind forecasting in terms of lead-time, quantitative measure of probabilistic information from both forecasters and user s point of view;
- To use current available products to their full capacity;
- Develop linkages with between meteorological office and disaster management authorities at natio nal level;
- To identify limitation of the value of current EPS, diagnostic products, nowcasting techniques and direction for improvement.

Potential products:

- Identify currently available products;
- Deterministic grid output (3-5 days in advance);
- Probabilistic information such as precipitation and wind higher than a certain threshold, EPSgr am (grid point information on temperature, precipitation, wind), diagnostics products (stability in dices, CAPE) (3-5 days in advance);
- Some regional model output (24-72 hour in advance).

Deliverables:

At the end of the demonstration project, the expected outcome would be:

- Evaluation on the utility of EPS guidance in improving lead time for disaster management auth orities for preventive and/ or counter measures;
- Better tools to forecast severe weather;
- Increase use of NWP and diagnostic products;
- Improved links with disaster management and civil protection organization;
- Identification of gaps and areas for improvement (i.e. additional products required, training nee ds, infrastructure enhancement such as telecommunication requirements to access the moder n NWP products). This could be used for future steps (e.g. to develop a proposal to enhance capabilities of NMCs in collaboration with disaster management sector).

Cascading approach:

1) Global NWP centres: provision of products of interest over the area covered by the project. This will allow assessing the ability of existing products to add value to the forecasting services in the participating countries. Global NWP centres are encouraged to enhance the list of products that they make available and improve the accuracy of the existing products based on feedback from users.

2) Regional centres (belonging to target region) with technical and human potential to run numerical model and generate new product adaptation tools for their own use and for dissemination and capacity

building for other countries. The role of the regional centre will be crucial during the demonstration project implementation phase. This centre through intensive discussion with the global NWP centres has to build an evaluation/validation process/mechanism from the beginning in order to detect any added value during and after the demonstration project period.

3) NMCs provide severe warning, evaluation of the project (e.g. the WWRP reference on the standard form for verification ~~is desired~~). They are also responsible to communicate with disaster management sector, particularly for hydrology group and DMCPA component. They are requested to comment on further improvement to be carried out by advanced centres.

Action plan:

During the discussion it was pointed out that the period of one year cannot be enough to show clear and strong added value. The idea to consider three phases around the demonstration project:

A) Pre-demonstration period-Feasibility phase:

During this phase an inventory of existing products, capacities (telecommunications, data-processing, human resources, etc…), vulnerabilities will be undertaken for potential candidate countries. This will allow selecting participating countries, ensuring that they meet criteria, and better defining problems to be addressed.

B) Demonstration period:

1) Demonstration project precision phase: as output of the feasibility phase the term of references of the demonstration project have to be well identified and detailed: general objectives, specific objectives, expected deliverables, team members, international, regional and national coordinators, time table, list of partners, list of product and processes, resources needed.

2) Implementation phase: during this phase one can start by generating the optimal use of existing products with the necessary adaptation. In this phase the role of the regional centre is crucial in term of product adaptation, process validation and capacity building.
The second step concerns the improvement of the existing processes even in the regional centre to engage communications with the NMCs, to ensure a mechanism for validation/feedback. The aim is to implement a pilot operational warning system in both regional centre and at least one NMC: coordination, optimization and facilitation of the exchange of information have to be considered. At the end of this phase a **dynamic warning information system** have to be implemented with easy access by the existing telecommunication tools (fax, telex, internet, satellite,…).

3) Sustainability phase of the warning system (Continuous evaluation/improvement): During this phase the warning system has to enter in operational suite assuring all the accompanying measures that allow robustness, maintenance and sustainability of the warning system. The Warning Information System has to be continuously updated; the interaction with the end users regularly maintained; systematic coordination assured, etc…

Post- evaluation:

It is proposed to assess the project after one year. Based on the assessment, it may be decided to continue the project for another period, to make some adjustment to the project or terminate the project.

Annex to paragraph 6.3

Suggested amendments to manual on the GDPFS - Appendix II-6

Add at the appropriate place:

Minimum list of LRF products to be made available by global scale producing centres

1. Forecast Products

Note: it is recognised that some centres may provide more information than the list below on the basis of the CBS-Ext.2002, Appendix V and may also include for example daily data, hindcast data.

Basic properties

Temporal resolution.
Monthly averages/accumulations for a season

Spatial resolution.
2.5° x 2.5° (note: selected to match resolution of current verification data)

Spatial coverage. **Global**
(separate areas of interest to users, down to sub-regions of a continent or ocean basin, may be provided on special request from Members)
Lead time. **0-4 months for seasonal forecasts.** Note on definition of lead time: for example, a three-monthly forecast issued on 31 December has a lead time of 0 months for a January-to-March forecast, and a lead time of 1 month for February-to-April forecast, etc.

Issue frequency. **Monthly and/or quarterly**

Output types. Gridded numerical values, area-averaged values and indices, and/or images. GRIB-2 should be used for products posted on FTP-sites or disseminated through the GTS or the Internet

Indications of skill including hindcast **must be provided**, in accordance with recommendations from CBS on the Standardised Verification System(attachment II-8). The minimum required is level 1 and level 2 verification. The verification of Nino3.4 index will only apply to those centres producing such indices. However GPCs are encouraged to provide level 3 verification. Verification results over the hindcast period are mandatory.

Content of basic forecast output: (some products are intended as directly meeting NMS requirements with regard to information needed for end-user applications [direct or further processed]; others are to assist the contributing global centres in product comparison and in the development of multimodel ensembles. These products are regarded as feasible from current systems).

A. **Calibrated outputs from ensemble prediction system showing the mean and spread of the distribution for:**
   - **2 metre temperature over land**
   - **sea surface temperature**
   - **precipitation**

- **Z500, MSLP, T850**

Notes:
1. These fields are to be expressed as departures from normal model climate.
2. SST used as boundary conditions for (two-tiered) AGCM predictions should be made available.

B. **Calibrated probability information for forecast categories. Tercile categories should be provided**, consistent with present capabilities. Information for larger numbers of categories (e.g. deciles) is foreseen, however, as capabilities increase and to match better the anticipated end-user requirements. These targets are implied also for forecasts from statistical/empirical models.
Note: information on category boundaries should be included.

- **2 metre temperature over land**
- **SST (Atmospheric coupled models only)**
- **Precipitation**

(Note: "Calibrated" implies correction based on systematic errors in model climatology, using at least 15 years of retrospective forecasts.)

Annex to paragraph 6.4

Statement of Guidance for Seasonal-to-Interannual Forecasts (updated Nov 2003)

This Statement of Guidance (SOG) was developed through a process of consultation to document the observational data requirements to support seasonal-to-interannual (SIA) climate prediction. This version was prepared originally by the ET-ODRRGOS with experts from the NWP community, and was subsequently updated in consultation with a number of experts from the climate community through AOPC. It is expected that the statement will be reviewed at appropriate intervals by the OPAG on Data Processing Forecasting Systems to ensure that it remains consistent with the current state of the relevant science and technology

The ET on Long-Range Forecasting reviewed the Statement of Guidance. Comments are inserted in bold.

1. Introduction

Coupled atmosphere-ocean models are used to produce seasonal-to-inter-annual forecasts of climate. While empirical and statistical methods are also used to predict climate conditions a season ahead, the present assessment of how well observational requirements are met relates only to the coupled model inputs. It is noted that historical data sets also play an important role in SIA prediction by supporting calibration and verification activities.

Whilst such forecasting is still subject to much research and development, many seasonal forecast products are now widely available. The complexity of the component models ranges from simple baroclinic models to full general-circulation-model representations of both the ocean and atmosphere. There is also large variation in the approach to the assimilation of initial data, with some of the simpler models assimilating only wind information while the more complex models usually assimilate subsurface temperature information and satellite surface topography and temperature data. Indeed, major challenges remain in the development of assimilation techniques that optimise the use of observations in initialising models. At present, useful forecast skill (as measured against ocean and atmosphere indices) is restricted to around 6-8 months lead-time and is confined primarily to the tropical Pacific and those regions directly impacted by El Niño, although useful skill has also been demonstrated in some extratropical regions.

The time and space scales associated with seasonal-to-interannual variability (large scale, low frequency) suggest the key information for forecasts will derive mostly from the slow parts of the climate system, in particular the ocean. The initial conditions for the atmospheric model component are not so significant. When considering impacts such as rainfall deficiencies or increased temperatures over land, however, there are very good reasons for considering variables associated with the land surface conditions. In particular, land surface moisture and vegetation health should be specified and predicted. The models should also include up-to-date radiative forcing (e.g. greenhouse forcing), which may be important for maximising skill in forecasts of land surface air temperature anomalies relative to recent historical reference-normal periods.

Comprehensive statements on requirements of AOPC, OOPC, TOPC, WCP, WCRP and CCl have appeared in several places, most recently in the proceedings of *First International Conference on Ocean Observing Systems for Climate*, and published separately in *Observing the Oceans in the 21st Century* (published by the GODAE Office and the Australian Bureau of Meteorology). In terms of key variables, the priorities have changed little since the Tropical Oceans-Global Atmosphere (TOGA) Experiment of 1985-1994. These requirements are being entered into the CEOS/WMO data base. The above references also provide details of ocean-based and space-based platforms capable of meeting these requirements. Further, the report of the IGOS Ocean Theme Team provides a consolidated and integrated perspective for the oceans that embraces SIA forecasts explicitly.

In this SOG, the requirements for SIA forecasts are based on a consensus of the coupled atmosphere-ocean modelling community. It builds on the requirements for Global NWP and represents in addition those variables that are known to be important for initialising models or for testing and validating models. For the most part, aspects that remain purely experimental (i.e. unproven) are not included. There is some attempt to capture the impacts aspects; that is, those variables that are needed for downscaling and/or regional interpretation.

2. Data Requirements

The following terminology has been adhered to as much as possible: marginal (minimum user requirements are being met), acceptable (greater than minimum but less than optimum requirements are being met), and good (near optimum requirements are being met).

2.1 Sea surface temperature

Accurate SST determinations, especially in the tropics, are important for SIA forecast models. Ships and moored and drifting buoys provide observations of good temporal frequency and acceptable accuracy, but coverage is marginal or worse over large areas of the Earth. Instruments on polar satellites provide information with global coverage in principle, good horizontal and temporal resolution and acceptable accuracies (once they are bias-corrected using *in situ* data), except in areas that are persistently cloud-covered (which includes significant areas of the tropics). Geostationary imagers with split window measurements are helping to expand the temporal coverage by making measurements hourly and thus creating more opportunities for finding cloud-free areas and characterising any diurnal variations (known to be up to 4 degrees C in cloud free regions with relatively calm seas). Microwave measurements provide acceptable resolution and accuracy and have the added value of being able to 'see through' clouds. Blended products from the different satellites and *in-situ* data can be expected to be good for SIA forecasts.

There is a requirement for high quality, fast delivery SST (ideally with accuracy < 0.1 deg C on 100 km spatial scale, available within 24h (by SST we mean e.g. bulk temperature at 2m depth).

2.2 Ocean wind stress

Ocean wind stress is a key variable for driving ocean models. It is important to recognise the complementarity between surface wind and surface topography measurements. Current models use winds derived from Numerical Weather Prediction (NWP), from specialist wind analyses or, in some cases, winds inferred from atmospheric models constrained by current SST fields. The tropical moored buoy network has been a key contributor for surface winds over the last decade, particularly for monitoring and verification, providing both good coverage and accuracy in the equatorial Pacific. Fixed and drifting buoys and ships outside the tropical Pacific provide observations of marginal coverage and frequency; accuracy is acceptable.

Satellite surface wind speed and direction measurements are now the dominant source of this information. Currently their data reach SIA models mostly through the assimilated surface wind products of NWP, where their positive impact is acknowledged. Overall, a two-satellite scatterometer system, or its equivalent, would provide good coverage and acceptable frequency, and it would complement the ocean-based systems. At this time, continuity and long-term commitment are a concern. Improved integration of the data streams and operational wind stress products from NWP and other sources will be needed to achieve acceptable or better coverage, frequency and accuracy.

High quality scatterometer winds are the best products available at the moment and need to be maintained operationally. Additional data would always be useful. For example data to allow better estimates of heat-fluxes and P-E could help give a better definition of the mixed layer structure.

2.3 Subsurface temperature and salinity profiles

Many, but not all, SIA forecast models assimilate subsurface temperature data, at least in the upper ocean (down to ~500 m depth). No current model assimilates salinity data (subsurface or surface), principally because of the paucity of data and inadequate knowledge of the variability. The Tropical Atmosphere Ocean (TAO) / TRITON moored buoy network provides data of good frequency and accuracy, and acceptable spatial resolution, of subsurface temperature for the tropical Pacific, at least for the current modelling capability. The tropical moored network in the Atlantic (PIRATA) is better than marginal but does not yet have the long-term resource commitments and stability to be classified as acceptable. There is no array in the Indian Ocean. The Ships-of-Opportunity Programme (SOOP) provides data of acceptable spatial resolution over some regions of the globe but the temporal resolution is marginal. It is noted that SOOP is evolving to provide enhanced temporal resolution along some specific lines. The *Argo* Project is providing increasing global coverage of temperature and salinity profiles to ~2000 m, mostly with acceptable-to-good spatial resolution, but only marginal temporal resolution in the tropics. In all cases the accuracy is acceptable for SIA purposes.

Ocean observation system over Equatorial Atlantic is deficient in moorings. Moorings at and near the equator are likely to be most important. Equatorial moorings in the Indian Ocean are also likely to be useful.

2.4 Ocean topography

Ocean altimetry provides a measure of the sea surface topography relative to some (largely unknown) geoid (or mean sea surface position) that in turn is a reflection of thermodynamic changes over the full-depth ocean column. In principle, the combination of altimetry, tropical mooring and *Argo* will provide a useful system for initialising the thermodynamic state of SIA models. Commitments are improving for long-term operation of satellite altimeters (e.g. through the Jason series). Research satellites are providing a mix of data with acceptable accuracy and resolution and data with good spatial resolution (along the satellite tracks) but marginal accuracy and frequency. The "synoptic" global coverage, particularly beyond the tropical Pacific, is an important requisite.

2.5 Surface heat flux

There are a few sites in the tropical ocean where the data on surface heat flux are of some value for validation. At a selected number of reference sites the accuracy and temporal resolution will be good. NWP products, in principle, have good resolution but the accuracy is at best marginal. Satellite data provide prospects for several of the components of heat flux, particularly shortwave radiation, but at present none is used on a routine basis for SIA forecasts. Precipitation estimates are important for validation because of the fundamental role of the hydrological cycle in SIA impacts. They also have potential importance in initialisation because of the links to salinity. However, there remain significant uncertainties in estimates of rainfall over the oceans.

2.6 Ocean current data

No model currently assimilates ocean current data. However, because of the central importance of dynamics and advection, current data are important for testing and validation. For example, experimental fields of surface current for the tropical Pacific and Atlantic are now being produced routinely by blending geostrophic estimates from altimetry with Ekman estimates from remotely-sensed wind observations. Inferred surface currents from drifting buoys are acceptable in terms of accuracy and temporal resolution but marginal in spatial coverage. Satellite altimetry is also being used to infer the distribution of ocean currents. Moored buoys are good in temporal coverage and accuracy, but marginal otherwise.

2.7 Sea level

In-situ sea level measurements provide an additional time-series approach (good temporal resolution and accuracy; marginal spatial coverage), particularly for testing models and validating altimetry.

2.8 Atmospheric data

Since several SIA systems are driven by winds and, in several cases, surface heat flux products from operational analyses, the global (atmospheric) observing system is important for SIA forecasts and their verification.

2.9 Other data

There are many other data sets that may play a role in future-generation SIA forecast models. Because these roles are largely unknown, it is premature to discuss the adequacy of observing systems to meet these needs; generally speaking, they are not expected to rank near the above data in terms of priority. These data sets include:

- Surface salinity (particularly from new space-based approaches). No present model uses surface salinity.
- Snow cover. Research suggests snow cover may be important, particularly at short lead times (intraseasonal-to-seasonal).
- Ice cover. Ice cover is important for high latitudes. It is implicitly included in the leading SST products.
- Soil moisture and terrestrial properties. Research suggests proper initialisation of soil moisture is important. There are also indications that terrestrial properties, such as the state of vegetation, may be important, particularly in downscaling and impacts/applications.
- Ocean colour. Ocean transparency is already included in several ocean models and is thought to be a factor in SIA models (helping to determine where radiation is absorbed). Ocean colour measurements provide a means to estimate transparency.
- Clouds. Poor representation of clouds remains a key weakness of most SIA models. Better data are needed to improve parameterisations but these needs are adequately specified under NWP and elsewhere.

Ice cover, Ice thickness, Snow cover depth and mass both for real time analyses and consistent analysis of the past are important and should be given same priority as data in above sections.

In order to have a realistic representation of the land surface conditions the following are necessary:
An accurate soil moisture analysis (together with consistent analyses of the past) in order to provide realistic soil moisture initial conditions to the LRF. This is very important for 1-2 month range forecasts in some parts of the world. Data describing soil water content, river run off, soil type, vegetation, land use (and its changes) are also needed in order to validate and improve the surface schemes.

Aerorols data such as volcanic ash is also required.

Global data that can be used to validate the Long Range Forecast. This is particularly important for rainfall, where high quality, high density and readily available data would be of great value both for assessing model quality, and, more importantly, empirical downscaling global model output for local use.

3. Summary

The following key points summarise the SOG for Seasonal to Interannual forecasts:

- The data requirements for seasonal-to-interannual modelling and forecasts are now entered in the CEOS/WMO data base (as well as available in several GCOS and WCRP documents; see Section 1);
- The WCRP has concluded that models show useful skill in predicting variability of the El Niño-Southern Oscillation but there is less useful predictability beyond the Pacific. The exploitation of skill is dominated by the signal of El Niño;
- Integrated and complementary approaches to the atmospheric and oceanic observing systems is required, exploiting synergies with other areas;
- The TAO/TRITON Array of moored buoys (SST and winds; subsurface temperature; currents) provides the backbone of the ENSO Observing System in place today and its continuation is essential;
- Enhancements from satellite wind vector and surface topography estimates, from autonomous systems such as *Argo*, and from enhanced surface flux reference sites, are providing a substantial contribution.

The key observational problems affecting improvements in seasonal to inter-annual forecasting are:

I. The transition of research networks and outputs (especially ocean-based) to operational status (i.e. with sustained institutional support);

II. The timely operational acquisition of data from research and non-governmental systems/sources;

III. The lack of long-term commitment to (a) a two-satellite scatterometer system, (b) tropical moored arrays in the Atlantic and Indian Oceans, (c) operational satellite altimetry, and (d) a network of surface flux reference sites.

Annex to paragraph 11.2

OPAG on Data-processing and Forecasting Systems

The Terms of Reference proposed for the OPAG on DPFS new Teams and Rapporteurs are as follows:

1. Implementation/Coordination Team on Data processing and Forecasting Systems

(a) Identify new emerging requirements (input required from RAs and other bodies);

(b) Determine how GDPFS Centres can best contribute to fulfill emerging requirements;

(c) Identify needs for workshops/training;

(d) Review the procedures and scope of verification statistics on the performance of forecasting systems and provide recommendations;

(e) Coordinate the implementation of decisions by CBS related to GDPFS;

(f) Review of Expert Teams and Rapporteurs and make recommendations to CBS concerning future work.

2. Coordination Group for Nuclear Emergency Response Activities (ERA)

(a) Test and improve the collective ability of all RSMCs, the IAEA, the RTH Offenbach and NMHSs in the ERA to fulfil the operational requirements specified in global and regional arrangements, according to adopted standards and procedures;

(b) Implement and further explore improved distribution/access methods for specialized products to NMHS, and the IAEA in collaboration with the IAEA and other relevant organizations;

(c) Examine the development of detailed procedures to activate additional observations in the event of nuclear accident (requires coordination with OPAG/IOS);

(d) Enhance cooperation with the CTBTO, including testing of concepts of operational arrangements and participation in a technical workshop.

3. Expert Team on Modelling of Atmospheric Transport for non-nuclear ERA

a. Identify the needs of the NMHSs for atmospheric transport modelling

b. Examine the atmospheric transport modelling capabilities of RSMCs and other centres for support to non-nuclear emergencies, for example in volcanic eruptions, dust storms, wildland fires, chemical and biological incidents and other hazards.

c. Identify the potential role of international organizations (e.g. WHO, UNEP, UN-OCHA, others)

d. Review the status and develop an action plan.

4. Expert Team on Ensemble Prediction Systems

(a) Developing education and training material for forecasters including rationale of concepts and strategies of EPS, and on the nature, interpretation and application of EPS products;

(b) Reviewing progress on EPS and its application to severe weather forecasting including progress on multi-centre ensembles and on regional model based EPS, and prepare ways to make best operational usage of these developments;

(c) Reviewing progress on the use of EPS for targeting of observations;

(d) Reviewing verification system for EPS products, providing guidance on the interpretation of verification and ensuring that verification system is adequate and meets CBS needs;

(e) Support the further development of the Lead Centre on Verification of EPS by reporting on verification measures and determining the best way of presenting skill of ensemble forecasting systems. Report on skill of available products. Provision of relevant software to NMHSs through the Lead Centre website;

(f) Review the list of fields and products that should be distributed taking into account the requirement of all relevant WMO Programmes;

(g) Propose an update to the Manual on the GDPS (WMO-No. 485) concerning the list of output products available for international exchange and dissemination, and the verification system for EPS;

(h) Develop and test procedures for the exchange of EPS data, including the needs of large centres to exchange their ensembles;

(i) Provide requirements for the dissemination of the products to help OPAG/ISS in determining appropriate means of dissemination to assess telecommunication implications.

5. Expert Team on Infrastructure for Long-range Forecasting

(a) On the basis of stated requirements for LRF products and their improvements, review input from the Global producing centres (GPCs), Regional Climate Centers (RCCs) and NMHSs and develop proposal concerning the establishment and implementation of appropriate operational infrastructure for the production, access dissemination and exchange of LRF including multi-model ensembles.

(b) Develop procedures for the exchange of LRF forecasts between potential centers and agencies concerned including defining products (multi-model ensemble, model output, forecast skill, etc.) and defining terms and conditions for exchange;

(c) Develop new interpretation guidance to facilitate correct use of LRF anomaly forecasts,

(d) Enhance exchange of long-range forecasts between GPCs and agencies;

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

6. Expert Team on Standardized Verification System for Long-Range Forecasts

(a) Coordinate the provision of long-range forecast verification scores and related information from GPCs for use by NMHSs and RCCs;

(b) Encourage and monitor feedback from NMHSs and RCCs on the usefulness of verification information provided by producing centres under the scheme;

(c) Review the effectiveness of the verification scheme in assisting NMHSs and RCCs to use the global-scale products to provide end-user services;

(d) Contribute to the further development of the Lead Centre role and the Web site including the development and provision of relevant software and data sets;

(e) Recommend updates to operational practices to be followed in computation of verification statistics and the information useful to attach to long-range forecast products in the light of the experience and progress in research on verification activities;

(f) In consultation with CAS (CLIVAR/Working Group on Seasonal to Interannual Prediction) and CCl, propose recommendations to CBS for improvements of the SVSLRF including for developing areas such as multi-model ensembles.

7. Rapporteur on the Impact of Changes to GOS on NWP

(a) Monitor changes to the GOS that may impact on NWP;

(b) Suggest studies as appropriate to evaluate impact of changes to the GOS for consideration by the GDPS centres;

(c) Review and report on sensitivity studies undertaken by GDPFS centre as appropriate, including targeted observations.

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

(a) Review the application of NWP to severe weather forecasting;
(b) Report on new developments and advances in severe weather forecasting.
(c) Review the minimum list of NWP products on the GTS in coordination with the Regional Rapporteurs on GDPFS.
(d) Provide advice on the proposed demonstration project(s)

PROVISIONAL AGENDA

1. OPENING OF THE MEETING

2. ORGANIZATION OF THE MEETING

   2.1 Approval of the agenda
   2.2 Working arrangements for the meeting

3. FORECASTING STANDARDS

   3.2 Weather Forecasting Technique considered as a Sequence of Standard Processes
   3.3 Implications of Quality Management on the forecasting process

4. ENSEMBLE FORECASTING SYSTEMS PRODUCTS AND APPLICATIONS

5. SEVERE WEATHER AND EXTREME EVENTS FORECASTING

6. LONG-RANGE FORECASTING (INFRASTRUCTURE AND VERIFICATION)

7. EMERGENCY RESPONSE ACTIVITIES

8. IMPACT OF CHANGES OF GOS ON GDPFS

9. REGIONAL PERSPECTIVES

10. NEEDS FOR TRAINING

11. FUTURE WORK PROGRAMME

12. CLOSURE OF THE MEETING

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