WORLD METEOROLOGICAL ORGANIZATION

COMMISSION FOR BASIC SYSTEMS

EXPERT TEAM MEETING ON INFRASTRUCTURE FOR LONG-RANGE FORECASTING

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PROCEDURES FOR EXCHANGE OF LRF FORECASTS INCLUDING DEFINING PRODUCTS

(Submitted by the Secretariat)

Summary and purpose of document

Requirements for extended range and long-range products from GDPS centres to other NMCs for their application.

Action proposed

The Team is invited to develop its recommendations taking into account the proposals submitted in this document.

1. PRODUCTS FOR EXTENDED RANGE AND LONG-RANGE:

The Expert team on EPS, Tokyo 15-19 October 2001 discussed also the requirements for extended range and long-range products and defined a set of products which could be provided by GDPS centres to other NMCs for their applications**. The team found however that the expertise of the group was limited to appreciate fully the real requirements for long-range prediction and consider that the list proposed, if it was a minimum to be transmitted, may need to be reviewed by other experts specialised in long-range prediction. The list developed by that team is therefore submitted to the ET on Infrastructure for Long-Range Forecasting for further review with a view to recommending it for adoption and inclusion in Appendix II.6 of the Manual on the GDPS.**

- **Ensemble Means anomalies/Spread:**

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

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

- **Probabilities:**

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

  - Precipitation
  - Z500
  - Z1000
  - T850 and surface temperature

- **Model fields:**

  - Full set or subset of EPS members variables and levels for requesting WMO Members for specific applications.
  - Relevant post processed fields from sequence of daily output (e.g., indices of monsoon onset, droughts, tropical storm activity, extratropical storm track activity (see statement of requirements by the Inter-Commission Task Team on Regional Climate Centres, Geneva 30 April-3 May 2001, in Annex 1 to this document).

In reviewing the above list of products which global product producing centres consider they can be made available, the team on ILRP should consider the overall statement of requirements for both global SI producing centres and the RCCs as given in Annex 1. It should also take into account the projected functions of the Regional Climate Centres as given in Annex 2 to this document for ease of reference.

Some issues related to observational data and product requirements in Annex 1 which are more effectively handled on a global scale may also have to be considered by the team

ANNEX 1

Requirements for Seasonal to Interannual Operational Prediction and Forecast Products.

1. Introduction

The Initial Planning Meeting (IPM), on the Co-ordination of Infrastructure Needs for Seasonal to Interannual (SI) Climate Prediction (April 1999), proposed that the WCP should undertake the preparation of a comprehensive statement of requirements for operational SI prediction and forecast products. It noted that much of the planning for infrastructure will depend on this requirement statement, and that input from Regional Centres, NMHSs as well as end users of climate services will be necessary. The Planning meeting further considered that the statement should include an analysis of training requirements and that sources of training documents should be identified. The need for a detailed user requirement for SI predictions was endorsed by Resolution 2 of the WMO Executive Council (EC-LII).

This paper meets many of the objectives of the IPM proposal although a wider range of inputs for the assessment would have been beneficial and continued work will be necessary. **Whilst the intent of the paper is to aid the planning of infrastructure,** it must be noted that the User Requirement must be subject to further changes as both service providers and end-users become more familiar with the products, their application and value.

The focus in the paper is on the inputs needed by those who provide a service, comprising customer-oriented products, to the end-users. These service providers may be NMHSs or private weather companies or institutions, Regional Centres serving the needs of a group of NMHSs, or a loose-knit regional organisation with responsibilities distributed amongst several members, or even a section of a global forecasting centre which may have customers in the public or private domain for products derived from its basic output. **It is the requirements of these providers that define this particular User Requirement.** No consideration is given to conditions that may attach to the provision of available products to points in the distribution chain.

The requirements should be seen as targets. **In several cases, it is not yet feasible to meet the stated needs.** It is acknowledge that in some regions during some seasons these requirements may not be achievable with sufficient skill. Producers need to identify which of these requirements are likely to be achievable and (if possible) with what quality on about a 5-year time frame. Likely shortcomings of quality need to be discussed with service providers so that they can review their priorities; this comparison is only likely to be possible on a general basis until requirements for quality can be properly quantified (see Section 2). In no way should the requirements be seen as rigid, rather they should be subject to a rolling review along the lines already established within WMO for dealing with observing needs and capabilities.

The input requirements of global centres of excellence in modelling of the climate system and NWP-based SI forecasting, and in statistical/empirical forecasting, are not considered here. These centres require inputs of observational data and products in order to function, and such requirements are considered and documented separately by the CBS Expert Team on Observational Requirements and Redesign of the Global Observing System. The Team has recently issued a Statement of Guidance relating to observations for NWP based SI forecasting, including those needed for coupled atmosphere-ocean models. However, observational needs **are** included in this paper if they relate to activities that will be carried out on a regional or national basis in many parts of the world. Such activities will include climate monitoring within a forecast period, SI forecast verification, locally developed statistics-based forecasting and downscaling.

Neither are the requirements of end users, for tailored products, considered here. The user end of the infrastructure, comprises the end-users themselves (ie a user external to the meteorological community) and sometimes an "intermediary" who is an adviser to the end-user on applications and impacts. Such intermediaries can be part of an NMHS but are often from Universities, other government or private agencies or international organisations. The range of tailored products the end-users and intermediaries require is very extensive, related to some 20 or so discrete applications (agriculture, water management, disaster preparedness, insurance, disease

management etc), geographical region, season, forecasting skill etc. It is not yet possible to produce an overall listing, nor necessary as explained later.

The paper is also intended to focus the attention of producers (of the basic statistical and numerical products) on the needs of service providers, and to lead to opportunities for the latter to examine more detailed output and thus facilitate capacity building.

2. Methodology

A methodology for determining the global user requirements was described in a consultancy report by Dr P Ryder, obtainable through the Secretariat of WCP Department. This report includes a "zeroth" order assessment as a basis for further focussed, purpose designed and directed research on the requirement. The proposed research involved either the establishment of regional workshops to explore the requirements related to a range of sectors of application, or of national points of contact determined by PRs who would be asked to provide detailed inputs to a questionnaire with updates on a three year cycle.

However, due to limitations on time and funding, the global assessment has been developed further by taking advantage of other meetings related to SI forecasting. In particular the Regional Climate Outlook Forum held in Pretoria, South Africa from 16 - 20 October 2000 was devoted to issues of global and regional infrastructure in support of SI forecasting and applications. The meeting was attended by representatives of NMHSs in Africa, South and Central America, the Caribbean, South East Asia, and the Pacific Islands, by the Presidents of the WMO Regional Associations in Europe and South America, by representatives of established regional centres such as ACMAD, the DMCs, AGRHYMET, and CATHALAC, by international providers such as NCEP, IRI, and ECMWF, by various national and international user agencies and by applications scientists (university and field-based) from most continents. Valuable input was generated relevant to the statement of requirements.

Account has also been taken of inputs from a range of institutional and commercial users at a workshop held on June 13-14, 2000 at the ECMWF on its SI outputs, and of an individual submission from Dr R Basher at the IRI.

It is at present very difficult for the users to state anything constructive with regard to the product quality that they wish producers to achieve. This is because the applications-related decision-making models, for which probability forecasts are but one input, range widely in complexity and utility around the world, and the sensitivity of decisions to errors in weather inputs has been assessed only on a limited and mostly theoretical case-study basis. Certainly users are not in a position to quantify the range of accuracy from which the forecast becomes useful to a limit beyond which further improvement will have little or no incremental benefit, a concept which is much more appropriate to deterministic forecasts.

However those who provide output tailored for end-users do need information on, or information that will enable them to derive some measure of the technical reliability and quality of the inputs they receive.

3. Product Requirements

Requirements are segmented according to whether they relate to forecast or data products, with further sub-divisions regarding variables, statistical nature of products, lead times etc. Requirements that have attracted a significant consensus are shown **in bold** (noting the need for wider review). Of course several of the requirements are new or newly stated. The skill associated with some products or product characteristics needs too be proven, an activity which should involve the user. As stated earlier, some requirements are not achievable at all at present.

3a. Forecast Products

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

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

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

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

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

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

Forecast Content.

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

However continuing dialogues with end-users are bound to result in changes to the input needs of their suppliers.

Confidence level.

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

Verification and reliability.

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

Documentation

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

3b. Observational data and Products.

As stated earlier, the observational requirements proposed here are related to regional and national forecasting and verification activities.

- **Real time synoptic data from the Regional Basic Synoptic Network.**
- **Sufficient national synoptic and climatological data to permit the development and updating of methods of downscaling.**
- **Monthly data and other statistics based on daily rainfall and temperature data (such as decile rankings) to be supplied from a subset of national stations to approved regional verification and monitoring centres. At least monthly data required within one week of end of month. Subset to give adequate representation of geographical regions (plateaux, flood plains etc)**
- **Grid box (2-degree square) averages of observational station percentile rankings for monthly rainfall and mean temperature within region, available within a month.**
- Regional soil moisture deficits and flood cover on a weekly basis, to be available within a week.
- Regional drought, fire and pollution indices on a weekly basis, to be available within a week.
- Global mappings of monthly pressure, rainfall and cloud cover anomalies, and anomaly maps of Northern Hemisphere snow cover, on a monthly basis.
- **Sea surface temperature** measurements, **but preferably weekly and monthly anomaly maps for the global oceans averaged over 2 1/2 degree squares.**
- Analyses of sea level, surface wind stress and global sections of temperature and salinity to 400m depth on a monthly basis.

- **SO and NAO indices, four week running means updated weekly and available within a few days.**
- **Archival data, including metadata, sufficient to determine the monthly climatology of the nation and region.**
- **Climate Atlases, station climate normals and other statistics relating to historical percentiles, extremes, return periods etc.**
- Historical data series for the SOI and Niño area SSTs.

4. Requirements for Training.

The following list mostly originates from discussions at the Pretoria meeting. All points relate to the training of forecasters and other providers of information to the end users. Many items on the following lists are already included in the CLIPS Training Workshops and the CLIPS Curriculum.

4a. Modelling and statistics.

- The basics of the NWP based models, including coupled ocean-atmosphere models. Ensemble forecasts. The statistical interpretation and presentation of model outputs. Scope, limitations and opportunities.
- The physical foundations for statistical correlations. Probability distributions. Existing statistical techniques including regression methods and discriminant analysis. Creating empirical models. Software packages for isolating and visualising statistical relationships between predictors and predictands and modelling. Scope and limitations.
- Downscaling techniques.
- Development of a consensus forecast.
- Verification techniques and activities. Hit rates. Skill scores. Developing measures of quality for local and sectoral use.
- Observational requirements for forecasts and verifications. Climate data banks and management. Access to predictand data holdings.
- Identifying research requirements in support of local and regional applications.

4b. Dealing with end users.

- Tools, techniques and pilot projects to assess the economic value of consensus predictions.
- General information on the economic value of climate information and services.
- The sectoral impacts of climate, and applications of climate forecasts. Identifying decisions that may benefit from the application of climate forecasts. Identifying sectorally related probability thresholds and critical weather events. Understanding the nature and scope of the users' decision making processes to react to probabilistic input, and assisting users to develop these processes. The need for close working relationship with users and intermediaries to determine their information, presentation and delivery requirements.
- The wider impacts of the release of advice, e.g. on water management in catchment areas, on futures buying and on national investment.
- Training the users on the strengths and limitations of products, understanding measures of quality, and future developments in service and quality. Assisting users to set up their own verification schemes and assessments of added value, and reporting back to the provider.
- Media interaction and Public Relations.

5. Other comments

There will be several determinants to an infrastructure to support the generation, distribution and application of seasonal forecasts. The analysis of product, verification and training requirements given above is an aid towards identifying some hubs in the structure and broad areas of responsibility. Some, but not all regions of the globe, have regional centres already established which undertake some of the tasks listed.

The information presented above will also facilitate a more precise specification of the functionality of Regional Specialised Meteorological Centres (RSMCs) with activity specialisation relating to climate, if that is required.

ANNEX 2

List of Regional Climate Centre functions

The requirements of NMHSs for RCC functions will vary from Region to Region, and may comprise only a subset of the following list. The required activities may be undertaken within a single centre or distributed amongst NMHSs.

Operational Activities:

- Interpretation and assessment of relevant output products from global prediction centres;
- Generation of tailored products to meet NMHS needs including seasonal outlooks etc.;
- Product verification, including the necessary exchange of basic data;
- Product distribution.

Coordination Functions:

- Strengthen collaboration between NMHS on related observing, communication and computing networks including data collection and exchange;
- Development of systems to facilitate harmonisation and assistance in the use of SI Forecast products;
- Assist in coordination with end users, including the organisation of workshops and other forums on users' needs;
- Assist NMHSs in the development of a media and public awareness strategy relating to SI Forecasts;
- To represent the needs of associated NMHSs.

Data Services:

- Rescue of climate data sets;
- Provision of climate data base and archiving services;
- Assist in the development and maintenance of software modules for standard applications;
- Advising on data quality management.

Training and Capacity building:

- Training of NMHS staff in SI Forecasting methods and characteristics to assist NMHSs to strengthen their services;

- Assist in the training of end-users on the application and impact of SI Forecast products;

- Assist in the introduction of appropriate decision models for end-users, especially as related to probability forecasts;

- Assist in technical capacity building on NMHS level.

Research and Development:

- Develop a climate Research and Development agenda and coordinate it with other RCCs in the Region;

- To arrange for studies of climate variability, predictability and impact in the Region;

- To develop consensus practices to handle conflicting information for the Region;

- Develop validation procedures relating to SI Forecast products in coordination with other centres;

- Develop and validate regional models, methods of downscaling and interpretation of global output products;

- Undertake application research, and assist in the specification and development of sector specific products;

- Arrange for studies of the economic value of climate information.

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