

WORLD METEOROLOGICAL ORGANIZATION

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CBS ET/ILRF/Doc. 3

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COMMISSION FOR BASIC SYSTEMS

(VI.XI.2001)

EXPERT TEAM MEETING ON INFRASTRUCTURE  
FOR LONG-RANGE FORECASTING

ITEM: 3

GENEVA, SWITZERLAND, 12-16 NOVEMBER 2001

ENGLISH ONLY

**INPUT TO ICTT ON CC, ON THE ESTABLISHMENT OF APPROPRIATE OPERATIONAL  
INFRASTRUCTURE FOR THE PRODUCTION AND EXCHANGE OF LRF**

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**Summary and purpose of document**

This document contains a review of the physical basis for atmospheric predictability on seasonal to interannual (SI) time-scales, the prediction methods status and the specifications for the WWW aspects of the infrastructure for the long-range forecasting (LRF).

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**Action proposed**

The Team is invited to discuss the submitted points of view and suggestions and to develop its recommendations on the WMO infrastructure for the operational LRF.

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## 1. Physical basis for atmospheric predictability on SI time-scales

In recent 15-20 years there has been considerable achievements in understanding and predicting of atmospheric circulation and rainfall on SI time-scales in the tropical regions and associated changes in many different parts of the world.

### 1.1. Basic idea of the methods of seasonal atmosphere anomalies prediction

The nonlinear nature of the atmosphere sets a fundamental limit of order of two weeks for deterministic weather prediction but the extended-range prediction beyond the average limit of deterministic predictability of individual synoptic-scale weather systems can arise mainly because (Charney and Shukla, 1981; Palmer and Anderson, 1994; Shukla et al, 2000):

- The time-averaged atmospheric circulation is more predictable than its instantaneous state;
- Slow and predictable variations in lower-boundary forcing (SST, sea-ice cover and temperature, land surface temperature and albedo, soil moisture and snow cover) influence the statistics of the atmospheric circulation.

Thus, whilst specific regime transitions will not be predictable during the season, the probability of the atmospheric finding in a given regime can be significantly influenced by specific lower-boundary anomalies.

### 1.2. Predictability of SST and atmospheric mean large-scale circulation on SI time-scale in different parts of the world

Studies have shown the considerable seasonal predictability of tropical SST and the overlying large-scale tropical circulation. The predictability of temperature, precipitation and other critical meteorological fields also exists in tropical zone but less known.

There are currently made skilful empirical SI time-scale predictions for some tropical regions. Among them:

- Empirical seasonal forecasts of the Indian summer monsoon;
- Statistical predictions of the SOI several months ahead (Climate Diagnostic Bulletin);
- Statistical prediction of the African Sahel temperature and precipitation anomalies based on observed correlation with the Indian and Atlantic SSTs as well as the Atlantic SSTs provide the most important predictors in north-east Brazil;
- Empirical prediction of the intensity the strength of hurricane activity in the Caribbean Golf, etc.

The potential for SI predictability in the extratropics is not currently clear because much of the variability in the extratropical atmosphere and ocean is directly associated with inherent nonlinearity and chaotic behavior of atmospheric circulation. The regions where surface temperature is teleconnected with the SOI presented in (Halpert and Ropelewski, 1992).

Apparently, there are no convincing examples of empirical long-range forecasts for extratropical areas excluding the ENSO episodes when the tropical oscillations can influence the extratropical circulations through teleconnections induced by Rossby-wave dynamics.

## **2. Status of modeling tools required to realize the potential for seasonal to interannual predictions**

### **2.1. Coupled GCMs**

Coupled atmosphere-ocean-land models based on fundamental physical principles are necessary for realization of the potential for SI prediction. To date, seasonal time-scale prognostic models of varying complexity exist. They are divided into three main categories:

- Tropical ocean circulation models coupled with a simplified global atmosphere assumed to be in perpetual equilibrium with the evolving ocean (intermediate coupled models);
- General circulation model of the atmosphere with prescribed lower-boundary forcing;
- Fully coupled ocean and atmosphere GCMs.

The intermediate coupled models are successfully used for the tropical SST prediction up to 6-9 months in advance. The predictability of coupled tropical ocean-atmosphere system depends on the season. Forecasts initiated in the winter of the Northern Hemisphere tend to be less skillful than those initiated after the spring.

The atmospheric GCMs with prescribed lower-boundary forcing are widely used for the 3-months seasonal prediction. These models predict anomalies from the seasonal cycle. It is reported that the skill scores for seasonal forecast 850 hPa temperature and precipitation calculated for entire tropical and some of the northern extratropical regions are high enough to have economic value (Palmer et al., 1999; Graham et al, 2000). Some of these atmospheric GCMs can provide global seasonal forecasting in near real-time mode.

Theoretically the fully coupled ocean-atmosphere GCMs are the most appropriate for seasonal to interannual prediction. The mean state is rather calculated than imposed as in the intermediate models. However, at present the operational prognostic systems have not yet been created, based on these type of models. The basic international project in this area, called DECEMETR is planned for implementation during 2001-2003.

## 2.2. Benefits of multi-model ensemble predictions

The usage of ensembles of integrations is the most promising way to get reliable assessment of the impact of lower-boundary forcing on atmospheric regime statistics on SI time-scales. There are two types of uncertainties. The first one is connected with initial conditions error, the second – with the uncertainties in physical parameterizations. Using of ensemble forecast integrations from different global modeling centers (multi-model ensemble) is extremely useful in reduction of uncertainties in model formulation.

The benefits of seasonal multiple model ensembles in Europe PROVOST (PRediction Of climate Variations On Seasonal to interannual Time-scales) project are shown (Palmer et. all, 1999; Graham et all, 2000). This approach allows to exploit the strengths of the individual atmospheric GCMs without extensive a priori calibration of each model. Other multi-institution joint research project is called Dynamical Seasonal Prediction (DSP) (Shukla et al, 2000). The multi-model project of seasonal prediction on real-time basis for Asia-Pacific region (APCN) is under the development.

It is important that ensemble spread appears a useful indicator of ensemble-mean skill.

## 2.3. Role of the atmosphere-land surface interactions

There is some evidence that fluctuations from the climate mean values in the soil and snow cover influence the generation of the seasonal atmospheric circulation anomalies. Thus, the vegetation and physical land processes should be also considered both as specified boundary conditions and as elements of the coupled system.

## 2.4. Observational data and data assimilation requirements

The WWW GOS provides the atmospheric observations to determine general atmospheric circulation variability. In addition, in situ and satellite observational data will be required to determine the circulation and heat storage of upper layer of oceans and land-surface characteristics. Cooperation with GCOS, GOOS and GTOS will be necessary.

The data assimilation should produce a regular, physically consistent, four-dimensional representation of the atmosphere/ocean/land surface system from a heterogeneous array of in situ and remote instruments. Models and observations are linked in construction of this representation. Variational four-dimensional assimilation methods can also provide information on model sensitivity that is necessary for building of the ensemble of the initial conditions.

Now advanced atmospheric data assimilation systems successfully operate at the lead GDPS centers. The development of an ocean and coupled ocean-atmosphere data assimilation system is the next step in this direction. The coupled ocean-atmosphere data assimilation system should be able using new types of in situ and remote observations.

### 3. Specifications for the WWW aspects of the infrastructure for the LRF

#### 3.1. The main concerns with the SI predictions:

- Quality both of numerical and empirical LRFs is not sufficient for many practical applications, especially in the extra-tropical areas of the Globe;
- Overlapping in available predictions for a number of areas of the Globe;
- Information on the quality of the forecast is often missing or unavailable for users;
- Products are often not comparable with each other by format, averaging period, lead-time, list of meteorological and oceanographic characteristics to be predicted;
- Predictions are issued sporadically but not regularly;
- Methods of compression and vivid representation of big volume of information generating in ensemble forecast are not developed sufficiently;
- Difficulties in understanding and using of probabilistic forecasts;
- “Overshadow” of the activity of the NHMSs in fulfillment of their functions in provision with climatic information on the territory of their countries due to the availability of long-range forecasts on the Internet.

#### 3.2. Major requirements for the WWW infrastructure for LRF

The infrastructure shall provide fulfillment of the following basic tasks (in the real-time mode) :

- global observational meteorological, oceanographic and land-surface data acquisition;
- observational data processing (decoding, monitoring, quality control etc.);
- data assimilation with the coupled atmosphere/ocean/land surface models;
- global/large-scale numerical (dynamical/statistical) ensemble LRF prediction;
- dissemination a full set or particular sub-set of the global/large-scale numerical ensemble LRFs;
- empirical LRFs issue, construction of the multi-model ensemble and development of consensus forecasts for some regions and some seasons;

- using the downscaling techniques for preparation user-oriented LRF products for some regions and some seasons;
- verification of all types of LRF products;
- usage of the experience of the WMO outside advanced research institutions;
- provide service to end-users.

(on the non real-time basis)

- development of the basic components of the prediction systems (models, data assimilation systems, statistical postprocessing packages, empirical forecasting methods, etc.);
- archiving of global and regional sets of data and products;
- training of the forecasters and end-users.

### 3.3. The possible organizational structure of the WWW global LRF system

The organisational structure should be flexible enough to meet above-mentioned requirements and to accommodate a foreseen rapid scientific evolution in LRF.

The hierarchical organizational structure, offered by the CBS consultant H. Allard, seems to be capable to satisfy many requirements and does not conflict with the recommendations of the EC-LIII.

It is not difficult to prepare the list of functions for each type of centers for the Global LRF System taking into account major requirements of 3.2.

## **4. Issues requiring urgent solution for practical realization of the WMO Global LRF System**

### 4.1. RSMCs with activity specialisation in long-range forecasting providing global and/or broad-scale regional products (RSMCs on LRFs)

Centers issuing global LRFs should obviously be under the CBS's jurisdiction. Operational issue of these forecasts is justified by rather high quality and significant practical usefulness of these forecasts for the tropical zone where more than 60 % of the globe population live. There is also convincing evidence of the economic usefulness of LRFs for North America. There is contradictory information in respect of the practical usefulness of LRFs for Europe, extra-tropical regions of Asia and extra-tropical part of the Southern Hemisphere.

For starting of the operational exchange of LRFs within the WWW the ET on Infrastructure for LRF has to solve among others the following urgent questions:

- to specify the list of centers already issuing operational numerical global LRFs (the list of centers wishing to participate is given in EC-LIII Pinks 4.1.34);
- to conduct the complete inventory of the issued global LRFs (perhaps it is appropriate to prepare a questionnaire?);
- to prepare the list of products of the first priority (it is advisable to have minimum list in pilot projects, for example, in zero approximation we can limit ourselves by suggestion to distribute of three-month ensemble forecasts of temperature at 850 hPa and precipitation or ensemble-mean and ensemble spread of indicated fields);
- to determine the minimum list of evaluations of the global numerical LRFs quality (hit rates, anomaly correlation coefficients, ROC, others?);
- to determine formats and mechanism for distribution of the basic products and the assessment of their quality (password - protected FTP and WEB access, others?);
- to foresee the access through the Internet for receipt of the full set of data and products (for construction of multi-model ensemble, getting the boundary conditions for regional climate model, etc.) at the request on bilateral basis.

For increasing of ensemble size it is not advisable to restrict the list of centers issuing global LRFs. Participation of any GDPS centers and also of interested research organizations outside of WMO is desirable.

Imposing of the responsibilities of RSMCs with specialization in global LRF can be carried out in accordance with the CBS procedure (Manual on GDPS, WMO No. 485, Suppl.No.4 (VIII.1997)). The center-competitors should demonstrate their capabilities.

#### 4.2. *RSMCs with activity specialization in regional climate prediction (RCCs) developing consensus regional forecasts*

RCCs are in the sphere of interest and activity of many WMO technical commissions and programmes including CCI, CBS, CAS, CAgM, CHy, CLIPS, etc. The functions of these centers have been defined by the ICTT (Geneva, 30 April - 3 May 2001). The ET on infrastructure for LRF may wish to make its own recommendations on RCCs infrastructure.

The procedure of RCCs designation may be the same as the procedure of the WWW RSMCs on LRF designation. However, since the functions of such centers extend beyond the frameworks of the WWW activity, the procedure of designation of these centers should be carried out with participation of the all interested WMO technical commissions and regional associations.

#### 4.3. *National Meteorological Centers (NMCs) responsible for preparation and delivery of LRFs to users*

NMHSs responsible in majority of the member- countries for provision of users within the country with the climatic data and products are fulfilling the functions of their NMCs. Data processing functions of NMCs are given in the Guide on the Global Data Processing System (WMO-No. 305). The ET on infrastructure for LRF may wish to make its own recommendations in respect of the verification of the NMCs' functions and the development of their infrastructure taking into account the possibilities being provided by the future WWW Global LRF System.

It should be noted that the fulfillment of functions of any of the three types of centers might be carried out both by one and by several organizations. In the later case, the center would be called "virtual" or "distributed".

On the other hand, several centers can be within one organization. For example, a certain center may simultaneously fulfill the functions of RSMCs on LRFs, RCC, and NMC.

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