WCRP Climate System Observational and Prediction Experiment (COPE)
- Workshop on Seasonal Prediction -

November 3-5, 2003, East-West Center, University of Hawaii, Honolulu, USA

This report summarizes the first COPE workshop on seasonal-to-interannual prediction, organized by the COPE Task Force on Seasonal Prediction (TFSP), and outlines a proposed World Climate Research Programme (WRCP) total climate system prediction experiment that will ultimately lead to seamless weekly to decadal forecasts.

The workshop included a presentation from a representative of the Joint Scientific Committee (JSC), which described the motivation and foundation for COPE. The Chair of the TFSP outlined the goals and purpose for the workshop. The workshop included several scientific presentations describing the current status of seasonal-to-interannual prediction, and how the various components of the climate system interact providing the potential to improve predictions. Finally, the workshop participants outlined a proposed total climate system prediction experiment that uses comprehensive coupled ocean-land-atmosphere climate models.

1. Welcome and opening remarks

The Climate System Observational and Prediction Experiment (COPE) Workshop on Seasonal Prediction was opened by the chairman of the COPE Task Force on Seasonal Prediction, Prof. Ben Kirtman (George Mason University; GMU), the local host Prof. Kelvin Richards (Internation Pacific Research Center; IPRC) and Dr. Andreas Villwock (International CLIVAR Project Office) who welcomed about 30 scientists (see Appendix 1) representing the various WCRP programmes, the main modelling centres involved in seasonal predictions and the CLIVAR Working Group on Seasonal-to-Interannual Prediction (WGSIP). Prof. Kirtman acknowledged in particular the support provided by the World Climate Research Programme, US-CLIVAR, the International Pacific Research Center (IPRC) and the Center for Ocean-Land-Atmosphere Studies (COLA). He introduced Prof. Jagadish Shukla (GMU), member of the Joint Scientific Committee (JSC) of WCRP and member of the WCRP Modelling Council.

2. Background: Motivation and Foundation for COPE

Prof. Shukla gave an introduction and described the motivation for COPE. He started with the overall objective of the World Climate Research Programme which is to assess the extent to which climate is predictable. In order to accomplish this overall goal, Shukla argues that scientists need to examine the climate system as a whole recognizing that the interactions among the all components of the climate system are critical to understanding and prediction climate variability. Nature is continuous, and artificially separating climate phenomena into discrete time scales in not particularly useful to society. These artificial boundaries in time scale also fail to recognize that time scale interactions are also important for understanding and predicting climate variability. With this understanding, the COPE initiative aims for seamless total climate system predictions on timescales ranging from weeks to decades. For this purpose it is required to take the total climate system into account, and thus an overarching WCRP-wide perspective is required. The WRCP sub-programmes focus on certain aspects or components of the climate system. For example, the main focus of CLIVAR is to examine how ocean processes impact climate variability and GEWEX emphasizes the role of land surface processes. The CliC programme examines the role of cryospheric processes and SPARC focuses on stratospheric phenomena. The objective of COPE is to bring all these elements of the WRCP sub-programmes together to produce a total climate system observation and prediction experiment. Furthermore, such an effort will be directly relevant to society and thus a close interaction with the International Human Dimensions Programme (IHDP) and the International Geosphere-Biosphere Programme (IGBP) is also required.

Prof. Kirtman provided additional background information regarding COPE and details of how this particular workshop was necessitated.

COPE is a total climate system prediction experiment with modelling and observational components cutting across the existing structure of WCRP. In particular, COPE will coordinate observational and modelling studies in support of:

(i) Description of the structure and variability of the global climate system (atmosphere, ocean, land and cryosphere) for a 40-year period (1979-2020) and to model and understand the mechanisms and coupled processes responsible for observed climate variability and change.

(ii) Determining the extent to which regional climate is predictable by making retrospective forecasts of weekly-seasonal-interannual-decadal variations for a 30-year period (1979-2009), and real time forecasts for a 10-year period (2010-2020).

(iii) Understanding the mechanisms that determine anthropogenic regional climate change and variability and its prediction.

Recognizing the importance of seasonal prediction as a specific objective under COPE, the JSC has formed a limited term Task Force on Seasonal Prediction (TFSP). This task force will draw on expertise in all WCRP core projects (i.e. CLIVAR, GEWEX, CliC and SPARC), WGNE, and WGCM, and will report to the JSC in March 2004. The overarching goal of the TFSP is to determine the extent to which seasonal prediction is possible and useful in all regions of the globe with currently available models and data.

In order to provide direct and immediate support and input to the TFSP, the International CLIVAR Project Office (ICPO) and the CLIVAR Scientific Steering Group (SSG) asked the Working Group on Seasonal-to-Interannual Prediction (WGSIP) to organize a seasonal prediction workshop drawing on expertise across all the relevant WCRP activities.

Prof. Kirtman summarized the overarching goal of the workshop, namely *to design a comprehensive set of WCRP wide coordinated total climate system prediction* *experiments with coupled ocean-land-atmosphere-ice models that will ultimately lead to seamless weekly to decadal forecast.*

3. Current Status of Seasonal Predictions - Overview

Dr. Mason started his review by distinguishing of two types of seasonal predictions:

1. **Global prediction** – seasonal-mean overview of regional anomalies within global climate system;
2. **Regional prediction** – detailed spatial and temporal forecasts, targeted/tailored for specific applications.

3.1 Global Predictions

With respect to global predictions Dr. Mason focused on 4 topics, namely:

- Production
- Performance
- Problems
- Presentation

As an example for a 1-tier approach, Dr. Mason presented results from the ECMWF seasonal forecast system, which builds uses the ECMWF atmosphere model, the HOPE ocean model and the OASIS coupler. The present configuration does not have an interactive sea-ice model.

For the 2-tier approach, the IRI forecast system was highlighted which uses results from a suite of atmospheric models applying ensemble techniques to create multi-model ensemble predictions. The main idea behind the multi-model ensemble predictions is that there are two main sources of uncertainty: errors in the initial conditions and errors in the model formulation. With respect to ensemble size, the results show improvements with an increasing number of ensemble members, although, depending on the parameter, ensembles larger than 20 do not improve the results significantly. In general, an improvement of the skill with ensemble size can be expected because of a) the reduction in errors in estimating forecast probabilities; and b) because of skill – spread (and shape) relationships. At present there is very little evidence for skill – shape relationships on seasonal time scales. In principle, there are several methods in combining predictions to a multi ensemble, e.g.:

- Equal-weight averaging of raw or corrected model output
- Preferential weighting of raw or corrected model output
- Statistical combination of model deterministic predictions

The problems with the so-called 1-tier approach include:

- Drift
- Limited record of hindcasts, due to lack of observing data necessary for initialization
- Systematic errors in reproducing correct patterns/magnitudes of important SSTA forcing

The problems with the so-called 2-tier approach are:

- Difficulty of incorporating reasonable estimate of SST uncertainty
- Neglect of intrinsic feedbacks (e.g., MJO)
- Potential physical inconsistencies in prescribing SSTs where ocean variability is forced by atmosphere (e.g., parts of the west Pacific & Indian Ocean)

3.2 Regional Prediction

Regional predictions differ from global predictions in spatial scale, temporal scale, and target forecast. Current operational methodologies include both statistical and dynamical downscaling. From the examples provided, Dr. Mason concluded that science needs to advance in all existing methods, and not just the most technologically advanced ones. The need for observations on the regional scales of the prediction for both forecast production and verification was emphasized.

Following are reports on the roles of the Atlantic and Indian Oceans in seasonal prediction. Concerning the Pacific, several ongoing WGSIP activities relate to improving and assessing skill in predicting tropical sea-surface temperature in the Pacific and workshop participants felt they were well informed on this topic.

3.2.1 The Atlantic Ocean and Seasonal Prediction

Prof. S.-P. Xie discussed Tropical Atlantic Variability (TAV) and its relationship to the NAO and ENSO phenomena. Atlantic sea surface temperature (SST) displays a pronounced annual cycle on the equator that results from continental monsoon forcing and air-sea interaction. This cycle interacts with and regulates the meridional excursions of the Atlantic intertropical convergence zone (ITCZ).

On interannual timescales, there is an equatorial mode of variability that is similar to El Nino/Southern Oscillation (ENSO) in the Pacific. This Atlantic Nino is most pronounced in boreal summer coinciding with the seasonal development of the equatorial cold tongue. In boreal winter, both ENSO and the North Atlantic Oscillation exert a strong influence on the northeast trades and SST over the northern tropical Atlantic. In boreal spring when the equatorial Atlantic is uniformly warm, anomalies of cross-equatorial SST gradient and the ITCZ are closely coupled, resulting in anomalous rainfall over northeastern Brazil. There is evidence for a positive air-sea feedback through wind-induced surface evaporation that organizes off-equatorial SST anomalies to maximize the cross equatorial gradient. The resultant anomalous shift of the ITCZ may affect the North Atlantic Oscillation, helping to organize ocean-atmospheric anomalies into a pan-Atlantic pattern.

In terms of prediction, Prof. Xie came to the conclusion that tropical North Atlantic SST and its effect on rainfall are predictable, whereas the predictability of the Atlantic Niño and the tropical South Atlantic SST remains to be determined.

3.2.2 The Indian Ocean - an Untapped Resource for Seasonal Predictability

Dr. Saji (IPRC) summarized the different mechanisms of Indian Ocean variability and its potential impact for seasonal predictions in the adjacent continents. A number of studies have investigated the importance of Indian Ocean SSTs to African rain variability during boreal winter. These studies showed that the influence of the Indian Ocean SSTs on East African rainfall is stronger than the ENSO teleconnection from the Pacific.

The so-called Indian Ocean SST Dipole (IOD) has received considerable attention in recent years. Through changes in atmospheric circulation and water vapor transports, a positive IOD event causes drought in Indonesia, above normal rainfall in Africa, India, Bangladesh and Vietnam and hot and dry summer in Europe, Japan, Korea and East China. In the Southern Hemisphere, the positive IOD causes dry winter in Australia and warm and dry conditions in Brazil.

While preliminary results suggest the important contribution of IOD variability in seasonal prediction, the precise role of air-sea interactions in the Indian Ocean and predictability associated with IOD remain areas of active research.

4. Role of the Cryosphere in Seasonal Prediction

Dr. Christensen started his presentation with a short introduction into the new WCRP Climate and Cryosphere programme (CliC). The principal goal of CliC is:

To assess and quantify the impacts of climatic variability and change on components of the cryosphere and their consequences for the climate system, and determine the stability of the global cryosphere.

Supporting objectives are:

- Enhance the observation & monitoring of the cryosphere in support of process studies, model evaluation and change detection
- Improve understanding of the physical processes and feedbacks through which the cryosphere interacts within the climate system
- Improve the representation of cryospheric processes in models to reduce uncertainties in simulation of climate and predictions of climate change

CliC focuses on the global cryosphere, i.e. snow; lake river and ice; sea ice; glaciers, ice caps and ice sheets; frozen ground and permafrost.

Major cryospheric related issues in climate research are:

- Arctic Ocean Sea-Ice Cover (understanding of recent past changes and future)
- Possible changes in the THC
- Mean Sea Level Rise
- Stability of the West Antarctic Ice Sheet
- Potential release of C from frozen ground to atmosphere
- Carbon balance, possibilities of sequestration
- Role of Tibetian Plateau in Monsoon Variability

CliC has a numerical experimentation group that is currently coordinating the following activities:

- Sea-Ice Model Intercomparison Project (SIMIP2)
- Arctic Ocean Model Intercomparison Project (AOMIP) (funded by IARC)
- Arctic Regional Climate Model Intercomparison Project (ARC-MIP)
- Ice Sheet Model Intercomparison Project (ISMINT)
- Permafrost Modelling Initiative
- PILPS2e

Parts of these projects have been taken over from the ACSYS (Arctic Climate system Study), which is ending in 2003. For the future, a Southern Ocean MIP (in collaboration with the CLIVAR/CliC Southern Ocean panel) and an Ice Shelf MIP are under discussion.

Dr. Christensen also gave some examples about recent observed cryospheric changes, such as snow cover, sea ice, ice sheets and permafrost:

(i) The Northern Hemisphere satellite-derived snow extent (1979 – 2003) from visible (NOAA) and passive microwave (SMMR & SSM/I) instruments does not show much of a trend.

(ii) Model results, such as presented in the 3rd IPCC assessment show that a number of models underestimate the snow fall and thus snow cover as well as sea ice.

(iii) With respect to sea ice a record minimum of sea ice extent and area has been observed in 2002. A recent paper noted that the sea ice thickness is highly correlated with the summer melt rather than changes in the circulation.

Finally, Dr. Christensen touched briefly on COPE data issues as seen from CliC. He noted that and inventory of cryospheric data is available. However, there are still open issues for a comparison with model output, such as common format for model output, model resolution, etc.) that complicate the intercomparison.

During the discussion Dr. Shukla asked whether CliC might consider to expand its goal statement to include the possible role of the cryosphere on predictability of the climate system. With respect to land surface processes, collaborations between CliC and GEWEX is starting with an initiative on snow data assimilation.

5. Role of the Land Surface in Seasonal Prediction

5.1 Observations and Offline Analysis

Dr. Dirmeyer started with an introduction to the GEWEX panels which are most relevant in this context namely:

- The GEWEX Hydrometeorology Panel coordinates the plans and the focus of scientific issues related to the development and implementation of the Continental-Scale Experiments (CSEs) and has oversight of all GEWEX hydrometeorology and land-surface projects. The principal task of the GHP is to guide these projects in the goal of achieving demonstrable skill in predicting

changes in water resources and soil moisture as an integral part of the climate system up to seasonal and annual time scales.
- GEWEX Radiation Panel guides GEWEX radiation projects in determining the radiation budget and fluxes in the atmosphere and at the surface, as an element of seasonal-to-interannual climate variability, and the response of the climate system on decadal-to-centennial time scales to changes in anthropogenic forcing.
- GEWEX Modelling and Prediction Panel (GMPP) oversees development and improvement of cloud and land-surface parameterization schemes of GEWEX Modelling and Prediction Projects to ensure their successful integration into global circulation models (GCMs).

Within GMPP the most relevant group is the Global Land-Atmosphere System Study (GLASS), which coordinates the development of improved land-surface schemes for coupled land-atmosphere models at all scales.

With respect to the relevance of land-surface processes for seasonal prediction, Dr. Dirmeyer stated that the land surface "memory" is concentrated in the seasonal time-scale (0-3 months), and provides potential predictability to be harvested for seasonal forecasts. The goals of land initialization are to provide the most accurate possible initial state for seasonal climate prediction and the initial conditions must have consistency with the model (between initial land state and land model).

Fields to initialize: Land state variables:

- Soil wetness (profile)
- Snow (mass, coverage)
- Soil temperature (profile)
- Surface water* (rivers), groundwater*, vegetation phenology*
  * if predicted

The potential sources of initialization are:

- Observations
- Independent model data sets (from a different model)
  - Offline (a la GSWP)
  - Coupled (reanalyses)
- Consistent offline data set (from the land model used, driven by meteorological analysis)
- Coupled LDAS (land and atmosphere models in some form of data assimilation mode)

For some variables Dr. Dirmeyer gave an assessment about the data availability for the purpose of model initialization, namely:

Snow Mass

- Cannot be measured directly from satellite, although snow cover can be determined.
- The coverage must be estimated

Soil Temperature

- Very few and scattered soil temperature measurements exist. Big gaps exist in current "networks".

Soil Wetness

- Very few and scattered soil wetness measurements. Some of the best long-term networks have decayed in last decade. Still gaps.
- Remote sensing limited to very near surface and vegetation-sparse areas.

Vegetation

- Good estimates of vegetation phenology exist from remote sensing (NDVI□LAI, Greenness).
- Hindcast: climatology versus observed
- Forecast: climatology versus persisted anomaly

Because GEWEX is concerned about the paucity of land data, the CEOP (Coordinated Enhanced Observing Period), a research integration effort through concomitant data collection, should help to overcome this problem. CEOP will bring together land data from multiple satellites, field campaigns and models. An overlapping strategy including modelling, analyses and observations will identify strengths and weaknesses in the model and analyses.

There several existing efforts to generate independent data sets by combining meteorological observations (forcings) with a model of the land surface, e.g.: Mintz and Serafini; Schemm *et al.*; Schnur and Lettenmaier; Willmott and Matsuura; Huang et al.; Fan et al. (CPC); Dirmeyer and Tan; current Land Data Assimilation System (LDAS) products and reanalyses: e.g., NCEP/NCAR, NCEP/DOE, ERA15, ERA40. Nevertheless, all these efforts have a basic shortcoming – the product is from involves output from some model.

At present the following consistent offline data sets exist

- Global Soil Wetness Project (GSWP)
  Historical data: GSWP is an ongoing GEWEX project involving over a dozen modelling groups on four continents. GSWP-2, a 10-year (1986-1995) global land-surface analysis, is now underway. GSWP-1 used the ISLSCP I-1 data to examine 1987-1988.
- Land Data Assimilation System (LDAS)
  - *Real Time*

The data sets use observed/analysis meteorological forcing to drive a land model uncoupled from atmospheric model. This processes generates land surface state variables and fluxes by prescribing the observed meteorology, but without feedback processes. A true LDAS (Land Data Assimilation System) will also assimilate land surface state variable observations. Currently there a some LDAS efforts in the US and Europe under development.

In a coupled LDAS the land model is coupled to its parent atmospheric model during integration. Shortcomings of atmospheric model fluxes (precipitation, radiation…) are overcome by some intervention:

- *Replace downward fluxes (poor-man's LDAS)*
- *Flux adjustment (similar to ocean-atmosphere)*
- *Empirical correction of state variables*

If it is not possible to run your own LDAS or similar analysis cycle to generate consistent land initial conditions, composite soil wetness can be obtained through:

- Interannual anomalies from a quasi-observed (global model) product
- Mean annual cycle from your land model (e.g., from AMIP-2, C20C, DSP/PROVOST, etc.)
- Scaling anomalies by the ratio of variances

In summary, caution is advised in preparing land initial conditions for climate prediction – there are many ways to do it wrong. All of the above initialization strategies assume that the climate model predictions will benefit from a better representation of the land surface, because land-atmosphere feedbacks can enhance predictability. This supposition through analysis of coupled land-atmosphere model results will be examined in the next presentation.

5.2 Land-Surface Processes – Coupled Analysis

Dr. Koster started off with the question: What is land-atmosphere feedback on precipitation? A possible (positive) feedback chain could be: Precipitation wets the surface causing soil moisture to increase which changes the surface energy balance in subsequent days affecting the overlying atmosphere and possibly inducing additional precipitation.

Many studies have show that the land-atmosphere feedback operates strongly in AGCMs. A strong correlation between altered soil moisture and resulting changes in simulated rainfall can be found. Such studies suggest that some events (e.g. 1988 drought and extremes in the Indian monsoon) may be the result of the superposition land feedbacks on SST-forced climate anomalies.

Does such a feedback exist in the real world? There is some indirect evidence. For example, certain statistical structures in the observational record are reproduced by the AGCM only when land-atmosphere feedback is "enabled."

In summary, various joint modelling/observational analyses show that land-atmosphere feedback does appear to be real – in nature, soil moisture anomalies do appear to feed back on precipitation, at least in some regions.

Nevertheless, the key question is: Does precipitation prediction improve when a forecast model is initialized with realistic soil moisture contents?

To our current knowledge, the impact of land-atmosphere feedback on seasonal prediction skill is currently rather limited. Because some skill does exist, though, and because some of the limitations in skill stem from immature modelling and data collection/processing systems, there are high hopes that someday, soil moisture initialization will be used to great advantage in seasonal prediction.

5.3 Impact of Soil Moisture on Seasonal Prediction

The motivation for the study presented by Dr. Kattsov is the potential contribution of soil moisture anomalies to predictive capability enhancement. The model used in this study is the MGO GCM, an AGCM with the following characteristics:

- T42L14
- Solar and terrestrial radiation with diurnal cycle
- Computed clouds and its optical properties
- Tiedtke convection
- Orography-induced gravity wave drag
- Boundary layer
- Land surface:
    - Surface inhomogeneity: up to 3 types of the surfaces can exist in a grid box.
    - Surface albedo depends on soil/vegetation types and accumulated snow mass.
    - 4-layer soil model.
    - Soil moisture and heat conduction are computed in the root zone of 3 m depth.
    - Evapotranspiration, thawing, surface and ground runoff

The experiment was designed as follows:

- Perfect model
- Prescribed monthly mean SST for 1979-2000
- Simulation of atmospheric and soil moisture states for 1979-2000
- 6 member ensembles for 4 months (from April 1, May 1, June 1)
- Two assumptions for initial soil moisture distribution:
    - Initialised soil moisture (soil moisture anomalies included);
    - Model soil moisture climatology (soil moisture anomalies excluded)
- Analysis over regions of subcontinental scales.

In summary the results show that

- Soil moisture anomalies can increase prediction skill on time scales of up to a season. However, their influence depends on many factors, including the season and region considered.
- Soil moisture anomalies have a noticeable impact on the prediction skill of SAT in northern Eurasia in summer. A salient increase in SAT prediction skill up to a season is found in low latitudes.
- Soil moisture anomalies have small impact on precipitation in the most regions considered, except for some regions in the tropics.

The results are model dependent. They depend on performance capability of the model in reproducing observed variability of various quantities in the atmosphere and upper soil layer (magnitude and extent of soil moisture anomalies). (There are evidences indicating that the current MGO GCM underestimates variability of some important variables in the atmosphere and soil layer.).

6. Stratosphere-troposphere dynamical coupling and extended-range weather forecasts

Dr. Baldwin provided a comprehensive overview about stratospheric processes that might be relevant for seasonal prediction. He pointed out that the relevant fluctuations in the stratosphere have timescales of 10-60 days which would mean that in the definition of seasonal prediction, “subseasonal” or “extended-range” scales have to be taken into account. He questioned how the TFSP will handle phenomena that are best forecast using statistical techniques, as it is currently the case for the stratospheric processes, e.g. forecasts of the Arctic Oscillation (AO).

The main question Dr. Baldwin addressed was: Predictability Beyond 10 Days - a role for the stratosphere?

With respect to seasonal predictions there boundary conditions (e.g. SSTs, Snow and Ice, Soil Moisture, etc.) and persistent phenomena (MJO, QBO, ENSO, etc.) play an important role. The question is whether such persistent stratospheric anomalies affect the troposphere?

One of the most prominent persistent stratospheric anomalies is the Northern Annular Mode (NAM), which is basically the same as the AO, but can describe higher levels in the atmosphere. The North Atlantic Oscillation (NAO), which used more frequently, is very similar to AO, but more oriented to the Atlantic sector.

Dr. Baldwin showed that statistical forecasts methods are useful in predicting the wintertime AO. Since most dynamical models used for seasonal predictions do not have a sufficient resolution in the stratosphere, their ability to simulate the relevant processes and the effect on the troposphere is very limited.

The observations show that:

- The AO timescale is longest when NAM anomalies are largest in the lowermost stratosphere (winter).
- The NAM in the lowermost stratosphere provides better predictability of the AO than the AO does of itself.
- Theory does not yet explain the observations.

Another aspect of climate relevant stratospheric processes is the Southern Hemisphere surface climate response to ozone depletion. The springtime ozone loss appears to drive changes in surface climate from late spring to summer. However, the modelling results are inconclusive suggesting that more research is required to get to a consistent picture of how ozone depletion on impacts large scale atmospheric circulation patterns.

Some institutions such as the NOAA NWS Climate Prediction Center monitor stratospheric conditions but do not use stratospheric information in forecasts at present. Their main interest at this time is understanding dynamical linkages to the NAO, PNA, and the tropics with some expectation that dynamical models will capture the physics in the future.

With respect to the design of the COPE Seasonal Prediction Experiments, Dr. Baldwin recommended to assess how well the models predict the AO. Therefore daily data of the NAM index should be stored. No additional experiments were recommended at this point.

In summary, stratospheric effects span the 10-60+ day time frame during extended winter (spring in the Southern Hemisphere. The dynamics of these phenomena are not well understood. With respect to the stratospheric variability there is an issue how to define "seasonal" and forecast periods. Lastly, is has to be discussed how to deal with phenomena best forecast by statistical or statistical/dynamical techniques.

7. Seasonal Prediction Activities Throughout the World

The following summarizes several presentations regarding seasonal prediction activities throughout the international community.

7.1 Diagnosing ENSO signal in the new NCEP coupled model

NCEP is in the process of implementing a new coupled system for climate forecasts which will replace the current NCEP operational coupled model The new Coupled Forecast System Model (CFS03) consists of the NCEP Global Forecast System 2003 atmospheric component and the global GFDL MOM3 ocean model which are coupled without applying flux adjustment. The model details are:

a) atmospheric component
   - Global Forecast System 2003 (GFS03)
   - T62 in horizontal; 64 layers in vertical
   - Recent upgrades in model physics
     - Solar radiation (Hou, 1996)
     - cumulus convection (Hong and Pan, 1998)
     - gravity wave drag (Kim and Arakawa, 1995)
     - cloud water/ice (Zhao and Carr,1997)

b) Oceanic component
   - Global Forecast System 2003 (GFS03)
   - T62 in horizontal; 64 layers in vertical
   - Recent upgrades in model physics
     - Solar radiation (Hou, 1996)
     - cumulus convection (Hong and Pan, 1998)
     - gravity wave drag (Kim and Arakawa, 1995)

       cloud water/ice (Zhao and Carr,1997)

- The objective of the study presented is to assess ENSO simulation by the new NCEP coupled model. The integrations were initialised on 1 January 2002 with initial conditions from NCEP GDAS (Global Data Assimilation System; atmosphere) and NCEP GODAS (Global Ocean Data Assimilation System; ocean).

A free integration of 32+ years was performed. Results show:

- CFS03 simulates an ENSO with amplitude and periodicity comparable to that observed.
- CFS03 reproduces the observed seasonality of ENSO variability, although the initial warming from January to May of the simulated El Nino events is somewhat too strong.
- Diagnoses of the simulated ENSO suggest that different mechanisms

(delayed oscillator, western Pacific oscillator, recharge oscillator, and advective-reflective oscillator) may all contribute to the ENSO variability.

Dr. Nadiga also presented some preliminary results on predicting tropical eastern Pacific SSTA. The new coupled model was shown to have higher correlation skill than either the old model or the statistical methods used at NCEP.

In the second part of his presentation Dr. Nadiga focussed on the assimilation of synthetic salinity data in a Pacific Ocean Model. In summary this study has shown a strong impact of the assimilation of salinity leading to a substantial reduction of zonal velocity errors. On the other hand, the assimilation of TOPEX/Poseidon data did not add anything.

7.2 Seasonal Forecasting at Météo -France

In the past Météo -France has been active in several EU-projects relevant to seasonal prediction, such as: PROVOST, ELMASIFA, POTENTIALS. Current research on this topic is focused in the DEMETER and post-DEMETER projects. In DEMETER 7 ocean-atmosphere coupled models under the leadership of ECMWF participated. 6-month lead multi-model experiments for 4 seasons were performed in DEMETER using ERA40 forcing. More details about DMETER can under http://www.ecmwf.int/research/demeter. After the end of DEMETER Météo–France will repeat DEMETER experiment using uncoupled atmosphere only simulations. In this case, the SSTs will prescribed either from observations or using a statistical prediction scheme. The next projects are

- ENSEMBLES: extending DEMETER to higher resolution or longer range
- Extend DEMETER to real time on IBM
- MERCATOR: better ocean analyses
- MERSEA: MERCATOR with higher ocean resolution (1/4°)

Operational seasonal forecasting has been introduced at Météo –France in 1999, after ELMASIFA. Statistical SST forecasts are performed on a monthly, 4-month range, 9 members, TL63 resolution basis. The results are only used internally and for some special targeted users.

7.3 Seasonal Prediction Activities in China

Dr. Ding reported that the main goal for seasonal prediction in China is to predict the seasonal march of the major rain belt in East Asia in flooding season (May –August) with special emphasis on

- Location and rainfall amount
- Onset dates and ending dates of regional rainy seasons. (Pre-summer, Meiyu, North China)
- Duration of regional rainy seasons and precipitation anomaly percentage

Dr. Ding described in detail the characteristics of the East Asian monsoon, in particular the moisture transport, and the onset and retreat of the monsoon. He further described preferred regions and persistence for prolonged droughts in China. An overview about the methods used for seasonal prediction was also provided. The first method is a statistically-derived conceptual prediction model has five main precursor signals, namely

- El Niño/La Niña events
- Snow cover anomaly over the Tibetan Plateau
- The Asian summer monsoon
- Blocking high over Eurasia
- Subtropical high over West-Pacific

The second method uses a CGCM (T63L16/T63L30). The atmospheric component the T63L16 AGCM developed by NCC through cooperating with other institutions, such as IAP/CAS. The model comprises comprehensive physical processes, such as large-scale topography, radiation, large-scale precipitation, cumulus convection, evaporation, etc.

The AGCM is developed on the basis of the operational medium-range prediction model (version T63) of National Meteorological Center of CMA, originally based on the ECMWF T63 model from 1988. The horizontal resolution corresponds to approximately 1.875°x 1.875°. There are 16 levels in vertical direction. A P—σ hybrid coordinate is used.

The ocean model is a T63L30 OGCM, which was developed by the LASG of IAP/CAS on the basis of the original LASG OGCM. The new OGCM has 30 levels in vertical and 1.875 x 1.875 degree horizontal resolution. There are 10 layers in the upper 250m, and 10 layers between 250m to 1000m, 10 layers from 1000m down to 5600m.

The results of the global model are used for simulations with a regional nested climate model (RegCM_NCC) based on the dynamic framework of the RegCM2 with some changes in the physical parameterizations. With the outputs of the CGCM as the large-scale lateral boundary conditions, the nested regional climate model RegCM_NCC shows some predictive capability, in particular for the 2003 summer severe flood in Huaihe River basin. 10-yr simulations and hindcasts for the flood season in China have shown that RegCM_NCC can simulate the monsoon precipitation climatology.

7.4 COPE related activities at BMRC

Dr. Power started his presentation with an introduction to the coupled model used for seasonal prediction in Australia. The POAMA(Predictive Ocean-atmosphere model for Australia) model is a global coupled model GCM seasonal forecasting system developed by a consortium of BMRC, BoM and CSIRO. It runs in real time since Oct. 2002. Experimental products are available at: http://www.bom.gov.au/bmrc/ocean/

Current activities include:

- Implementation of the ECMWF Land Surface scheme
- Examine MJO-ENSO links
- Develop verified products

- Statistical downscaling
- ENSO dynamics
- ENSO-Indian Ocean links

During recent years a rainfall and dam inflow drop in south-west Western Australia (swWA) over past 30 years of 10% and 40%, respectively has been observed. Furthermore the SST in Southern Indian Ocean and SH oceans generally and swWA air temperature all have risen. This is a major concern to people in the region. A study with the NCAR/DoE PCM has been performed to investigate these changes.

7.5 Seasonal Forecasting at ECMWF

Dr. Hagedorn started her presentation with a description of the current coupled system currently used at ECMWF for seasonal forecasting. The model consists of the IFS atmospheric model in T_L95L40, Cy23r4, 1.875 deg grid for physics (operational in 2001) resolution, with a fully interactive land surface scheme (TESSEL) and a moderate representation of the stratosphere. The ocean component is a HOPE-E ocean model with a resolution of 1 x 1 deg at mid-latitudes, 0.3 deg meridional near equator, and 29 vertical levels. There is no interactive sea-ice, but it is relaxed towards climatology. The coupling is performed using an OASIS coupler, coupling once per 24 hours (so no diurnal cycle in ocean) without applying flux correction.

Considerable effort has been taken in order to initialize the coupled system. The aim is to start system close to reality. Ensemble forecasts are performed in a burst-mode, i.e. A 40-member ensemble integration is started on 1st of the month. Each prediction is for lead times of up to six months.

To remove systematic error an estimate of the systematic error from set of previous forecasts is performed. The ensemble is generated by:

Wind perturbations
- uncertainties in windstress represented by adding perturbations
- ensemble of ocean analysis (5 members) is produced

SST perturbations
- uncertainty in SST analysis not negligible
- SST perturbations added to each ensemble member at start of forecast

Stochastic physics
- stochastic increments are added to tendencies in atmospheric model to represent atmospheric unpredictability

The model drift is comparable to the signal, both in SST and atmospheric fields. In order to calibrate the model, forecasts with respect to model climatology are calculated, i.e. the model climate is estimated from 15 years of past forecasts (1987 – 2001). Note that the model climate is function of start date and lead time. The forecast products are all based on anomalies. Furthermore, linearity is assumed with respect to the predicted model anomaly (relative to the model climate), which corresponds to the true anomaly (relative to true climate).

Dr. Hagedorn gave an outline on the new multi-model concept at ECMWF. Two main sources of error are:

a) Initial conditions: ensemble concept
b) Model formulation: multi-model concept

The multi-model approach provides a "consensus" forecast. There are two general approaches to combine models, either merging models with equal weights or estimating optimal weights for each model, based on past performance. Examples of the performance using simple regression, and Bayesian methods were given. The main difficulty of the second approach is to find robust weights.

The current forecast concept of ECMWF has three streams of forecasts, which are not continuous in terms of a seamless system ranging from weather to climate forecasts. New approaches will try to integrate a seamless system, ranging from 1 day to 5 years.

Finally, Dr. Hagedorn reported briefly about the new European project: ENSEMBLES. This project with 70 partners from 16 countries and a budget of 15 Million Euro will work towards the development of an integrated prediction system for time scales from seasons to decades and beyond. Other foci are an assessment of reliability of model system used for climate scenario runs and ensemble prediction methods. The project is envisaged to start by April 2004.

7.6 Multi-Model Ensemble Forecasts and Predictability at JMA

The seasonal prediction activities at JMA have already a long history, starting with statistical one-month and three-month forecasts in 1942, and statistical warm/cold season forecasts a year later. In 1996 the first dynamical one-month forecast was performed followed by a regular El Niño Outlook with a coupled model in 1999. Since 2003 dynamical three-month forecasts and dynamical warm/cold season forecasts are being performed.

The operational models for seasonal forecasts are

- One month forecasts: AGCM with fixed SSTA
  T106L40 GSM0103 26 member
- Three month forecasts: AGCM with fixed SSTA
  T63L40 GSM0103 31 member
- Warm/Cold season forecasts: Two tier method
  T63L40 GSM0103 31 member using SSTA from CGCM02

The new ENSO Forecast Model (JMA-CGCM02) has been in operation since July 2003 and consists of an AGCM (T42L40) coupled to an OGCM (0.5°x 2.5°xL20).

The results show that the system has an overall skill of seasonal forecasts for seasonal mean temperature over Japan. The percent correct in three category forecasts is about 40~50%. This value corresponds to the correlation between ensemble mean and observation of 0.23~0.52. Even though the percentage of correct forecasts is 40~50%, the probability forecast is still useful.

Dr. Sugi described the statistical method being used at JMA to conduct multi-model ensemble forecasts. By using multi-model ensemble simulations the model independent signal variance and potential predictability, the signal amplitude and model error variance for each model, and the optimum weight for multi-model ensemble can be estimated.

7.7 Seasonal Forecasting at the UK Met Office

Dr. Davey presented a brief overview on the seasonal forecasting activities at the Met Oiffce. The system used called GloSea (Global Seasonal) is a CGCM forecast system based on the Hadley Centre climate model HadCM3 (2.5° x3.75° x19L AGCM, 1.25°x1.25°x20L OGCM with equatorial refinement up to 0.3°m 40 ocean levels, coastal tiling).

For the ocean analyses a system of GloSea ocean + Met Office FOAM system is used to assimilate sub-surface temperature. It includes a bias correction scheme, NWP surface fluxes and a strong relaxation to observed SST.

The ensemble prediction method applied uses wind stress and SST perturbations designed to estimate uncertainty in the observations. Six month real-time ocean atmosphere global forecast are performed with a 40 member ensemble, based on a 16 year calibration period (1987-2002) with a 15 member ensemble.

The seasonal forecast products provided are:

1. Public web site (http://www.metoffice/weather/seasonal)
   - Global 3-month-mean temperature and precipitation anomalies
   - 2-4, 3-5 and 4-6 month outlook
   - probability of above/below
   - skill maps (Heidke score)
   - empirical products
   - Sahel, East Africa, N.E. Brazil, UK Summer, NAO, global annual temperature
2. NMS web site (restricted access)
   - ensemble mean
   - skill "masking" (ROC area<0.6, MSSS)

In future more products will become available such as:

- tercile (above/normal/below) products
- extremes
- Niño3, 3.4, 4 SST plume diagrams
- NAO, SOI indices
- additional parameters
- multi-model products - with ECMWF and other DEMETER partners

In addition Dr. Davey presented an intercomparison of the GloSea model (using HadAM3 atmosphere and a dynamical ocean GCM and HadAM3 integrations (HadAM3 atmosphere and statistical prediction of SST based on persistence of SST anomaly). As part of the DEMETER project 43 years of retrospective forecasts (1959-2001) have been completed with both GloSea and the two-tier HadAM3 systems to assess the impact of ocean coupling on prediction skill. For verification see http://www.ecmwf.int/research/demeter/

Results:

- GloSea gives substantially improved predictions of tropical Pacific SST relative to HadAM3. The best improvements are at the 3-month lead - GloSea is successfully extending the predictability range
- For 2m temperature, there is better skill for the GloSea model for spring and winter seasons, both for tropics and extra tropics
- A focus on specific rainy seasons found improvement in skill for NE Brazil and Guinea at both 1-month and 2-month leads
- Improvements are not universal. Further study of cases where HadAM3 provides better skill should be useful in improving coupled model performance

8. Seasonal Predictability of SMIP and SMIP/HFP

The SMIP (Seasonal prediction Model Intercomparison Project) is coordinated by CLIVAR through the Working Group on Seasonal to Interannual Prediction (WGSIP). Coordinators are G. Boer(CCCma), M. Davey (UKMO), I.-S. Kang (SNU), and K. R. Sperber (PCMDI). The purpose of the study is to investigate 1 or 2 season potential predictability based on the initial condition and observed boundary conditions. Dr. Kang provided a comprehensive overview of the results from these experiments.

The seasonal prediction experiments for SMIP are as follows: 7 month x 4 season x 22 year (1979-2000) with 6 or more ensembles. Four institutes (NCEP (USA), CCCma (Canada), SNU/KMA (Korea), MRI/JMA (Japan)) with 5 models have participated.

Follow-on studies are the SMIP-2 and SMIP/HFP (Historical Forecast Project) experiments.

- SMIP2 aims to assess the potential predictability 12 seasons in advance by carrying out 7-month ensemble integrations of atmospheric GCMs with observed initial conditions and observed (prescribed) boundary conditions.

- SMIP2/HFP will investigate the actual predictability for one season in advance by carrying out 4-month ensemble integrations of atmospheric GCMs with observed initial conditions and predicted boundary conditions or coupled GCMs.

9. International Climate of the Twentieth Century Project (C20C)

Dr. J. Kinter briefed the participants about the International Climate of the Twentieth Century Project (C20C). The goal of the C20C project is:

> *To characterize climate variability and predictability of the last ~130 years through analysis of observational data and ocean-forced atmospheric general circulation models (AGCM)*

The first C20C workshop was held in 1994 and there was a special C20C session at the first international AMIP conference in 1995.

The idea of C20C was revitalized as International C20C Project by Hadley Centre and COLA with an invitation to several modelling groups to participate in 1998. The infrastructure for the project is provided by COLA (www.iges.org/c20c; GDS (GrADS-DODS Server)). A second workshop was held at COLA in February 2002 where a set of experiments, diagnostics and sub-projects were formulated. Finally, the International C20C Project established as official CLIVAR project in 2003.

The C20C has three phases:

- *Phase 1: SST and sea ice*
    - Hadley Centre provides HadISST1.1 SST and sea ice data set as lower boundary conditions
    - Integrate over 1871-2002 (at least 1949-2002)
    - Ensembles of at least 4 members
- *Phase 2: atmospheric composition*
    - Greenhouse gases – CO_2, O_3, etc.
    - Aerosols (volcanic)
    - Solar variability
- *Phase 3: land surface variability*
    - specified evolution of soil wetness and vegetation

C20C future plans include a third workshop, which will take place at ITCP (Trieste, Italy), 19-23 April 2004. The workshop will review the results of the first phase and develop plans for phase two and beyond. Discussion with experts from WCRP on the issue of the prescribed forcing will also be discussed at the workshop. In the long-term, a more rigorous comparison to coupled models, coordinated with WGCM is envisaged.

Finally, Dr. Kinter focused on the question how C20C can help the COPE Task Force on Seasonal Prediction. C20C is already using a multi-model approach, Phase 1 simulations (observed SST and sea ice only) can provide baseline runs for seasonal predictions, Phase 2 and 3 can contribute to other parts of the draft plan (see. Appendix x). Furthermore, C20C will facilitate the attribution of observed 20th century climate anomalies to global SST, sea ice, atmospheric composition, aerosol loading and solar variability.

9.1 The relative importance of additional forcing factors in simulating the regional climate anomalies in hindcast experiments

Dr. Syktus presented results from 20th Century experiments using the CSIRO AGCM in T63/L18 resolution and studies with a regional climate model with 15km horizontal resolution.

Experimental details are:

- NCEP MRF9 T40/18 – 10 runs: 1965 – 2003 *NCEP AGCM 6hrs data used to double nest DARLAM*
- CSIRO RCM 75km/L18 – 15 runs: 1965 - 2003

- CSIRO RCM 15km/L18 – 15 runs: 1965 - 2003
- CSIRO T63/L18 AGCM – 15 runs: 1871 & 1949 - 2003

The AGCM study was carried out in the C20C framework. Conducted experiments were:

- HadISST1.1 SST and Sea Ice , ensemble approach
- SST only forced runs
- SST and monthly varying solar (Lean)
- SST, monthly solar and CO_2
- SST, monthly solar, CO_2 and stratospheric ozone

The results indicate that the reduction in rainfall observed during the past 30-40 years in northern and eastern Australia may be caused by global warming. Changes in SH stormtrack activity or the decrease in tropical cyclones maybe responsible for the observed decrease in rainfall.

10.0 A Pan-WCRP Seasonal Prediction Experiment

One of the overarching goals of COPE is determine the predictability of the complete climate system on time scales of weeks to decades. Here we focus on seasonal time scales. By complete climate system, we mean contributions from the atmosphere, oceans, land surface, cryosphere and atmospheric composition in producing regional and seasonal climate anomalies. Advances in climate research during the past decade have led to the understanding that modelling and predicting a given seasonal climate anomaly over any region is incomplete without a proper treatment of the effects of SST, sea ice, snow, soil wetness, vegetation, stratospheric processes, and chemical composition (carbon dioxide, ozone, etc.,). The observed current climate changes are a combination of anthropogenic influences and the natural variability. In addition to possible anthropogenic influence on climate due to changing the atmospheric composition, it is quite likely that land use in the tropics will undergo extensive changes, which will lead to significant changes in the biophysical properties of the land surface, which in turn will impact atmospheric variability on seasonal time scales. It is therefore essential that the research by the two communities (i.e., climate change and seasonal prediction) be merged into a focused effort to understand the predictability of the complete climate system.

This problem of prediction and predictability of seasonal climate variability is necessarily multi-model and multi-institutional. We argue that the multi-model approach is necessary because there is compelling evidence that, with imperfect models, perturbing the physics of the models is superior to perturbing initial conditions of one model in terms of resolving the probability density function or quantifying the uncertainty. A multi-model approach is essentially a simple and consistent way of perturbing the physics. Moreover, by testing our hypotheses with multiple models it is possible to determine which results are model independent, and hence likely to be robust. This problem is also necessarily multi-institutional simply because the level of effort and computational resources required is just too large for any one institution.

The primary role of COPE (and the JSC) should be to ensure that these experiments are coordinated across all relevant WCRP activities. The various component projects of the WCRP will continue to provide the key elements for this experiment through their efforts to develop strategies and experiments for improving the forecasts and component models, and by carrying out observing system evaluations, process studies and field campaigns.

10.1 The Total Climate System Prediction Experiment

The TFSP proposes a comprehensive seasonal prediction experiment that is designed to test the following hypothesis:

> *There is currently untapped coupled predictability due to interactions and memory associated with all the elements of the climate system (Atmosphere-Ocean-Land-Ice).*

The core experiment is an 'Interactive Atmosphere-Ocean-Land-Ice Prediction Experiment' emphasizing the use of comprehensive coupled general circulation models, which include realistic interactions among the component models (each representing different elements of the climate system). The experiment is to perform six-month lead ensemble (10-members) predictions of the total climate system. If possible longer leads and larger ensembles will be encouraged. The initialization strategy is to use the best available observations of all the components of the climate system.

While the emphasis is on comprehensive coupled general circulation models, uncoupled component, intermediate, simplified and statistical models are encouraged to participate where appropriate. The fundamental experimental design is to mimic real prediction in the sense that no "future" information can be used after the forecast is initialized. For example, the DEMETER or DSP experiments would be excluded because they use observed SST as the simulation evolves, whereas the SMIP/HFP experiment could be included as subset since no future information is used as the forecast evolves[1].

The component models should be interactive, but this is left open to allow for a wider participation, e.g. for groups without sea-ice or vegetation model. The only firm requirement is that no "future" information is used once the prediction is initialized. This requirement means that model tuning and development using observations should be done with data taken from an independent time period (ie in a cross-validated way). This is also the case with any statistical model development for the possible prediction of the boundary conditions. The intent here is to mimic real forecast situations and to exclude any artificial skill.

The component models are:

- Ocean – Open but interactive (e.g., slab mixed layer or GCM)

[1] The SMIP/HFP experiment is viewed as a subset of the experiments proposed here since they do not necessarily include feedbacks from land surface or sea ice processes or the initialization of these components of the climate system.

- Atmosphere – Open but interactive, most likely a GCM
- Land – Open but interactive, e.g. SSiB, Mosaic, BATS, CLM, Bucket …
- Ice – Open but interactive (e.g., thermodynamic or dynamic)

The results of these experiments provide a framework for future experiments, specifically these prediction results will:

(i) Provide a baseline assessment of our seasonal prediction capabilities using the best available models of the climate system and data for initialisation.
(ii) Provide a framework for assessing of current and planned observing systems, and a test bed for integrating process studies and field campaigns into model improvements
(iii) Provide an experimental framework for focused research on how various components of the climate system interact and affect one another
(iv) Provide a test bed for evaluating IPCC class models in seasonal prediction mode

The TFSP recognizes that certain elements of the proposed experiment are already part of various WCRP activities. The intent here is to leverage these ongoing activities and to coordinate and synthesize these activities into a focused seasonal prediction experiment that incorporates all elements of the climate system. These experiments are the first necessary steps in developing seamless weekly-to-decadal prediction of the complete climate system.

The parameters of the experiment are as follows:

(i) Coupled models and resolution are left to the individual participants, but it is desirable that the models have a realistic simulation of the atmosphere, ocean, land and ice and the interactions among these components. Simplified component models (e.g., slab mixed layer or statistically predicted ice) are acceptable as long as the no future information is used in developing the simplified model.
(ii) Atmospheric initial states to be taken from NCEP (or ECMWF) reanalysis each month of each year from 1979-present. Forecasts should be initialized on 00Z and 12Z on the last five days of each preceding month forming a 10-member ensemble. Other strategies for generating the ensemble members are acceptable as long as the basic principle of no future information as the forecast evolves is not violated. Each ensemble member should be run for at least six months. Additional ensemble members and longer leads are encouraged.
(iii) Oceanic initial states: (if appropriate) to be taken from most appropriate ocean data assimilation system.
(iv) Sea Ice initial states: (if appropriate) to be taken from best available observational data.
(v) Land initial states: (if appropriate) to be taken from most appropriate land data assimilation system or consistent offline analyses driven by observed meteorology (i.e., GSWP).
(vi) Atmospheric output:
    a. Every 24 hours at 00 GMT-

i. Pressure levels (instantaneous): Geopotential Height, Temperature, Velocity and specific humidity for 850, 500, 200, (if available 100, 50, 10; these higher pressure levels are used for interactions with SPARC) hPa.
ii. Surface (instantaneous): 2m Tmax – daily, 2m Tmin – daily, Total soil moisture, Snow depth, Sea surface temperature and/or some temperature over land, Mean sea level pressure
iii. Surface (accumulated): Total precipitation, Downward surface solar radiation, Downward surface longwave radiation, Surface net solar radiation, Surface net longwave radiation, Top net solar radiation, Top net longwave radiation, Surface momentum flux, Evaporation.

b. Every 6 hours at 00, 06, 12, 18 GMT-
i. Surface (instantaneous): Total cloud cover, 10m wind, 2m Temperature, 2m Dew Point, 2 m specific humidity.

(vii) Oceanic output (where appropriate)
a. Every 24 hours at 00 GMT-
i. Accumulate temperature, salinity and currents in the upper 250 meters, surface fluxes of heat, momentum and fresh water, sea level height, mixed layer depth

b. Every 6 hours at 00, 06, 12 18 GMT-
i. Surface fluxes of heat, momentum, and freshwater. Sea level height and mixed layer depth

(viii) Sea Ice output (where appropriate)
a. Every 24 hours at GMT –
i. Surface fluxes of heat and momentum. Snow cover, Sea ice concentration, thickness and temperature.

(ix) Soil wetness and vegetation predicted.
(x) Snow cover and depth predicted.
(xi) Chemical Composition (carbon dioxide, ozone …) prescribed and varying. This explicitly includes the transient changes in the chemical composition from 1979-present.

10.2 Examples of Potential Diagnostic Sub-Projects

In order to maximize collaboration and minimize duplication of effort, the proposed experiment will include a diagnostic sub-project approval process. The following is an abbreviated list of potential sub-projects. It is anticipated that a large number of addition sub-projects will be implemented as the experimental results become available.

- Limit of Predictability Estimates: One potential estimate for the limit of predictability is to determine when a particular forecast probability density function (pdf) is indistinguishable from climatological pdf of the forecasts.
- ENSO mechanism diagnostic: Recharge oscillator versus delayed oscillator, role of stochastic forcing, westerly wind events.
- Impact of the AO on seasonal predictability
- Regional predictability

- Local land surface predictability
    - Extreme events
    - Monsoon predictability
    - Diurnal cycle in ocean
    - Diurnal cycle in the atmosphere
- Coupled Feedbacks
    - Intra-seasonal oscillations

10.3 General Discussion

Within the discussion a number of points were raised that should be taken into account in the next revision:

- A timeline for COPE should be developed. Although is was agreed to discuss this issue in more depth at the next session of the JSC, a date around 2008 or 2009 (30 years of FGGE) was suggested for completion of the first phase of COPE. It was recognized that earlier dates would be hard to match because of the IPCC AR4.
- SMIP/HFP experiment should be continued. It was considerable value-added to the COPE experiment.
- Dialogue with ENSEMBLES was encouraged, since this project has very similar goals and scope. Nevertheless, not all diagnostics and analysis will match with COPE.
- The final proposal should also include a connection to applications of the predictions (links to IHDP). IRI (*S. Zebiak to draft this part*).
- Data: The data requirements from the DEMETER project could serve as a starting point. Details need to be fleshed out. The TFSP should start to develop a data management for COPE, which should be handed over to WCRP once their DM structure is in place. (*J. Kinter to write an outline for the COPE DM*).
- Observational data requirements for verification: These requirements need to be formulated as well as the requirements for data in order to initialise the experiments. (*M. Harrision to propose some requirements following the WMO adequacy report*)

Appendices

1. List of participants
2. Agenda

Appendix 1

COPE Workshop on Seasonal Prediction – List of Participants

Mark Baldwin
Northwest Research Associates
14508 NE 20th Street
Bellevue, WA 98007-3713
USA
Phone +1 425-644-9660 x323
Fax: +1 425 644-8422
mark@nwra.com

George Boer
CCCma
Meteorological Service of Canada
University of Victoria
PO Box 1700
3964 Gordon Head Road
Victoria, BC V8W 2Y2
Canada
Phone +1-250-363 8226
Fax: +1-250-363 8247
George.Boer@ec.gc.ca

Michael Davey
Meteorological Office
Hadley Centre for Climate Prediction and Res.
Meteorological Office
FitzRoy Road
Exeter EX1 3PB
United Kingdom
Phone +44 1392 xxxx
Fax:
mkdavey@metoffice.com

Michel Deque
CNRM-Meteo France
42 Av. G. Coriolis
F-31057 Toulouse
France
+33 5 61 07 93 82
+33-5-61 07 96 10
michel.deque@meteo.fr

Paul Dirmeyer
Center for Ocean-Land-Atmosphere Studies
4041 Powder Mill Road #302
Calverton, MD 20705-3106
U.S.A.
Phone +1 -301-902-1254
Fax: +1-301-595-9793
dirmeyer@cola.iges.org

Renate Hagedorn
ECMWF
- Diagnostics & Predictability Research Section -
Shinfield Park
Reading RG2 9AX
United Kingdom
Phone +44 118 9499 257
Fax: +44 118 9869 450
renate.hagedorn@ecmwf.int

Mike Harrison
Meteorological Office
FitzRoy Road
Exeter EX1 3PB
United Kingdom
Phone +44 1392 xxxx
Fax:
mike.harrison@metoffice.com

Jens Hesselbjerg Christensen
Danish Meteorological Institute
Lyngbyvej 100
DK - 2100 Kopenhagen O
Denmark
Phone +45-39157428
Fax: +45-39157460
jhc@dmi.dk

In-Sik Kang
Seoul National University
Department of Atmospheric Sciences
Kwanak-ku,
Seoul 151
Korea
Phone +82-2-880-6718
Fax: +82-2-885-7357
kang@climate.snu.ac.kr

Vladimir Kattsov
Voeikov Main Geophysical Observatory
7 Karbyshev Street
St. Petersburg 194021
Russian Federation
Phone +7-812-247-8668
Fax: +7-812-247-8661
kattsov@main.mgo.rssi.ru

James L. Kinter III
Center for Ocean-Land-Atmosphere Studies
4041 Powder Mill Road #302
Calverton, MD 20705-3106
U.S.A.
Phone +1 301-595-7000
Fax: +1 301 595 9793
kinter@cola.iges.org

Ben Kirtman
Center for Ocean-Land-Atmosphere Studies
4041 Powder Mill Road #302
Calverton, MD 20705-3106
U.S.A.
Phone +1 301-595-7000
Fax: +1 301 595 9793
kirtman@cola.iges.org

Randal Koster
NASA / GSFC
Code 974
Greenbelt, MD 20771
U.S.A.
Phone +1-301-286-7061
Fax: +1-301-286-1758
randal.koster@gsfc.nasa.gov

Simon J. Mason
International Research Institute for Climate Prediction
PO Box 1000
Palisades, NY 10964-8000
USA
Phone +1 845-680-4514
Fax: +1 845-680-4865
simon@iri.columbia.edu

Sudhir Nadiga
NOAA/NCEP
5200 Auth Road
Camp Springs, MD 20746
U.S.A.
Phone +1-301-763-8000 (ext:7593)
Fax:
Sudhir.Nadiga@noaa.gov

Paulo Nobre
INPE
Centro de Previsão de Tempo e Estudos Climáticos
Rod.Presidente Dutra, Km 40
Cachoeira Paulista, S.P. 12630-000
Brazil
Phone +55-12-560 8425
Fax: +55-12-561 2835
pnobre@cptec.inpe.br

Scott Power
Bureau of Meteorology Research Centre
GPO Box 1289K
Melbourne, Vic 3001
Australia
Phone +61-3-9669-4214
Fax: +61-3-9669-4660
S.Power@bom.gov.au

Anthony J. Rosati
NOAA Geophysics Fluid Dynamics Lab.
Princeton University
P.O. Box 308
Princeton, NJ 08540
U.S.A.
Phone +1-609-452-6584
Fax: +1-609-987-5070
ar@gfdl.gov

Venkataramaiah Satyan
World Meteorological Organization
World Climate Research Programme
Case Postale No. 2300
CH-1211 Geneva 2
Switzerland
Phone +41 22 730 8418
Fax: +41 22 730 8036
Satyan_V@gateway.wmo.ch

Jagadish Shukla
Center for Ocean-Land-Atmosphere Studies
Institute of Global Environment and Society Inc.
4041 Powder Mill Road #302
Calverton, MD 20705-3106
U.S.A.
Phone +1-301-595-7000
Fax: +1-301-595-9793
shukla@cola.iges.org

Masato Sugi
Climate Prediction Division (CPD)
Climate and Marine Department
Japan Meteorological Agency (JMA)
1-3-4 Otemachi, Chiyoda-ku
Tokyo 100-8122
Japan
Phone +81-3-3212-8341 (Ext. 3151)
Fax: +81-3-3211-8406
msugi@met.kishou.go.jp

Jozef Syktus
Dept. of Natural Resources

Queensland Centre for Climate Appl.
QCCA Building, Gate 4, 80 Meiers Road
Indooroopilly, Queensland 4068
Australia
Phone +61 7 3896 9730
Fax: +61 7 3896 9843
Jozef.Syktus@dnr.qld.gov.au

Andreas Villwock
International CLIVAR Project Office
c/o Institut für Meereskunde
Düsternbrooker Weg 20
D-24105 Kiel
Germany
Phone +49-431-600-4122
Fax: +49-431-600-1515
avillwock@ifm.uni-kiel.de

Ding Yihui
China Meteorological Administration
National Climate Center
46 Zhongguancun Nan Da Jie
Beijing 100081
China
Phone
Fax:
dingyh@cma.gov.cn

Stephen Zebiak
IRI
Columbia University
Palisades, NY 10964
U.S.A.
Phone +1 845 680 4497
Fax: +1 845 680 4865
steve@iri.columbia.edu

Appendix 2

AGENDA

Monday, November 3rd *COPE Workshop on Seasonal Prediction*

1. 9:00-9:30 Welcome and opening remarks

(Ben Kirtman (chair COPE Task Force for Seasonal Prediction), J. Shukla (JSC), IPRC Representative (local host), Andreas Villwock (ICPO)) Presentation of the Agenda

2. 9:30-10:00 Background- Motivation and Foundation for COPE (Kirtman, Shukla)

Scientific Direction and Structure of WCRP
Description of COPE
Charge for the COPE Task Force - Draft Terms of Reference

3. 9:30-10:30 Current Status of Seasonal Prediction (S. Mason and S. Zebiak)

4. 10:30-11:00 Coffee Break

5. 11:00-12:30 Role of Oceans in Seasonal Prediction (CLIVAR)

Atlantic Ocean and Seasonal Prediction (S.-P. Xie; 11:00-11:30)
Pacific Ocean and Seasonal Prediction (A. Rosati: 11:30-12:00)
Indian Ocean and Seasonal Prediction (N. H. Saji: 12:00-12:30)

6. 12:30-1:30 Lunch

7. 1:30-2:30 Discussion

8. 2:30-3:30 Role of Cryosphere in Seasonal Prediction (CliC; J. H. Christensen)

9. 3:30-4:00 Coffee Break

10. 4:00-5:00 Discussion

11. 5:30-8:00 Reception (Sponsored by COLA)

12. 8:00 Transportation to Hotel

Tuesday, November 4th *Cope Workshop on Seasonal Prediction*

13. 9:00-10:00 Role of Land Surface in Seasonal Prediction (GEWEX; R. Koster and P. Dirmeyer)

14. 10:00-10:30 Discussion

15. 10:30-11:00 Coffee Break

16. 11:00-12:00 Role of Stratospheric Processes in Seasonal Prediction (SPARC; M. Baldwin)

17. 12:00-1:00 Lunch

18. 1:00-2:00 Discussion on Seasonal Prediction in a Changing Climate

19. 2:00-3:30 Developing a Coordinated Plan for Pan-WCRP Seasonal Prediction

20. 3:30-4:00 Coffee Break

21. 4:00-5:00 Developing a Coordinated Plan for Pan-WCRP Seasonal Prediction

22. 5:00 Transportation to Hotel

Wednesday, November 5th

23. 9:00-10:30 Developing a Coordinated Plan for Pan-WCRP Seasonal Prediction

24. 10:30-11:00 Coffee Break

25. 11:00-12:30 Developing a Coordinated Plan for Pan-WCRP Seasonal Prediction

26. 12:30 COPE-TFSP End