Major WGSIP Research Activities (B. Kirtman)

The working group for seasonal-to-interannual prediction (WGSIP) is coordinating two major modeling and prediction efforts that are of interest to the Atlantic Implementation Panel (AIP). The first activity is the Climate-System Historical Forecast Project (CHFP), which was developed in a major Pan-WCRP (World Climate Research Program) effort. The CHFP is managed and coordinated by WGSIP, but includes design input and collaboration from all of the relevant WCRP programs (i.e., CLIVAR, GEWEX, SPARC, CliC). The second major project is being developed in coordination with the working group on coupled modeling (WGCM) and will be part of the AR5 experimental design. This modeling project emphasizes decadal climate prediction. These two projects are summarized below.

1.0 *Climate-system Historical Forecast Project (CHFP)*

One of the overarching goals of the WCRP is determine the predictability of the complete climate system on time scales of weeks to decades. 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 has lead to the understanding that modeling 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 past research by two somewhat non-interacting 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. This multi-model multi-institutional aspect of the problem requires WCRP coordination.

In 2005, the WCRP formed the Task Force on Seasonal Prediction (TFSP) and commissioned it over two years to assess current seasonal prediction capability and skill considering a wide range of practical applications, and to enable the development and implementation of numerical experimentation specifically designed to enhance seasonal prediction skill and the use of seasonal forecast products for societal benefit. Since June 2007, the TFSP has ceased to exist and its mandate has been transferred to the CLIVAR Working Group on Seasonal to Interannual Prediction (WGSIP). WGSIP has now assumed the primary role of TFSP, that is to insure that these experiments are coordinated across all relevant WCRP activities, and that the seasonal prediction data is made readily available to both the applications and physical science communities. The various components of the WCRP will continue to lead assessment of the forecasts, developing strategies and experiments for improving the forecasts and component model, and observing system evaluations and process study and field campaign integration. The First WCRP Seasonal Prediction Workshop, held in June 2007, addressed how to improve seasonal prediction and how to assess our progress in improving forecasts and their utilization for societal benefit and, in early 2008, a WCRP position paper on seasonal prediction will be produced as the main deliverable of the Workshop.

A comprehensive seasonal prediction experiment is proposed 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 results of these experiments provide a framework for future experiments, specifically these prediction results will:

- Provide a baseline assessment of our seasonal prediction capabilities using the best available models of the climate system and data for initialisation.
- 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
- Provide an experimental framework for focused research on how various components of the climate system interact and affect one another
- Provide a test bed for evaluating IPCC class models in seasonal prediction mode

It is recognised 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.

1.1 Total Climate System Prediction Experiment Proposal

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

While the emphasis in 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 PROVOST 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 accomplish a wider participation, e.g. for groups without sea-ice or vegetation model. The only requirement is that no "future" information is used once the prediction is initialized. This requirement necessarily includes any tuning or training either the component models or the development of statistical prediction schemes.

Thus, the component models are:

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

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[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.

(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 February, May, August and November 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.
    a. Addition retrospective forecasts using each month of each year from 1979-present are encouraged.
    b. Additional retrospective forecast using initial conditions from each February, May, August, and November 1960-1978 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; GLACE2).
(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 surface radiative temperature over land (if available), Mean sea level pressure, soil heat flux over land (if available).
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, latent and sensible heat flux.

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 Month-
i. Accumulated temperature, salinity and currents in the (at least) upper 400 m, surface fluxes of heat, momentum and fresh water, sea level height, mixed layer depth.
b. Every 24 hours at 00 GMT-
i. Temperature, salinity and currents in the (at least upper 400 m) at the equator, 2N and 2S (5N and 5S optional).
c. Every 6 hours at 00, 06, 12 18 GMT-
i. Surface fluxes of heat, momentum, and freshwater. Sea surface temperature 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.

(xii) Finally, it is noted that some forecast provides may no be able to provide the complete list noted here. Participation is strongly encouraged even if all the data requirements cannot be met.

1.2 Examples of Potential Diagnostic Sub-Projects

In order to maximize collaboration and 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
- The diagnostic sub-projects will also include extensive interactions with the applications community and the regional panels within CLIVAR, GEWEX, SPARC and CliC. These interactions and collaborations are viewed as critical elements of the implementation plan and are strongly encouraged.

2.0 Decadal Climate Prediction

Basic model runs:

2.1 10 year integrations with initial dates towards the end of 1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995 and 2000 and 2005 (see below).

Ensemble size of 3, optionally to be increased to O(10)

Ocean initial conditions should be in some way representative of the observed anomalies or full fields for the start date.

Land, sea-ice and atmosphere initial conditions left to the discretion of each group.

Model run time: 300 years (optionally, an additional 700 years)

2.2 Extend integrations with initial dates near the end of 1960, 1980 and 2005 to 30 yrs.

Each start date to use a 3 member ensemble, optionally to be increased to O(10)

Ocean initial conditions represent the observed anomalies or full fields.

Model run time: 180 years (optionally, an additional 420 years)

Further details on these runs:

- Calendar start date can be 1st September, 1st November, 1st December or 1st January, according to the convenience of the modeling group. Dates should allow complete years/decades to be analysed, eg start 1st Sep 1960, 1st Nov 1960 or 1st Jan 1961.
- Actual integration length should be long enough to produce 10 or 30 complete calendar years. We expect any extra 'initial' months to be discarded in the analysis.
- Choice of initial conditions is up to each group, subject to the principle that they should represent the observed anomalies for the start date. Analyses of past ocean states and/or anomalies are available. Methods to transfer such analyses into an ocean model's initial condition exist. Most experience so far is of using observed anomalies on top of the coupled model climate, but initializing with the full state is also allowed, and will be used by some groups.
- All forcings should be included as observed values for past dates, with prescribed concentrations of well-mixed GHGs. The details should be the same as used in the CMIP5 historical (20th C) runs, with the same flexibility on the treatment of ozone and aerosol and the same specified observational datasets.
- For future dates, the RCP4.5 scenario should be used if possible. Specification of reactive species and aerosols will follow those used in CMIP5.
- Any deviations from the standard specifications should be properly documented.
- Note the treatment of volcanic aerosol: observed values should be used for past dates, as per CMIP5, but values to be used after 2005 should be specified based on the assumption of no further volcanic eruptions. The model runs are thus configured to predict what will happen to climate, relative to the observed past, if no major eruptions take place, which is a possible outcome for a thirty year period.
- **Optional:** Additional runs from 1960, 1975, 1980, 1985 and 1990 should be made without including the Agung, El Chichon and Pinatubo eruptions. This allows an assessment of the impact of volcanic eruptions on decadal predictions. It also allows an estimate of "overall skill" of decadal prediction to be made, complementing a dual analysis of "expected skill conditional on no big volcano" and "possible impact of volcano". These runs could either all be 10 years long, or the 1960 and 1980 runs could be 30 years to assess the longer term impact of the volcanoes.

Requested model runs (not compulsory, but part of coordinated comparison)

2.3 10 year integrations from near end of 2001, 2002, 2003, 2004, 2006 (2007, ..)

Each start date to use a 3 member ensemble, optionally to be increased to O(10)

Runs from 2007 onwards encouraged where possible

These runs make use of the recent well-observed era, and are a step towards possible real-time prediction.

Model run time: 150+ years (optionally, an additional 350+ years)

2.4 For those models that are able to produce 20th Century climate runs, the CMIP5 20th

Century / RCP4.5 runs should be increased in number to create an ensemble of the desired size of continuous runs extending to 2035. Details as per CMIP5 long term integrations. Ensemble size to match those used in 2.1 and 2.2.

These runs form a "control" against which the value of initializing short-term climate and decadal forecasts can be measured.

2.5 For models which do not have 20th century and other standard runs, it is requested to make a 100 year control integration, and a 80 year run with a 1% per year increase in CO_2, starting 20 years into the control run. These integrations will allow an evaluation of model drift, climate sensitivity and ocean heat uptake, and give some idea of the natural modes of variability of the model.

(For groups that want to use an anomaly initialization method, a transient run with observed forcings might be run from the end of the control. With due consideration to the 'cold-start' problem, this could give a late 20th century model climate which can be compared to the observed ocean climate for the purpose of defining initial condition anomalies to be inserted into the model. However, this is considered part of the initialization method - it is up to each group to choose the most suitable approach.)

Summary of runs

Section	Experiment	# years (3 members)	# years (10 members)
1.1	10 year runs	300	1000
1.2	30 year runs	180	600
1.1+1.2	Volcanoes removed	150-270	500-900
1.3	ARGO era 1 year interval	150+	500+
1.4	Additional CMIP5 members		
1.5	Simple reference runs		
Totals	1.1 - 1.2 basic set	480	1600
	1.1 - 1.3, 10yr volcanoes	780	2600

Additional notes

- The output of the model integrations needs to be defined. We start with the assumption that the output will be the same as that requested for the long term CMIP5 runs.
- Data handling needs to be defined. It is hoped that data from section 1 of this proposal can be archived as part of the general AR5 archive, to allow access by the wider scientific community.