PROSPECTUS FOR SHORT-TERM CLIMATE SIMULATIONS USING THE CCSM

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Long before the industrial revolution, human activity began to alter the Earth's environment. However, only recently has the scale of these alterations become apparent. The human fingerprint is abundantly seen in the global atmosphere, the world oceans, and the land of all continents. This insight has brought about profound changes in the goals, priorities and processes of both science and government.

Today, there is tremendous scientific, as well as societal, interest in how climate will change over the next several decades. There are many scientific questions to be answered; for instance, the likelihood of changes in extreme events at the regional scale. Such regional scale simulations will require an ensemble of runs using finer resolution models, likely with the inclusion of simple chemistry, aerosols, and dynamic vegetation.

Serious discussions of using the CCSM to produce short-term climate simulations have arisen at the past several CCSM Advisory Board (CAB) meetings, including a lengthy discussion led by Eric Sundquist and Tom Crowley at the CAB meeting in Washington, D.C. in February 2006. In addition, the issue was revisited in summer 2006 at the joint SSC/CAB/WG Co-chairs meeting in Breckenridge, where NSF also seemed quite interested in supporting this line of inquiry. Also, decadal climate simulation was discussed extensively at the joint WGCM/AIMES workshop held in August 2006 in Aspen, CO. For reference, the report from that meeting is available at: http://www.aimes.ucar.edu/MEETINGS/SSC_2006/WORKING_PAPERS/ESM_AGCI_WGCM_AIMES_Long.pdf

Motivated primarily by the critical scientific questions, opportunities and challenges presented by this approach, and the generally high level of enthusiasm within NCAR for it, the goal of this preliminary prospectus is to gather community feedback on this idea and its implementation in the framework of the CCSM. In particular, such an effort cannot be successful without a strong community contribution and, at this stage, help in identifying the key issues and challenges. There was some community feedback providing important input to the November 10th, 2006 SSC meeting, where the prospectus was thoroughly discussed by the SSC.

It is important to emphasize that these short-term simulations would be done in addition to the more traditional type of climate change scenarios out to 2100 and beyond. The CCSM implementation plan outlines the procedure to produce a CCSM 4 to be used for these traditional scenario runs that include some form of carbon cycle and the indirect effects of aerosols. At the aforementioned WGCM/AIMES workshop, these traditional scenario runs and the new short-term simulations have both been proposed as standard integrations for the IPCC AR5.

The proposed form for these short-term climate simulations would likely be:

a) Starting the integrations in 1980, or perhaps a few years earlier in order to capture the mid-1970s "climate shift", and then run in pure simulation or simulation/assimilation mode until 2005. The short-term simulation would be from 2006 to 2030.

b) The optimal ensemble size has not yet been determined, and that in itself is another important scientific question. However, discussion at the 2006 CCSM Workshop and the WGCM/AIMES workshop recommended a minimum ensemble size of 10 simulations in order to address changes in extremes.

One very interesting and really important question is: Does it make an important difference if the CCSM is "initialized" to the actual climate of 2005? Exactly how to initialize the CCSM is a major challenge, and one that other groups around the world are wrestling with as well. At a minimum, it will require data assimilation into the ocean component and possibly sea ice extent in the Arctic. Do we need to get the correct state of the tropical Pacific and ENSO, and the North Atlantic meridional overturning circulation in order to produce a realistic short-term simulation for 2006-2030? There are many other data assimilation issues that are not outlined here; for instance how to initialize around the modes of coupled variability intrinsic to the model.

Some advantages of short-term climate simulations include:

a) Because the short-term simulation runs are relatively short, the atmosphere component can be run at somewhat higher resolution than previously used for IPCC scenario runs. Thus, they will produce regional information for the near future that is more relevant to decision makers.

b) Most of the climate change signal is already committed up until 2030, so the forecasts are much less dependent on uncertainty in future forcing scenarios.

c) In terms of a multi-model ensemble, there is a factor of three smaller range in transient climate response than in equilibrium response. This makes the multi-model ensemble more interesting because the range in model sensitivity is no longer the primary cause for the differences in the inter-model short-term simulations.

d) This use of the CCSM allows many different, new questions to be addressed about future changes in climate. These questions go beyond CGD, and encourage collaborations across other divisions within ESSL, as well as CCSM partners in other laboratories and across the universities.

Some challenges of short-term simulations include:

- No work so far has been done assimilating data into the CCSM ocean and sea ice components. This assimilation work would need to be planned and started soon. There are ongoing efforts nationally and internationally in this area, including a Data Assimilation Project within NCAR that would have to be brought into the fold.

- Should the atmospheric chemistry component of the CCSM be run in prognostic mode or using time slices? Should the full carbon cycle be included in these runs?

- This increases the goals and workload of the CCSM project. In addition, the project's highest current priority is to reduce the systematic biases in the CCSM 3 simulations of ENSO, land temperatures and precipitation, SST biases in upwelling regions, etc.

> The short-range simulation approach would arguably make the reduction of long-standing systematic biases even more critical.

Scientific opportunities from short-term simulations include:

1) The runs with and without data assimilation between about 1980 and 2005 could be used to address the predictability of the climate system on decadal timescales. In addition, the evolution of model systematic errors on shorter timescales might give insight into the mechanisms associated with these errors.

2) Stimulus for a variety of multi-scale modeling activities, such as a very high resolution one-way downscaling over the U.S.A. This could be used to examine implications for hydrology and water supplies, such as snow pack and runoff in the west, which is controlled by local mountainous topography.

3) Changes in extremes, such as extended heat waves, floods, droughts and in Atlantic hurricane frequency and intensity.

4) With the atmospheric chemistry component included, there could be simulations of air pollution (aerosols, ozone) in major urban areas and mega-cities.

5) An assessment of historical and short-term aerosol forcing, compared with on-going aerosol and temperature observations, may allow a better understanding of aerosol climate forcing, and hence climate sensitivity.

6) Higher resolution would allow for better representation of soil, topographic, and vegetation controls of the carbon cycle. Higher resolution would also permit simulation of different classes of permafrost, and their different susceptibilities to, and interactions with, future climate change.

7) This type of short-term climate simulation would emphasize human-induced changes in land use, which would require simulations using the dynamic vegetation module that is in the current CCSM land component.

8) Mineral aerosols might help sort out the importance of human (land cover change) versus natural (drought) controls of dust emissions. Also, the feedback of wildfires on climate through albedo, carbon cycle, and aerosols could be addressed.

9) What are the impacts of higher resolution on the mean biases in the upwelling regions? What are the changes in the ocean ecosystem model, and possibly in coastal ecosystems?

Requirements:

This would be a new focus and effort for the CCSM project. As a consequence, Jay Fein has indicated that new resources (additional FTEs) might be available in order to handle the additional workload and to reach the scientific objectives. These additional resources are a necessary condition so that these short-term climate simulations can be produced in a timely fashion. Allocation of these resources would have to be discussed and agreed upon by the SSC, but most likely they would be used for additional Associate Scientists and Software Engineers.

An ensemble of ten 50 year simulations would require a very substantial amount of computer time, but we would probably run fewer traditional climate scenarios for the IPCC AR5 report. However, there are solid plans to increase the amount of computer time available to the CCSM project both at NCAR and Oak Ridge National Laboratory. We think computer time is probably not going to be the limiting factor in whether this new type of simulation can be developed over the next few years. If there is to be a limiting factor, in our view, it will be human resources, and time to understand the successes and limitations of these short-term climate simulations.

Additional human resources needed:

We believe about six new support positions are needed to accomplish this work in a timely fashion that would mean the CCSM could contribute on this topic to the IPCC AR5 report:

- An Associate Scientist in the AMWG to facilitate improvements in the FV version of the atmosphere component. This position would interact with outside of NCAR developers of alternative parameterizations (convection, PBL physics, clouds, aerosols) in assessing and integrating their efforts on a more rapid timescale than at present.

- An Associate Scientist in the OWG to work on data assimilation in the ocean and sea ice components. This position would interact very closely with Jeff Anderson in the Data Assimilation Project. There are three reanalyses of the oceanic state that go back to 1980 that the ocean component could be nudged towards, but their quality in the global ocean is open to question. In particular, there are only a few deep salinity measurements in the North Atlantic, which makes initializing the meridional overturning circulation a real challenge. There is much more experience in initializing the upper tropical Pacific Ocean that is done on a regular basis to initialize ENSO forecasts for up to a year in advance.

- A Software Engineer in the Land Model WG to help with the necessary developments needed in the land component and in the terrestrial biogeochemistry.

- A Software Engineer in the Atmospheric Chemistry WG to help with the necessary developments needed in the atmosphere chemistry component.

- Two Software Engineers in the CSEG. These positions would be needed to develop the CCSM toward assimilating the new components necessary for this work, such as the carbon cycle components and the chemistry component. New capabilities with respect to atmospheric aerosols, the ocean ecosystem component, and the new land ice component would also have to be incorporated.