

Implementation Plan for the CCSM 4

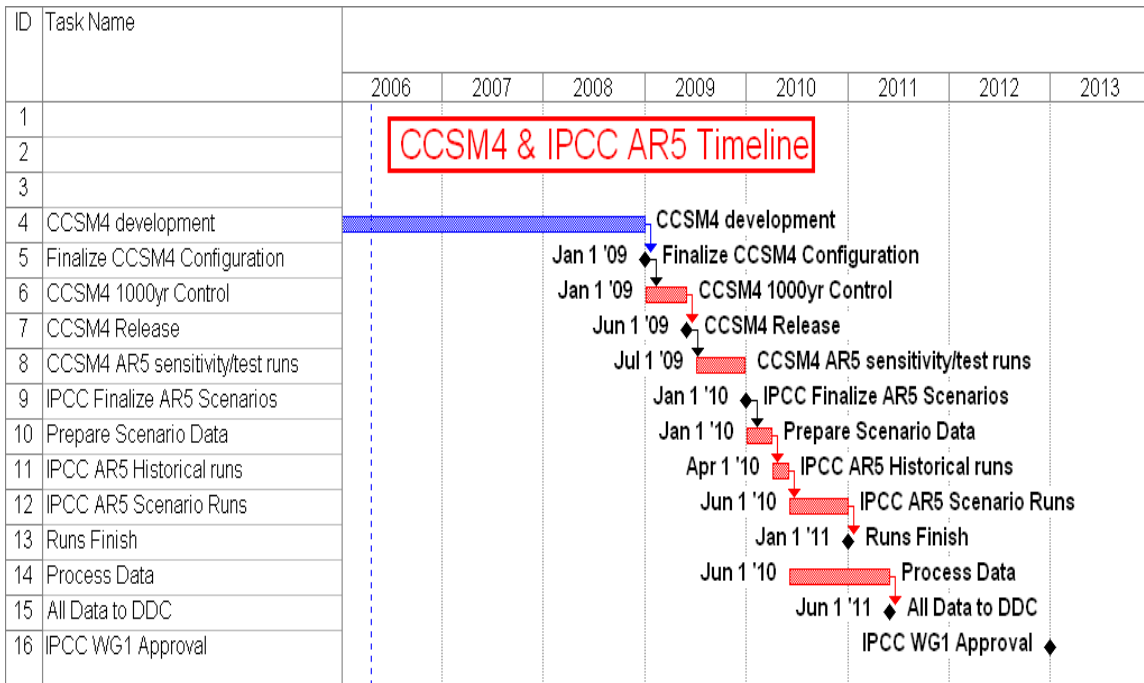
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1) Introduction

Working backwards from the assumed schedule for the IPCC AR 5, it has been agreed by the SSC that CCSM 4 needs to be finalized by the end of 2008. Then a long control run can be completed in the first half of 2009, and the model and control run released at the June 2009 Workshop. As the chart shows, the 1% CO₂, 20th and 21st century runs and their analysis can then be completed on a comfortable time schedule for the IPCC AR 5. At the April 3, 2006 SSC meeting, it was agreed that CCSM 4 should include:

- a) CCSM 4 should have a carbon or carbon/nitrogen cycle component.
- b) The indirect effects of aerosols should be included in CCSM 4.

This implementation plan was discussed at the November 10, 2006 SSC meeting, and at the CCSM Workshop in Breckenridge in June, 2007. It has been updated after Stage I, the assembling of an interim version CCSM 3.5, was completed in July 2007.



2) Stage I

Stage I was completed in July 2007, when the interim version CCSM 3.5 was assembled, and the final settings and parameter values chosen. CCSM 3.5 uses the FV dynamical core in the atmosphere component, a dilute plume parameterization and vertical momentum transport in the deep convection scheme, and a change in how the Arctic low cloud fraction is calculated. The ocean component uses the updated POP 2 code, with more vertical resolution, a revised horizontal viscosity, and modification to the tapering of the GM coefficient near the surface. The sea ice component uses the latest CICE 4 version, which includes an improved ridging scheme. The land component, CLM 3.5, has been extensively revised and improved by including a much improved soil hydrology scheme and a frozen soil parameterization. The interim version of the biogeochemistry land component was chosen to be the CN code, which includes an active carbon/nitrogen cycle. Probably the most significant improvement in CCSM 3.5 is its simulation of the El Nino - Southern Oscillation (ENSO) in the tropical Pacific Ocean. All previous versions of the CCSM had a peak in the ENSO frequency near 2 years, which is much shorter than in reality. This problem has now been overcome in CCSM 3.5, which shows a realistic frequency peak between 3-6 years.

The Biogeochemistry Working Group has been running an older carbon cycle version in the T31x3 version of the CCSM 3. They now plan to use a newer carbon/nitrogen cycle version in the CCSM 3.5. This will be a real advance towards CCSM 4, in that the base codes of the atmosphere, ocean, and sea ice components will all be updated, several parameterization improvements in all components will be included, and the resolution of all components will be significantly increased.

3) Stage II

Finalize the physical, biogeochemistry and chemistry components of CCSM 4 by September 30, 2008.

The developments likely to be included in CAM 4 are the Bretherton shallow convection and boundary layer schemes, and the Morrison/Gettelman microphysics. The scheme for the indirect effect of aerosols needs to be finalized by Steve Ghan and colleagues. There are also parameterization changes being worked on by the Ocean, Land, and Polar Climate Working Groups.

- a) CLM 3 had a DGVM (dynamic global vegetation model) based on the carbon cycle and vegetation dynamics parameterizations of the LPJ model. This will continue to be supported in CCSM 4, and has now been incorporated into the latest version of the land component. Not using a DGVM excludes a large feedback associated with the carbon cycle, i.e., changes in vegetation biogeography that alter terrestrial carbon storage. Second, the lack of a DGVM excludes an integrated assessment of vegetation feedback on climate. An additional complexity is how to represent the land use forcing of climate. Land use, particularly deforestation and the conversion of forest to cropland, is an important component of the global carbon cycle because it alters albedo, the hydrologic cycle, and surface fluxes. Should the carbon cycle model include land use, and how will this be coordinated with studies in the Climate Change and Land Model WGs to examine the land use forcing of climate?
- b) A biogeochemistry land model intercomparison, called C-LAMP, between the CASA', CLM-CN and IBIS models is ongoing. Of the three carbon cycle models being considered by the BGC WG, the CASA' and CN models use prescribed, time-invariant biogeography. Only the IBIS model has a DGVM as part of its carbon cycle. However, the protocol for the model comparison is to turn off this feature, and run IBIS in prescribed vegetation mode. Thus, the C-LAMP intercomparison will evaluate models without dynamic vegetation.
- c) Include the land ice component in prognostic mode that is being developed by Bill Lipscomb of LANL. The Climate Change WG has plans to run with this new component, but in an offline mode, as soon as it is ready.
- d) A chemistry component is being developed, and will be an option in CAM 4. It could be used to predict tropospheric ozone, for example, and be used to evaluate chemical pollution especially near major cities. This component will be used in short-term simulations using the CCSM, but is unlikely to be used in long-term scenarios where the carbon cycle is included. This would depend on a cost/benefit ratio demonstration for these long-term scenarios.

4) Stage III

The rest of 2008 would be used to test, finalize, and thoroughly understand the CCSM 4 that includes the new physical components, the final carbon cycle component, aerosol

indirect effects, and the new land ice component. This includes obtaining the very long spinups required for the biogeochemistry and land ice components, and determining the final parameter settings for the CCSM 4, such as the sea ice albedos, etc. We suggest that the only changes allowed to the physical components during the rest of 2008 would be something that significantly improves one of the major CCSM biases. What constitutes a “major bias” and “significant improvement” would have to be decided by the SSC.

For the coupled carbon/nitrogen cycle simulations, the horizontal resolution probably will be that used in Stage I. So, the atmosphere FV and land resolution would be 2.2 x 1.9 deg (160x96 points), while the ocean and sea ice resolution would be the x1 values.

In addition, there has been discussion at the November 10, 2006 SSC meeting and at a CGD meeting about using the CCSM to produce “Short-term Climate Simulations”. The idea is to produce information on regional scales, especially over North America, using higher atmosphere resolution than for the longer scenarios described above. The proposed form of the runs is to start in 1980, and run to 2005 reproducing the relatively well observed recent past, and then continue the runs until 2030. An important question is whether the ocean component needs to be initialized to the observed state in 2005, in order to improve the realism of the ENSOs and North Atlantic overturning circulation in these short-term simulations? The CAB has strongly advised against CCSM developing a new ocean data assimilation scheme for POP2. They recommended constraining the ocean solution strongly during 1980-2005 towards an ocean reanalysis, such as those provided by GFDL or the SODA project. Runs with and without ocean data assimilation over the 1980-2005 period could also be used to address climate predictability on decadal timescales. Discussion after the 2007 CCSM Workshop has suggested that the first Short-term Simulations use a middle-atmosphere version of CAM with 60 levels and possibly 0.5x0.5 degree resolution. The chemistry component would be run in prognostic mode in order to predict stratospheric ozone, because there is evidence that this influences the North Atlantic Oscillation and the Southern Annular Mode. These runs would also be relevant to an international activity called “Atmospheric Chemistry and Climate” that is sponsored by IGBP-IGAC and WCRP-SPARC. These initial runs will probably not include the full carbon/nitrogen cycle, but it is still an open question whether to include it in later runs. A longer prospectus on “Short-term Climate Simulations using the CCSM” has been written, and is also available on the CCSM web site.

A lower resolution version of CCSM 4 has been requested by the Paleoclimate WG. It will also have to be assembled and tested during 2009.

5) Potential Failure Points

- a) The first potential failure point is that the timeline in Stage II slips. Historically, this has happened every time there has been a release of the CCSM. The physical component Working Groups plan to include several changes to each component, and this takes more time to complete than originally estimated. Based on past experience, I think this a quite likely scenario. If the slippage is just a few months and Stage II has been thoroughly completed, then I think there is enough slack in the Stage III timeline that it should be completed on schedule by the end of 2008.
- b) If the a) failure point causes a slippage of many months to a year, then a baseline fallback position is that the coupled model CCSM 3.5 becomes the basis for CCSM 4 to be used for the IPCC AR5. Note, however, that CCSM 3.5 does not have the indirect aerosol effect or the land ice component, so that these would have to be added to produce the final CCSM 4.

6) Verification

SSC members have recently been saying that the best way to validate the CCSM 4 is to “simulate the observed climate record with as much fidelity as possible”. However, this does depend on the assumptions made for some of the specified forcings over the 20th century, such as the volcanic effect and aerosols. Note that this is not how we have finalized previous versions of the CCSM, because this has been done by tweaking a 1990, or present day, control run to give answers we like, such as thermodynamic balance at the top of the atmosphere (tweaking cloud parameters), and reasonable Arctic sea ice thickness (tweaking snow and ice albedos). If we change to validating CCSM 4 by how well it reproduces the 20th century climate, then it will take considerably longer than previously. The reason is that a 1870 control and one or more 20th century runs will have to be completed in order to make a decision, instead of a single present day control run. There is also the tricky question of, if the model does not reproduce the 20th century observed temperature record when it has the indirect effect of aerosols for example, then is the model climate sensitivity too low, or is the volcanic effect too strong?

7) IPCC AR5 Runs

There were some problems with the strategy used for CCSM 3 IPCC AR4 runs, that were mostly caused by time pressures. The main one was to concentrate on radiatively balancing a 1990 control run, which then meant that the 1870 control was 0.5 W/m**2

out of balance. Another problem was the large 20 year oscillation in the North Atlantic meridional overturning circulation in the T85 control runs, and the 20 year interval chosen between starting points for the ensemble of 20th century runs.

We should obtain a 1870 control run with CCSM 4 that is in radiative balance at the top of the atmosphere. We should vary the interval in the 1870 control between initializing 20th century runs. We also need to decide how to initialize the short-term climate simulations for 1980. We could either obtain another control run for 1980, or we could use the 1980 conditions from these 20th century runs, and interpolate onto the higher atmospheric and land resolution.

8) Personnel Resources Required

Maintaining the present CCSM staffing levels is a serious, ongoing challenge that needs to be continually addressed. In my opinion, and that of the CAB, the CCSM software engineering group is presently understaffed. The CCSM is a very complicated code, and we wish to use it on a variety of supported computer platforms. Making sure the development version of the CCSM runs correctly and efficiently on a variety of computer platforms at NCAR, Oak Ridge NL and elsewhere, is a large, ongoing requirement. In addition, CCSM 4 will have changes and upgrades to the present physical components, and some new components: biogeochemistry in the atmosphere, land and ocean, the aerosol indirect effect in the atmosphere, and the land ice component. I note, for example, that the Land Model WG currently does not have a software engineer to support the CLM. This is beginning to significantly limit the scientific development of this component, in particular a coordinated biogeochemistry/dynamic biogeography version of the land component. The plan also calls for assembling these components more than once in order to develop the CCSM 4, and producing a different resolution version for the short-term climate simulations. Assembling the Stage II and III coupled models, making sure they run correctly and efficiently, and then actually getting the required runs finished is also a large software engineering task. In the longer term, there is also the large software engineering task of ensuring that the CCSM scales well enough that it can effectively use the proposed petascale computers of the future.

In my opinion, the present CCSM software engineering group is not large enough to ensure that the path to CCSM 4 will not be held up, possibly even temporarily derailed, by lack of software engineering support. There is presently great demand on the group's time, and I only see this increasing over the CCSM 4 development period to June 2009. I think the minimum required size of the CCSM software engineering group that would

almost guarantee that there isn't a software holdup for CCSM 4 is four more software engineers than at present. This would bring the CSEG staffing level back to what it was at the end of 2004, which is what has been recommended by the CAB over the last three years, and would give us a safety margin for the development of CCSM 4.

9) Computer Resources Required

The NCAR computer resources are divided roughly 50/50 between the Community (NCAR and the University users), and the CSL. The IBM Blueice machine is now the main computer of the CSL. The CSL computer capability and the CCSM CSL allocation will be increased again in December 2008 by a factor of 2.5. The NCAR mass storage system is also designed to grow to keep pace with Blueice and future expansion.

The National Center for Computational Sciences (NCCS) at the Oak Ridge National Laboratory features two major systems; a Cray X1E vector system with a speed of 18.5 teraflops (Tfs), and a Cray XT3 250 Tfs scalar system. The next expansion of the XT3 system would be to a 1 petaflop system in late 2008. The plan for the center is to continue to grow the archival storage system so that it can support the machines at that scale. There also are multiple 10 gigabit (Gb) links in and out of the NCCS to ESNet, Internet 2, National Lambda Rail, and TeraGrid. The center already has the infrastructure to support many more 10 Gb links and to add 40 Gb links as they become available.

It is difficult to estimate the computing cost of the CCSM 4 outlined above compared to the CCSM 3. The carbon cycle version will include the additional biogeochemistry, indirect aerosol and land ice components, and the short-term climate simulations will have considerably enhanced atmosphere and land resolution and include the chemistry component. I think that the carbon cycle CCSM 4 will be a factor of at least five times the CCSM 3 in computing cost. The NCAR and Oak Ridge plans outlined above show that the available computing resources for the CCSM will also increase by about the same factor by the end of 2008. Therefore, providing the CCSM will be in a position to take advantage of the new petascale computers, I think that computing resources will not be the limiting factor in producing the proposed CCSM 4. However, doing all the proposed IPCC AR 5 runs will stretch the CCSM computing resources to the absolute limit. In my opinion, the limiting factors in producing CCSM 4 are new parameterizations to reduce or eliminate the present biases, enough time to implement and evaluate them by the end of 2008, and software engineering support to include the additional components, get them working correctly and efficiently on a variety of computer platforms, and executing the necessary runs to evaluate the proposed Stage II and III versions of the CCSM 4.