CCSM

Community Climate System Model

CSL Accomplishments Report

01/01/2007 – 08/31/2007

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Introduction

The major accomplishment of the CCSM project over the first half of 2007 is that an interim version called CCSM 3.5 has been assembled. This uses the new finite volume dynamical core in the atmosphere component, the updated POP 2 code for the ocean component, the latest CICE 4 version for the sea ice component, and a much updated version of the land component compared to the CCSM 3. There have also been significant parameterization improvements in all the components. Probably the most significant improvement in CCSM 3.5 is in its simulation of the El Nino – Southern Oscillation (ENSO) in the tropical Pacific Ocean. All previous versions of the CCSM, and most other climate models, had a peak in the ENSO frequency near 2 years, which is much shorter than in reality. This problem has now been corrected in CCSM 3.5, which shows a frequency peak between 3-6 years. These improvements were documented and shown at the CCSM Workshop in June 2007. In addition, development work towards CCSM4 has been accomplished by all model components, and especially in the carbon/nitrogen cycle component and the chemistry component to be used with CCSM4.

Under the Production allocation, there have been significant integrations by the BGCWG with the carbon cycle model that was put into the low resolution version of the CCSM 3, with important results on the impact of the nitrogen cycle. The CVWG has completed an AMIP style set of integrations with the CAM 3, and, in collaboration with the CCWG, a large ensemble of IPCC scenario runs. This is to address the important question of how large an ensemble should be run of future scenario integrations for the next IPCC report.

Atmosphere Model Working Group (AMWG)

Development work continues on the atmosphere component to transition from the spectral to the finite volume dynamical core, and to assess the characteristics of a variety of modifications that have been incorporated into CAM in preparation for CAM4. Notable modifications include:

- A substantially revised convection scheme following the work of Neale et al. (2007), and Richter and Rasch (2007).
- Revisions to the aerosol formulation, and aerosol emissions, software methods used to connect the aerosol to the radiation and cloud microphysics schemes.
- Assessment of a new cloud microphysics parameterization (Morrison and Gettelman, 2007, Gettelman et al., 2007).
- A new PBL and shallow convection scheme (Bretherton and Park, 2007). More work on the PBL scheme is ongoing, and we expect significant additional changes to the PBL resulting from collaborations with G. Svensson, B. Holtslag, the LMWG, and the OMWG.
- Substantial changes to the software infrastructure to improve scalability of the model, and to ease interaction with the model.

Ocean Model Working Group (OMWG)

The major development activity of 2007, in preparation for CCSM3.5, has been the development and testing of the following ocean physics improvements in the ocean component of CCSM, both singularly and in combination, as well as in both uncoupled and coupled configurations:

- Enhanced vertical mixing over rough bottom topography
- Lax-Wendroff advection of active and passive tracers
- Resolved Tropical Instability Waves through reduced ocean viscosity.
- Mesoscale eddies in the mixed-layer
- Vertical variability of mesoscale eddy mixing
- Increase in the number of vertical ocean levels from 40 to 60
- Modified ocean topography to improve the Indonesian Through-Flow, the Equatorial ocean near the Galapagos islands, and the mode waters of the North Pacific.

These developments have improved the uncoupled ocean in several respects, including equatorial stratification, coastal upwelling, Indian Ocean temperature and salinity, and the representation of Tropical Instability Waves.

Another planned development has led to a demonstration that the HYCOM model can be used as the ocean component of CCSM, with successful short period integrations of the fully coupled CCSM with HYCOM being accomplished.

Under the production allocation, a global eddy resolved ocean integration, to study the impact of meso-scale eddies on ocean climate, in particular the distribution of deep tracers, is ongoing, with completion of a full annual cycle in 2007.

North Atlantic Ocean nudging experiments, where the path of the Gulf stream is forced to follow more closely the observed path were completed. The impact of the usual poor representation of the Gulf Stream in CCSM3 on fully coupled simulations was found to be relatively modest in the context of global climate.

A series of experiments were finished in support of a paper; "Ocean viscosity and climate." In particular, the CCSM3 control at T42x1 was rerun first without Smagorinsky mixing, then with the lowest possible ocean viscosity. The major improvements to the coupled solutions are reduced sea-ice in the Labrador and Bering Seas, and stronger tropical instability wave activity.

Coupled and uncoupled integrations with the Mediterranean Overflow, closed, open and parameterized, were run in support of a paper "On the effects of parameterized Mediterranean Overflow on North Atlantic ocean circulation and climate." The climate impact of the parameterized overflow is an interesting pattern of varying ocean-atmosphere coupling, as defined by the change in surface heat flux per degree of SST change. However, the signals are relatively weak, so the impact on the global climate is not overly significant.

Land Model Working Group (LMWG)

The LMWG has made use of CSL resources during the period January 2007 to August 2007 to address two main CLM model development projects. The first project is related to an apparent bias in CLM3.5 with respect to the variability of soil moisture in the upper soil levels. Although CLM3.5 resolved a major bias in soil water content over the annual cycle, surface interannual soil moisture variability appears weak when compared to available direct soil moisture observations. Numerous solutions have been proposed by members of the LMWG community. Many of these solutions, both in isolation and in combination, have been evaluated. These analyses will lead, hopefully, to a preferred solution to the variability bias. The second major development activity is the merging of CLM-CN with CLM-DGVM. The software engineering for this merge has been completed. The performance of the integrated model is promising, although some aspects, especially with respect to the timescales of response of dynamic vegetation under the coupled carbon – nitrogen cycle framework, need to be further investigated.

Additional CSL resources have been used to conduct pilot land-cover/land use experiments with CLM3.5, and utilizing a new land cover change dataset developed by Peter Lawrence at CIRES. An analysis of land-atmosphere coupling strength across various versions of CAM-CLM has also been conducted within the framework of the Global Land Atmosphere Coupling Experiment protocol. The results of this analysis will motivate future experiments aimed at an assessment of the role of land-atmosphere coupling on the influence of land cover change and on climate-change driven hydrological cycle change.

Polar Climate Working Group (PCWG)

Sea ice melt ponds are prevalent on Arctic sea ice during the spring and summer, and contribute substantially to the sea ice albedo feedback. Recent simulations performed under the CSL development allocation included a new sophisticated formulation for melt ponds on sea ice and a more realistic treatment of shortwave radiation in snow and sea ice. To assess the influence on the simulated ice-albedo feedback, integrations were carried out to test the sensitivity of these two new physics options in both current day climate conditions and a doubled CO2 climate. It was found that the sea ice simulation was sensitive to the parameterization of the melt ponds. The results of these simulations were presented at the 12th annual CCSM workshop in Breckenridge this summer, and will form the basis of a publication in preparation.

Rapid future summer Arctic ice loss is present in CCSM3 21st century integrations, and is related to pulse-like increases in ocean heat transport to the Arctic. The importance of these heat transport anomalies for ice retreat is being assessed using a number of integrations performed under the CCSM CSL production allocation. These simulate near-future (2020-2040) climate conditions and were initialized with slightly different ice and ocean states. These simulations provide insight into the predictability of rapid ice-loss events and the role of the ocean low-frequency variability in the timing and character of the near-future Arctic ice retreat. A manuscript is in preparation on these results for inclusion in an AGU monograph on future Arctic sea ice change.

Biogeochemistry Working Group (BGCWG)

The Biogeochemistry working group has accomplished several tasks in the past year. Most importantly, we have a CCSM3-carbon cycle simulation spunup at T31, and have finished several experiments with this model, including the impact of land use and the nitrogen cycle on climate change projections. These projections suggest that including the nitrogen cycle makes the climate feedbacks for including a carbon cycle change sign versus previous models which have a more crude carbon-only land carbon model. In addition, we include land use change in our simulations explicitly, which results in a much larger change in carbon from land use than previous projections. We have also conducted studies showing the sensitivity of the fires in the system to climate change and land use change, as well the impact of dust aerosols on climate under different climate regimes.

In addition, we have been both accessing the ability of existing state of the art carbon models to capture atmospheric biogeochemical variability, as well expanding our ability to incorporate nutrient fluxes into the model. Evaluation of carbon dioxide concentration and atmospheric potential oxygen fluctuations suggest that these models can capture the seasonal cycle, but have difficulty with the interannual variability (Nevison et al., 2007a, 2007b). Desert dust is important for ocean biogeochemistry because of its iron content, and we have examined our ability to capture dust's variability in the CCSM, as well as the feedback of dust direct radiative forcing onto climate (Mahowald et al., 2006a, 2006b, Yoshioka et al., 2007).

Chemistry Climate Working Group (ChemWG)

The CSL allocation was used to simulate the 1870s and 1990s using CCSM3.5 as a first step in tuning the atmospheric energy budget (P. Hess and F. Vitt). The simulations were run in two steps: first, using a prognostic aerosol package with prescribed oxidant fields; second using the output from the above simulations with a prescribed aerosol package and prognostic greenhouse gases. These simulations were facilitated by incorporating the aerosol packages from MOZART (Model of Ozone and Related Tracers) into CAM using information generated by the chemistry preprocessor and flexible chemical namelist variables. The chemistry-climate working group also supplied up-to-date oxidant fields for these simulations and biomass burning emissions.

The incorporation of aerosol packages from MOZART into CAM allowed a systematic examination of the aerosol radiative forcing in different configurations of the aerosol package (P. Hess and F. Vitt): 1) the use of online chemistry (versus offline chemistry), 2) the inclusion of ammonia aerosols under current and future conditions, 3) the sulfate oxidation scheme, 4) the inclusion of secondary organic aerosols. Globally averaged differences between these configurations were generally small (a maximum of .1 W/m^2 at the top of the atmosphere), compared with the approximately 1 W/m^2 change between 1990s and the 1870s. Regional differences in these configurations could be significant, however.

The CSL allocation was used to implement the Model for Emissions of GAses from Nature (MEGAN, developed at NCAR by A. Guenther) in the CLM and to expand the representation of secondary-organic aerosols (SOA) by including the yield from isoprene oxidation (C. Heald, Colorado State University). Present-day and future simulations were performed to study the role of climate change on the formation of SOA; a publication from this work is under review in JGR; "Predicted change in global secondary organic aerosol concentrations in response to future climate, emissions, and land-use change."

The CSL allocation was used to develop a version of CAM with chemistry in which stratospheric chemistry is explicitly resolved, including a representation of polar stratospheric clouds (J.-F. Lamarque). A set of simulations spanning 1970-2005 were performed to simulate the role of composition change on stratospheric ozone. A publication from this work is under review in JGR; "Simulated lower stratospheric trends between 1970 and 2005: 1 identifying the role of climate and composition changes."

Paleoclimate Working Group (PaleoWG)

Bette Otto-Bliesner and Esther Brady (NCAR/CGD) carried out sensitivity simulations with fresh water inputs to the North Atlantic. The last of a series of paleo simulations investigating the sensitivity of the coupled climate system to glacial freshwater input into the North Atlantic was completed. The results suggest that the response of the North Atlantic meridional overturning circulation is proportional, though not linearly, to the size of the freshwater added. On the other hand, the southward migration of the ITCZ over the tropical Atlantic displays a threshold response to the amount of freshwater forcing. This has implications for detecting small freshwater events using the Cariaco Basin records.

Cecilia Bitz (U. Washington) carried out a CCSM3 simulation for the time period of 14,000 before present (14k). The simulation for the 14k period is exhibiting many interesting results. In particular, the thermohaline circulation is weaker than at LGM by about 50% (or about half of the strength at present), and thus the northern North Atlantic and Greenland surface temperatures are actually colder than at LGM. This is intriguing because there are records that show times in the last glacial that were briefly colder than at LGM.

Christine Shields and Jeffrey Kiehl (NCAR/CGD) carried out a CCSM3 simulation of the Latest Permian time period where islands were removed from the Paleo-Tethys Sea. This sensitivity study was developed to study the response of the monsoon to changes in the position of the warm pool of water in the Paleo-Tethys Sea. The simulation indicates that the monsoon is strongly dependent on the Tethyian warm pool.

Climate Variability Working Group (CVWG)

Since January 2007, the CVWG has completed a 10-member ensemble of integrations with CAM3 at T85 resolution, forced with evolving "IPCC" atmospheric radiative forcings (greenhouse gases, tropospheric and stratospheric ozone, sulfate and volcanic aerosols, and solar output) and a fixed seasonally-varying climatology for SST and sea ice during the period 1950-2001. These runs complement the existing suite of AMIP integrations (with and without IPCC forcings) for the period 1950-2001, and are available to the community through the CVWG web page.

The CVWG is continuing to complete a set of IPCC scenario runs with CCSM3 at T42 resolution in conjunction with the Climate Change Working Group (CCWG), a project begun in 2005. The purpose of these experiments is to provide a large ensemble (~ 30 members) of integrations driven by a fixed, standard "business-as-usual" climate change scenario during 2000-2061. Such a large ensemble will allow an assessment of uncertainties in climate projections resulting from intrinsic system variations, as well as the evolving properties of interannual variability. The ensemble members all begin from the same ocean/land/seaice conditions taken from the last year of the 1870-1999 historical runs, with different atmospheric initial conditions. Since January 2007, 18 ensemble members have been completed using the CVWG CSL production allocation.

Climate Change Working Group (CCWG)

Under the development allocation, the first three of the proposed hurricane runs have been finished. They are:

1. standard (30-55m/s max wind speed) 10 hurricanes per year run for 100 years
2. weak (20-40m/s max wind speed, 10 hurricanes/year)
3. active (1.5x number of standard hurricanes).

The difference between standard and weak hurricane runs is that the hurricane is about 30% weaker, but the number of hurricanes is the same. By putting each of these different hurricanes in the model, we do not see a significant increase in the Atlantic meridional heat transport. These runs will be analyzed by Aixue Hu and Jerry Meehl, with input from Greg Holland of MMM. The data will released to the community following the CCSM data management policy.

The CCWG Production allocation was used to carry out the large ensemble of runs in collaboration with the Climate Variability Working Group. The goal is to investigate the uncertainties in climate projections resulting from intrinsic variations of the climate system in order to assess the optimum number of ensembles to run in future climate change simulations. The process consists of carrying out an 1870 to year 2000 historical run, then the different ensemble members were branched off at three-day intervals surrounding January 1 2000 and run out to year 2060. Since March, 14 ensemble members (numbers 12 through 25) have been run, leaving only 5 more to complete. The lead PI's (Deser, Branstator and Meehl) have been receiving numerous requests for this data, and will have an open access policy for the data once the runs and the initial quality control checks have been completed.

Software Engineering Working Group (SEWG)

In 2007, the SEWG worked to create a robust and scalable CCSM3.5 model system. This new code base was accompanied by substantial improvements to all CCSM components, as well as an entirely new set of data forcing components. In addition, the CCSM3.5 scripts were upgraded to flexibly handle a much larger parameter space via the introduction of experimental use cases that are anticipated to be part of the next IPCC simulations. Hundreds of tests were carried out at numerous resolutions and model configurations as part of the creation of CCSM3.5. Furthermore, load-balancing experiments were frequently performed as the model system was developed, to ensure optimal performance and efficiency on the NCAR and other supercomputer platforms.

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CCSM gratefully acknowledges our primary sponsors,
the National Science Foundation and
the Department of Energy.