Report of the CCSM Polar Climate Working Group Meeting, 8 July 2004
Santa Fe, New Mexico

The Polar Climate Working Group met in the Eldorado Hotel in Santa Fe on Thursday, July 8, 2004. The meeting consisted primarily of prepared presentations, with a short discussion period at the end. During the group lunch at the Blue Corn Cafe, we thanked Dick Moritz for his 8 years of service as PCWG co-chair.

Presentations

Cecilia Bitz, University of Washington
The Coupled Ice-Ocean Response to Increasing CO_2 in CCSM3

The wintertime ice coverage has a profound effect on climate. The ice edge departs from a symmetric ring around either pole due to coastlines, ice motion, and the melt rate at the ice-ocean interface. The oceanic heat flux that melts sea ice depends primarily on absorbed solar radiation and the convergence of heat transported by ocean currents. The distance between the ice edge and the pole and the magnitude of the ocean heat flux convergence at the ice edge are inversely related. The chief exception to this rule is in the East Greenland Current, where the ocean heat flux convergence just east of the ice edge is relatively high but ice survives due to its swift southward motion and the protection of the cold southward flowing surface water. In regions where the ice edge extends relatively far equator-ward, absorbed solar radiation is the largest component of the ocean energy budget. When the model is subject to increased CO2 forcing up to twice pre-industrial levels, the ocean heat flux convergence weakens near the ice edge in most places. This weakening reduces the heat flux from the ocean to the base of the ice and tends to offset the effects of increased radiative forcing at the ice surface, so the ice edge retreats less than it would otherwise.

In most models, heat transport decreases at the southern margin of the Arctic ice pack with greenhouse warming owing to the reduction in the North Atlantic thermohaline circulation (THC) and the strength of the subpolar gyre. However, Holland and Bitz (2003) showed the heat transport actually increases poleward of about 60-70N in 6 out of 7 CMIP models. An analysis of CCSM3 reveals that the THC also increases poleward of the Scotland Ridge. The "ideal age" of ocean water from CCSM3 indicates that increased ventilation is occurring just off the Siberian Shelf in the Arctic Ocean. This ventilation may seem paradoxical because the Arctic Ocean surface is fresher, from increased precipitation and runoff. We speculate that brine rejection from higher sea ice growth in fall along the Siberian shelf drives this ventilation. Evidence from 14C indicates that the Arctic waters were ventilated more about 500 years ago during the advance in the Thule culture, which may have been driven by a warmer climate. These findings will be the subject of a future paper.

Alex Hall and Xin Qu, UCLA
Observed and simulated controls on planetary albedo variability

We assess controls on planetary albedo variability by examining the ISCCP D2 data set (1983-2000). This ISCCP data set contains surface and TOA radiation fluxes, generated based on observations at 3 different channels (visible, near IR, and IR) and a radiative transfer model. We found that the surface contribution to planetary albedo variability in ISCCP is significant everywhere except for

the ice-free oceans. It is dominant in the SH sea ice zone year around, and in the other cryosphere regions for most of the year. This indicates that if surface albedo were to decrease in a warming climate as a result of the retreat of the cryosphere, there would be a significant increase in net incoming solar radiation in high latitudes. Therefore our study supports the strong positive surface albedo feedback seen in nearly all climate change simulations.

To allow for as direct a comparison with the ISCCP data as possible, we used a simulated time series with approximately the same mix of internal variability and externally-forced climate change. A recent CCSM3 scenario run was used, with data taken from the same time period as ISCCP (1983-2000). The contribution of the surface to planetary albedo variability is significantly smaller in CCSM3. It turns out this is because CCSM3 has substantially less surface albedo variability than ISCCP in snow and ice regions. Understanding the reasons for this discrepancy may lead to ways to improve CCSM3's surface albedo parameterization, and in the process, improve its simulation of surface albedo feedback.

Bruce Briegleb, NCAR, and Bonnie Light, University of Washington
A new shortwave radiation parameterization for the CCSM sea ice model and its implications for meltwater and other physics

Despite recent improvements in the CCSM sea ice component, the snow/ice albedo parameterization and associated absorption/transmission through sea ice remains quite simple. Difficulties in simulating observed Arctic sea ice thickness and distribution, as well as high polar amplification during climate change, point to potential biases, calling for an improved shortwave radiation in the CCSM sea ice component.

The snow/ice albedo parameterization in CCSM3 is based on assignment of values depending on snow and ice thickness, surface temperature and spectral (visible, near-ir) band. A constant fraction of shortwave not reflected is absorbed at the surface, the rest being absorbed in the ice or transmitted and absorbed within the underlying ocean. These processes do not accurately represent shortwave interaction across a wide range of ice conditions. They are not consistently related to one another nor to any inherent optical properties of snow and ice, and only roughly to physical properties of the snow/ice system. The scheme cannot be easily generalized nor can a treatment of salinity and meltwater be done consistent with optical properties.

An improved treatment is presented based on a two-stream multiple scattering method dependent on inherent optical properties of snow/ice. Such a scheme would yield an equivalent comparison with surface albedo measurements, be more accurate and self-consistent, easily generalized, and would provide optical properties for specific meltwater conditions. Such an approach (or similar one) is suggested for future versions of the CCSM sea ice model.

Joel Finnis, University of Colorado
Representation of the Atmospheric Hydrologic Cycle over the Arctic in CCSM3

The annual cycles of precipitation, evaporation and net precipitation north of 60 degrees from CCSM3 closely resemble those seen in observations, although precipitation and evaporation appear somewhat high. When annual cycles of the variables over smaller regions are compared to observations we see good agreement over the North Atlantic and northern Eurasia, and excessive

model precipitation over the Mackenzie River Basin (MRB) during autumn and winter. Composite analysis reveals that atmospheric circulation patterns associated with variability of modeled net precipitation also agree well with observations over the North Atlantic and Eurasia, but not over the MRB during winter. Rather, MRB winter composites show patterns that closely resemble those seen during infrequent cold-season Gulf Redevelopment (GR) events. Although it can't be confirmed using the monthly averages examined in this study, it may be that the excessive MRB winter precipitation is due to overproduction of modeled GR-like events. This work inspires confidence that CCSM3 reasonably reproduces the atmospheric hydrologic cycle over the majority of the Arctic, with the noted exception of northwestern North America.

Eric DeWeaver, University of Wisconsin–Madison
Maintenance of Arctic and sub-Arctic atmospheric circulation in observations and CCSM3 simulations

This study presents a diagnostic analysis of the dynamical mechanisms which generate and maintain the low-level atmospheric circulation in high northern latitudes. Motivation for the research comes from studies like Bitz et al. (2002), in which model biases in surface circulation were found to have a profound effect on the simulated distribution of Arctic sea ice in AMIP simulations. Such biases have been significantly reduced in the most recent control run of the NCAR CCSM3, due in part to enhanced horizontal resolution. However, the underlying atmospheric dynamics which control Arctic SLP remain elusive, and the CCSM3 climatology still contains significant biases even at the higher resolution.

For the winter season (DJF), Arctic SLP is quite low in CCSM3 compared to ERA40, and the low bias is more extreme at T85 (high resolution) than at T42 (low resolution). The lowering of SLP at higher resolution is also found in AMIP integrations of CCM3 by C. M. Bitz.

A linear stationary wave model is used to diagnose the dynamics of the zonally asymmetric wintertime surface circulation in NCEP/NCAR reanalysis and CCSM3. In the reanalysis, the most important forcing mechanism for the Beaufort high in the 0.995 sigma eddy streamfunction field is stationary nonlinearity, or the mutual interaction of eddies generated by diabatic heating, transient forcing, and mountains. While this result is somewhat ambiguous, it provides evidence that the position and strength of the Beaufort high is not determined primarily by the preferred paths of traveling anticyclones. Further diagnosis of CCSM3 with the stationary wave model suggests that 1) the excessive strength of the anticyclonic surface circulation over the Rocky mountains is due to the strong westerly bias of the model's zonal-mean surface winds; and 2) large errors in CCSM3 tropical heating have an impact on the model's climatological Arctic circulation.

In summer, the T42 model integration shows a strong local maximum of zonal-mean SLP at the North Pole, a feature which is greatly reduced at T85 resolution. However, the reanalysis shows a local minimum in SLP at the pole, with a local maximum around 75N. The polar minimum is flanked by surface westerlies which are not simulated by CCSM3 at either resolution. Moreover, the surface westerlies are accompanied by all of the elements of a classical Ferrell cell: northward momentum flux, a thermally indirect mean meridional circulation, and an upper tropospheric westerly jet in the Arctic, distinct from the midlatitude westerly jet. None of these features appears in the model simulations.

Richard Grotjahn, University of California, Davis
Some Associations between Arctic Sea Level Pressure and Remote Phenomena Seen in Daily Data

The presentation by R. Grotjahn discussed possible links between the sea level pressure pattern over the Arctic and remote phenomena. The sea level pressure (SLP) CAM3 bias in NH winter is a series of quasi-concentric rings centered on a point near southern Novaya Zemlya. The pattern is similar in earlier model versions. The T42 and T85 SLP bias are similar in pattern and amplitude but the latter has a negative mean over most of the Arctic. The talk focused on three different markers that may relate the midlatitude cyclones activity to the Arctic SLP: tropospheric eddy heat fluxes, stratospheric momentum fluxes, and an upper tropospheric sector mean zonal wind index. None of the three markers had a notable link to the Arctic SLP. Some evidence was found linking Arctic SLP to tropospheric temperatures (T). The observed atmosphere may deviate from the climate mean in a way similar to the model bias when the wavenumber 2 component of the T field is lessened and possibly when the wavenumber 1 component (trough over Asia) is deepened.

Wieslaw Maslowski, Naval Postgraduate School
Arctic-Subarctic Fluxes from a Regional Ice-Ocean Model: 1979-2002

A regional ice-ocean model consisting of an older version of POP than used in CCSM and a sea ice model similar to CSIM and configured at 1/12-deg and 45-level grid was used to investigate fluxes of heat and fresh water in and out of the Arctic. Model results show that the Barents Sea Opening plays an important role in water mass transformation and property fluxes into the Arctic Ocean, comparable to those through Fram Strait. Lower resolution simulations (18 km) demonstrate that regional ocean currents and properties are not adequately represented in the Barents Sea compared to the higher resolution (9 km) simulations, especially the pathway of fresh Norwegian Coastal Current and its interactions with the warm and salty Nord Cape Current. The grid resolution also significantly affects eddy and total kinetic energy within the Labrador and Nordic Seas.

These simulations trace the circulation of main water masses through the Arctic basins (for example, the Barents Sea branch of Atlantic Water crossing the Lomonosov Ridge into the Canadian Basin) and allow to determine comparative strengths and variability of the various flow outlets. For instance, in the 9 km simulation, the contribution of fresh water flux through Fram Strait into the Irminger/Labrador Seas was significantly less than that through the Canadian Arctic Archipelago and Davis Strait, and the flux through Hudson Strait was greater than that rounding the southern tip of Greenland (Cape Farewell).

Model results demonstrate that high resolution not only improves the representation of bottom bathymetry and land geometry but also increases the realism of large scale circulation, energetics, and Arctic-subarctic exchanges. Those findings suggest that realistic modeling of variability of polar climate may require a special treatment in GCMs.

Bill Lipscomb, Los Alamos National Laboratory
Sea ice model development: CICE 4 and CSIM 6

New versions of the Los Alamos sea ice model, CICE 3.1, and the NCAR CCSM sea ice model, CSIM 5, were recently released. Development of CICE version 4 is now under way at Los Alamos. The major software change in the new model is the addition of a third horizontal index. This change

allows for cache-friendly grid decomposition and improved load balancing, as well as code portability to tripole and geodesic grids. A geodesic version of CICE is being assembled and tested as part of a new climate model based at Colorado State University. In addition, more realistic physics will be incorporated in the snow and ridging parameterizations. The code has already been rewritten with multiple snow layers, which will improve the vertical resolution of temperature. Later code versions may include snow metamorphosis and liquid water content. The improved ridging scheme should achieve two goals: elimination of unstable feedbacks between the ridging and dynamics, and improved agreement of the ice thickness distribution with observations. In collaboration with CSU and the UK Hadley Centre, work has begun to combine the implicit vertical temperature solvers in the ice and the lower atmosphere. The new version of CICE should be ready for public release sometime in 2005. Some or all of the CICE changes could be included in the next version of CSIM.

Discussion

Uma Bhatt invited everyone to attend the next AMS meeting in San Diego, January 9–13, 2005. The abstract deadline is August 2, 2004.

Marika Holland provided an overview of the Journal of Climate special issue and the CSL computing proposal (7 polar climate topics), and invited feedback from anyone who is interested.

The polar climate papers anticipated for the special issue are
1. Influence of the ITD on CCSM3 Simulations (Holland, et al.)
2. Resolution influence on the polar climate of CCSM3 (DeWeaver, et al.)
3. Influence of ice dynamics and qflux on climate sensitivity in SOM runs (Bitz, et al.)
4. Influence of sea ice albedo feedback on CCSM3 climate sensitivity (Bitz, et al.)
5. Polar atmosphere and ocean heat budgets in CCSM3 (Hall, et al.)
6. High latitude variability (joint with the Ocean Model Working Group, who is leading the paper)

CSL projects include
Development
1. A new shortwave radiation parameterization for the CCSM sea ice model
2. Snow model development work
3. Improved sea ice ridging scheme
4. General software/physics enhancements

Production
1. The role of polar regions in abrupt climate change
2. The influence of sea ice on climate sensitivity
3. The influence of Arctic freshwater budgets on global climate
4. Atmospheric circulation and sea ice connections
5. Polar?tropical climate connections
6. Representation of wintertime cloudiness in the Arctic
7. Penetration of Arctic air masses into middle latitudes.

There is an effort within CCSM to build a regional coupled model, but nothing is planned yet for the polar region.
Andrey Proshutinsky suggested that the PCWG needs to get more polar oceanographers involved in its activities.