**CCSM Polar Climate Working Group**
**Meeting Report**
**Tuesday, 16 June 2009**
**Breckenridge, Colorado**

The Polar Climate Working Group met during the CCSM Annual Workshop in Breckenridge, Colorado to hear updates on current model development and simulations using CCSM. Presentation topics included sea ice interactions with the atmosphere, clouds, ocean flow, penguins and algae, and the potential impact of methane release from the Arctic sea bed.

**David Bailey, NCAR**
*CCSM4 / CICE4 Update: When the Dust Settles*

David summarized the status of CICE 4.0 in CCSM including the new default shortwave radiative transfer scheme, melt ponds, and the deposition of aerosols (dust and black carbon) on the sea ice. He showed a few results from the 1850 control and 20th century integrations using CCSM version 4 in a 'Track I' two-degree atmosphere configuration. He discussed tuning of the albedos (snow grain radius) to improve the Arctic sea ice thickness. He also highlighted a possible area of improvement with the low sea ice concentrations in the Arctic. Overall, the results looked encouraging in both hemispheres in Track I; more work needed to be done for the one-degree and Track V configurations.

**Elizabeth Hunke, Los Alamos National Laboratory**
*Update on CICE Activities*

Elizabeth discussed improvements to the CICE sea ice model since the release of version 4.0 in August 2008. These include the addition of a 3D salinity variable, an algal ecosystem model, ice bergs, and multi-frequency history output. She provided a quick overview of her work with Cecilia Bitz using the ice age tracer in CICE 4.0 (detailed on a poster at the workshop), and then outlined current model development work. She is studying various approaches for ice-ocean dynamic coupling, ranging from alternative formulations for the surface stress to full "embedding" of the sea ice in the ocean. She and Cecilia began working on a prognostic salinity parameterization last winter; this work will continue with the help of a new postdoc at Los Alamos. A project modeling the Arctic sea ice ecosystem in collaboration with IARC scientists is underway. A LANL summer student will work on ice berg dynamics within the context of CICE, including berg-sea ice interactions. Community users continue to upgrade the model through new parameterizations and extensions of existing physics.

**Stephanie Jenouvrier, Woods Hole Oceanographic Institute**
*Linking Demographic Models and IPCC Climate Predictions: Are Emperor Penguins Marching to Extinction?*

In the face of climate change, there is a growing demand for accurate forecasts of its environmental, ecological and societal impacts. It is crucial to predict the impact of climate change on wildlife population viability for each IPCC scenario of greenhouse gas emissions. Especially as mankind faces a choice for the future socio-economic development of our planet, the consequences of these developments on animals and plants population and eventually biodiversity should play a role in this choice. Studies have reported important effects of recent climate change on Antarctic species, but there has been to our knowledge no attempt to explicitly link those results to forecasted population responses to climate change. Antarctic sea ice extent (SIE) is projected to shrink as concentrations of atmospheric greenhouse gases (GHGs) increase, and emperor penguins (*Aptenodytes forsteri*) are extremely sensitive to these changes because they use sea ice as a breeding, foraging and molting habitat. Stephanie projects emperor penguin population responses to future sea ice changes using a stochastic population model that combines a unique long-term demographic data set (1962–2005) from a colony in Terre Adelie, Antarctica, with projections of SIE from General Circulation Models (GCM) of Earth's climate included in the most recent Intergovernmental Panel on Climate Change (IPCC) assessment report. She shows that the increased frequency of warm events associated with projected decreases in SIE will reduce the population viability. The probability of quasi-extinction (a decline of 95% or more) is at least 36% by 2100. The median population size is projected to decline from approximately 6000 to 400 breeding pairs over this period. To avoid extinction, Emperor penguins will have to adapt, migrate or change the timing of their growth stages. However, given the future projected increases in GHGs and its effect on Antarctic climate, evolution or migration seem unlikely for such long lived species at the remote southern end of the Earth.

**Nicole Jeffery, Los Alamos National Laboratory**
*Some Impacts of Sea Ice Microstructure on Ice Algal Production*

Sea ice algae is of growing interest to sea ice and biogeochemistry modelers for several reasons: 1) concentrations of Arctic bottom (skeletal) algal chlorophyll and DMSP (the precursor to the cloud nucleating gas, DMS) are orders of magnitude larger than in oceanic blooms; 2) algal chlorophyll potentially modifies the optical and thermodynamic properties of sea ice; 3) ice algae provides an important niche in polar ecosystems; and 4) the ice edge phytoplankton community, the most productive zone in polar waters, are intimately connected to the ice algal and nutrient concentrations released during melt. We have developed two complimentary modeling approaches to quantify the impact of ice algae in sea ice and, eventually, in the climate system. The first approach, the skeletal layer model, is designed to reproduce the DMS seasonal spike in the Arctic ocean. Algal production is restricted to a single, 2-cm layer at the bottom of the sea ice, and bottom nutrient flux is proportional to a quadratic function of sea ice growth, fit from data. The second approach, a multi-layer ice algal model, is designed to reproduce algal concentrations in all polar seas under a wide range of physical conditions and sea ice evolutions. Vertical transport is dependent on a sea ice microstructure parametrization as well as growth/melt rate. Preliminary results indicate that the microstructure parametrization derived for brine-driven bottom nutrient flux is consistent with measurement.

**Ed Blanchard, University of Washington**
*Temporal Characteristics of Arctic Sea Ice in CCSM and Observations: Implications for Seasonal Predictability*

Ed analysed the temporal characteristics of Arctic sea ice extent and area in terms of its autocorrelation (a metric for memory) at the monthly/seasonal timescales both in observations and CCSM ensemble model runs. He finds that both observations and model generally match and show a red noise spectrum, in which significant memory is lost within a couple of months. However, the model shows a persistent September-to-September one-year memory that is absent in observations. Additionally, there is a variability in the one-month autocorrelation throughout the year, with low values in spring and autumn, and high values during summer. The difference between these low and high values is statistically significant for both model and observations. Therefore September sea ice extent, an often used metric to characterise the state of the Arctic sea ice system, is significantly correlated with the previous August and July (and thus these months show a predictive skill of summer minimum), and yet is uncorrelated with June and previous months—this again is common to the model and observations. The reason for the high summer autocorrelation in the sea ice may be a combination of the sea ice albedo feedback, which model runs show is significant only in mid-to-late summer, and a shift in the atmospheric forcing of the sea ice from the first EOF mode of sea level pressure early in summer, to more regional patterns later in the summer uncorrelated to large scale variability.

**Jen Kay, NCAR**
*Atmospheric Response to the 2007 Sea Ice Loss in CAM3.5 and CAM4*

Jen discussed the atmospheric response to sea ice loss using short-term CAM weather forecasts. Recent observations of a weak cloud response to summer ice loss, but cloud increases over newly open water during early fall (Kay and Gettelman, 2009) motivated the work. The CAM atmospheric response to sea ice loss is stronger in September than in July because there is little change (increase) in the net atmospheric energy absorbed during July (September). In CAM3.5, Jen found unrealistic July cloud increases over newly open water because stratus clouds are only diagnosed over open water. These unrealistic cloud increases decrease the net surface energy absorbed by $\sim 5$ Wm$^2$ ($\sim 9$ Wm$^2$ decrease in net surface shortwave). In a modified CAM3.5 and CAM4, the weak July cloud response to sea ice loss is more consistent with observations. September CAM3.5 increases in low cloud amount are also qualitatively consistent with observations. Jen's results illustrate the importance of evaluating the modeled atmospheric and cloud response to sea ice loss using observations.

**Steve Vavrus, University of Wisconsin, Madison**
*Future Cloud Changes in the Arctic: Whats Ice Got to Do With It?*

A fundamental uncertainty in polar climate change is the relative importance of processes within high latitudes compared with remote forcing from lower latitudes. Another key unknown is the impact of clouds in affecting future polar climate. Steve addressed these questions for the Arctic by conducting a set of enhanced greenhouse simulations with both the atmosphere-only version (CAM) of CCSM, as well as with the fully coupled version. The experiments consist of prescribed SSTs and sea ice extent, in which both of these boundary conditions in CAM are either fixed at their modern values or at the values produced from a fully coupled, $2xCO_2$ CCSM run. The Arctic cloud response produced in a simulation with future SSTs and sea ice globally was decomposed into its component regional influences by using (1) modern SSTs globally but future Arctic sea ice coverage and (2) future SSTs globally but modern Arctic sea ice coverage. The results suggest that projected future Arctic cloud increases commonly simulated by climate models, including CCSM, are attributable to two primary processes. Low cloud increases are caused by enhanced evaporation within the Arctic due to reduced sea ice cover, while cloud increases at higher levels are driven by increased meridional moisture transport from lower latitudes in a more humid global atmosphere. The enhanced low cloudiness from sea ice loss appears to constitute a positive feedback, resulting in large increases in cloud radiative forcing during the coldest months.

**Masha Tsukernik, NCAR**
*Atmospheric Influences on Fram Strait Sea Ice Export in Observations and CCSM*

In this project Masha investigates atmospheric forcing of sea ice export through Fram Strait in observations and CCSM3. Daily observational data reveal an east-west dipole pattern with Barents and Greenland centers of action. This pattern also corresponds to the second EOF of the sea level pressure of the Atlantic sector of the Northern hemisphere. The dipole pattern persists year around, being slightly stronger in winter than in summer. Spectral analysis reveals that this relationship peaks at the 10-60 day band. On monthly timescales the dipole pattern is “masked” by the dominant mode of variability, but the Barents center of action is still dominant. CCSM monthly results are very similar to observations for both sea ice motion and sea ice volume export. High resolution CCSM4 analysis is proposed to test for the seasonality and spectral peak of the atmosphere–sea ice relationship.

**Andreas Muenchow, University of Delaware**
*Scales of Variability in Time and Space of Flows and Fluxes from the Arctic to the North Atlantic Oceans to the West of Greenland*

Ocean flow and density fields from Nares Strait, a major passageway connecting the Arctic to the Atlantic Oceans to the west of Greenland were presented. These suggest that most of the spatial variability takes place at the internal Rossby radius of deformation, about 10 km. Volume flux estimates from both synoptic surveys and a 3-year mooring record provide consistent net southward values of about $0.8 \pm 0.3$ Sv and $0.72 \pm 0.11$ Sv (1 Sv = $10^6$ $m^3/s$), however, during the 2003-2006 observational period values at high as +2.5 Sv (southward) and small as -1.5 Sv (northward) occur at weekly time scales.

**Scott Elliott, Los Alamos National Laboratory**
*Marine Methane Cycle Simulations: Arctic Clathrates in the Global Warming Era*

The effects of methane release into Arctic seawater by the potential decomposition of climate-sensitive clathrates is simulated within the Parallel Ocean Program. First, the background distribution is validated against surface saturation ratios, vertical sections and slope plume studies. Hydrate injection sites are then specified around the Arctic Ocean shelf break by assigning methane fluxes consistent with porous flow through warming sediment, in single ocean bottom cells. An empirical removal function limits methane plumes, although accumulated effects disperse widely via the high latitude general circulation. Concentrations are sufficient to alter local acid-base and oxidant properties. Next, carbon, oxygen and nitrogen biochemical reactions are treated directly, including influence on the global ecosystem. Several types of nutrient restriction on methane consumption, including the oxidation states of nitrogen and trace metals, may allow dissolved methane to accumulate in the ocean. Consumer growth and population dynamics depend on methane kinetic limits and seeding from below, but both remain poorly understood. Geochemical plumes in the present work are relatively small because they represent only the first few decades of sea floor change, but regional marine and atmospheric perturbations ultimately cannot be excluded.

**Bill Lipscomb, Los Alamos National Laboratory**
*The New Land Ice Working Group*

As the Greenland and Antarctic ice sheets lose mass at an increasing rate, there is more urgency than ever to develop realistic ice sheet models that can be used to predict future sea-level rise. To support this task, a new CCSM Land Ice Working Group (LIWG) has been formed. The primary goals of the new working group are (1) to couple a well-validated, fully dynamical ice sheet model to CCSM and (2) to determine the likely range of sea-level rise associated with the loss of land ice. The first LIWG meeting is scheduled for June 17, 2009. The inaugural meeting of the SeaRISE assessment project, which aims to narrow the range of uncertainty associated with 21st century ice sheet retreat, will be held the following day.

Work continues on coupling an ice sheet model to CCSM. The Glimmer ice sheet model was recently ported to CCSM4, the version to be used for IPCC AR5 climate change experiments. A new surface mass balance scheme for ice sheets has been added to the land component, CLM. Next we will test the mass balance scheme and try to reproduce a realistic Greenland ice sheet in a control climate. We will then undertake a series of climate change experiments, including standard IPCC scenarios as well as paleoclimate simulations. Meanwhile, there is an ongoing effort to develop an improved Community Ice Sheet Model (CISM) based on Glimmer. The new model will be a parallel code with higher-order dynamics and more realistic physics.

### Poster Ads and Other Updates

Richard Grotjahn (UC Davis) gave an overview of his poster, "Northern Hemisphere Winter CAM3 Bias Analysis."

Marilyn Raphael (NCAR) is coordinating discussion and collaborations between modelers and observationalists studying Southern Hemisphere sea ice. She requested that anyone interested please contact her at raphael@ucar.edu.

Jonathan Bamber (U. Bristol) advertised the journal *Cryosphere*, which has traditionally contained articles about land ice and glaciology. The editors encourage more submissions about sea ice, ice-atmosphere and ice-ocean interactions. Time to publication is 12–16 weeks, and pre-refereed "discussion" versions are placed online immediately, along with referees' comments when they become available.