

**CCSM Polar Climate Working Group Meeting
REPORT**

19–20 February 2009

Santa Fe, New Mexico

Marika Holland (NCAR) and Elizabeth Hunke (LANL), Co-chairs

The Polar Climate Working Group met in Santa Fe, New Mexico, to hear about new climate modeling studies and progress in model development. Several people from Los Alamos National Laboratory participated, who otherwise would not have attended. The meeting was sponsored jointly by the National Center for Atmospheric Research, the Climate, Ocean and Sea Ice Modeling Project at Los Alamos, and the Los Alamos/University of California Institute of Geophysics and Planetary Physics.

Marika Holland began the meeting with an update on progress towards CCSM4. Some model developments in the atmosphere component are still in progress, necessitating the formulation of a fall-back model; CCSM expects to define this fall-back model in the next month. The ocean component now includes 60 vertical levels, an overflow parameterization, and Nares Strait is open. The sea ice component now features aerosol deposition and cycling, including transport horizontally and vertically, with melt water scavenging. Climate Process Teams (CPTs) for ocean model development (overflows, near-surface eddy fluxes) have been successful and could be used for some aspects of sea ice, ice sheet or land process development.

Land and ice sheets

Dave Lawrence, National Center for Atmospheric Research

The contribution of snow condition trends to future ground climate

Global climate models predict that terrestrial northern high-latitude snow conditions will change substantially over the 21st century. Results from a Community Climate System Model simulation of 20th and 21st (SRES A1B scenario) century climate show increased winter snowfall (+10%-40%), altered maximum snow depth (-56 cm), and a shortened snow-season (-147 days in spring, +209 days in autumn). By conducting a series of prescribed snow experiments with the Community Land Model, we isolate how trends in snowfall, snow depth, and snow-season length affect soil temperature trends. Increasing snowfall, by countering the snowpack-shallowing influence of warmer winters and shorter snow seasons, is effectively a soil warming agent, accounting for 10%-30% of total soil warming at 1m depth and 16% of the simulated 21st century decline in near-surface permafrost extent.

A shortening snow season enhances soil warming due to increased solar absorption whereas a shallowing snowpack mitigates soil warming due to weaker winter insulation from cold atmospheric air. Snow deepening has comparatively less impact due to saturation of snow insulative capacity at deeper snow depths. Snow depth and snow-season

length trends tend to be positively related, but their effects on soil temperature are opposing. Consequently, on the century timescale the net change in snow state can amplify or mitigate soil warming and over most of the domain it explains less than 25% of total soil temperature change. However, for the latter half of 20th century, snow state variations account for 50-100% of total soil temperature variations.

Joel Rowland, Los Alamos National Laboratory

Arctic river mobility in response to climate change and its implications for floodplain dynamics and hydrology

The ability of rivers to erode their banks and hence migrate across floodplains is controlled by a combination of factors including but not limited to: bank strength; magnitude, duration and frequency of flows; and the character and magnitude of the river sediment load. In arctic settings with permafrost, frozen materials may represent a significant if not dominant source of bank strength. Additionally, factors such as ice damming, bed-fast ice, and ice covered banks may influence the patterns and rates of bank erosion. Warming associated with global climate change has the potential to alter rates of bank erosion by: 1) increasing the rate of permafrost thawing along exposed river banks; 2) changing the timing and frequency of erosive flows; and 3) altering the sediment loads of rivers. The rate at which rivers migrate will influence the release and fate of carbon, nutrients and sediment presently stored in permafrost-dominated floodplains. Due to the presence of deep thaw zones (talik) beneath rivers, increased river migration may lead to a more rapid thawing of permafrost than is presently predicted by models of active layer dynamics alone. Preliminary analysis of migration rates of the Yukon River across the Yukon Flats region of Alaska from 1978 to 2008 shows average migration rates well below those observed for temperate rivers. Ongoing analysis is focused on extend the period of record of the analysis, using higher resolution imagery to better constrain erosion rates, and examining the spatial and temporal trends associated with river reaches exhibiting maximum erosion rates. Additional work is focused on integrating the thermal dynamics associated with rivers into a general hydrological model, including heat transport, for floodplain systems that explores the interactions of surface and groundwater systems.

Bill Lipscomb, Los Alamos National Laboratory

Miren Vizcaino, University of California, Berkeley

Ice sheets in CCSM4

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 and couple them to global climate models. I have coupled the GLIMMER ice sheet model to the Community Climate System Model (CCSM) and developed a new surface mass balance scheme in the land component, CLM. The ice sheet model exchanges fields with the land model via the coupler. The

ice surface mass balance is computed on the coarse (100 km) land grid in 10 elevation classes and downscaled to the finer (10 km) ice sheet grid. These changes are now being ported into CCSM4, which will be released in 2009 and used for IPCC climate change experiments. The next step is to 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. These experiments are described in the follow-up talk by Miren Vizcaino.

GLIMMER uses the relatively crude shallow-ice approximation. There is general agreement on the need for next-generation models with higher-order dynamics, improved subglacial hydrology and basal physics, finer grid resolution, and realistic treatments of subshelf melting, iceberg calving, and grounding line migration. No such model exists, although many of the required elements are being developed. Time is limited if we are to make a meaningful contribution to the next IPCC assessment report, AR5, which is scheduled for release in 2013. Responding to this need, a workshop entitled Building a next-generation community ice sheet model was held at Los Alamos National Laboratory in August 2008. The goal of the workshop was to create a detailed plan for developing a community ice sheet model, or CISM, suitable for sea level prediction. CISM will be the ice sheet component of the U.S. Community Climate System Model (CCSM) and will be openly available to the glaciology and climate communities for both standalone and coupled experiments. Workshop participants agreed on a software development strategy and identified physical processes that should be included in CISM in time for AR5. Focus groups have been formed to coordinate the development of software, datasets, and new parameterizations and to design strategies for sea-level assessment.

Ocean

Beth Wingate, Los Alamos National Laboratory

A new theoretical result for slow dynamics at high latitudes and its implications

The dynamics of the Arctic ocean can be characterized by a close proximity to the axis of rotation and weaker stratification than in other parts of the ocean. Beth Wingate's work showed that ocean dynamics in regions like this can be described by new reduced equations whose character is very different from quasi-geostrophy thought to hold over the globe. The theory, based on a slow/fast decomposition for the method of multiple scales, states that:

1. The horizontal dynamics reduces to the 2D Navier Stokes equations and has two conserved quantities, the horizontal kinetic energy and the horizontal vertical vorticity. This implies that the Arctic could have numerous barotropic vortices.

2. The flow is non hydrostatic in a special way. There is a component of the vertical velocity, but its dynamics is two-dimensional (vertically integrated) and forced by the

vertical integral of the buoyancy. There is a conservation law for these dynamics that is an area integral over the vertical kinetic energy and the buoyancy (potential energy).

3. A key part of this is that the ratio of the slow total energy to the total energy remains constant in the absence of dissipation but that the ratio of the slow potential enstrophy relative to the total potential enstrophy goes to 1. This implies that the potential enstrophy is the more important quantity to 'get right' and that there may be some important consequences for the turbulence cascade in the Arctic.

Some of these results are supported by the observations of Woodgate et al. (2001) who observed numerous barotropic (depth about 1000 meters) vortices in the Arctic.

Atmosphere

Steve Vavrus, University of Wisconsin, Madison

The role of arctic clouds during intervals of rapid sea ice loss

The Arctic climate system appears to be veering quickly toward a much warmer, less icy state. GCMs have long projected this kind of shift, though the simulated rate of change and the amount of polar amplification are model-dependent. Some climate models also produce periods of rapid future climate change superimposed on the long-term warming trend. These intervals coincide with abrupt reductions in sea ice and have been dubbed rapid ice loss events (RILEs). Previous work has identified the existence of RILEs in several GCMs and attributed them in part to pulse-like increases in meridional ocean heat transport and the positive surface albedo feedback.

Here we present new evidence that clouds may also play an important role in RILEs, based on ensemble simulations using NCARs Community Climate System Model (CCSM3). Consistent with most GCMs, the CCSM3 projects a gradual increase in future cloudiness over the Arctic, as greenhouse warming takes hold this century. Although the simulated cloud increase occurs in all seasons, it is greatest during autumn and winter (when polar clouds exert the strongest surface warming signal) and appears to be driven mainly by enhanced evaporation from the warming Arctic Ocean. During one simulated RILE in a transient greenhouse simulation, the cloud coverage in CCSM3 varies seasonally to optimize the surface warming and promote ice melt. In this event and typically during simulated RILEs, cloud anomalies become enhanced (muted) during autumn-winter (summer), such that both longwave and shortwave radiation at the surface increase. This favorable combination for ice loss results in a sustained interval of positive cloud radiative forcing (CRF) anomalies that hinder ice growth and promote ice melt. We suggest that increased surface evaporation associated with sea ice retreat may be important for initiating and/or maintaining RILEs, in addition to stochastic variations in atmospheric circulation that occasionally favor seasonally optimal combinations of anomalous cloud amount.

Gijs de Boer, University of Wisconsin, Madison
Arctic mixed-phase clouds: Observations and modeling challenges

Feedback mechanisms between clouds, atmospheric radiation and sea ice are yet to be fully characterized. This is in part due to the difficulties that numerical models have in simulating the often long-lived low- and mid-level stratiform mixed-phase clouds observed in the Arctic. The liquid portion of these clouds has significant impacts on long and shortwave radiative profiles, and recent studies have attempted to link their presence (or lack thereof) to rapid changes in sea ice extent. The longevity and thickness of the liquid layer has been shown to be strongly linked to ice nucleation within the cloud. In order to better understand the characteristics of these clouds and the mechanisms supporting their extended lifetimes, measurements from ground-based observational platforms at Eureka, Canada and Barrow, Alaska have been reviewed. Important findings from this dataset include the non-linear relationship between liquid water fraction and temperature in these clouds, the wide range of temperatures under which these clouds have been observed, the possible relationships between vertical motion and ice production within these layers and the seasonal and location dependant variations of both macro- and microphysical properties. In addition, this information has been combined with aerosol composition measurements to derive a theory that presents immersion freezing as a significant source of ice particle nucleation within these cloud layers. The goal of this work is to create a more thorough understanding of the mechanisms supporting the lifecycle of these clouds so that they can be more accurately simulated in models of all scales, eventually resulting in a better understanding of their impact on sea ice extent in future climate scenarios.

Ed Andreas, Northwest Research Associates
The SHEBA bulk turbulent flux algorithm

The SHEBA Atmospheric Surface Flux Group has been working for some time to create a bulk turbulent surface flux algorithm based on our year of flux data from SHEBA, the experiment to study the Surface Heat Budget of the Arctic Ocean. I am pleased to report that we have developed and are now releasing version 1.0 of that flux algorithm.

In our jargon, a bulk turbulent flux algorithm is a flux coupler. It predicts the turbulent surface fluxes of momentum and sensible and latent heat from readily measured or modeled mean meteorological quantities such as wind speed, air and surface temperature, and humidity. As a result, it can provide the lower flux boundary conditions for atmospheric models or the upper flux boundary conditions for sea ice or the ocean. Our algorithm treats three distinct sea ice environments: winter sea ice, which is compact and snow-covered and the snow is dry enough to blow and drift; summer sea ice, which is characterized by a high percentage of the surface being covered by open water in melt ponds and leads; and the marginal ice zone, which is the transition region between the compact central pack and the open ocean.

Unlike most flux couplers, which are a potpourri of parameterizations kludged together from various sources, our flux algorithm is a unified set of equations that have been developed from SHEBA and other polar data and tested as a coherent package with measured surface fluxes. Our algorithm includes new Monin-Obukhov similarity functions for the stratification corrections in stable stratification; implements parameterizations for windless transfer in both stable and unstable stratification; introduces new parameterizations for the surface stress over winter sea ice, over summer sea ice, and in the marginal ice zone; and verifies an earlier theoretical model for the scalar roughness lengths over sea ice.

In my presentation, I described these components of the SHEBA bulk flux algorithm and demonstrated how well it does in predicting the turbulent fluxes of momentum and sensible and latent heat over winter and summer sea ice. The algorithm is available as FORTRAN code that I am willing to share with interested scientists.

Jen Kay, National Center for Atmospheric Research
Forcing datasets for 2007 hindcast ocean-ice model integrations

Jen began by discussing typical forcing datasets used in ocean-ice hindcasts. Next, she highlighted previous work on simulation uncertainty associated with forcing datasets: 1) Curry et al. (2002) showed the forcing time resolution was critical for predicting the melt season evolution. Key events such as rain on snow events (best with at least daily forcing) or processes the diurnal cycles affect on freezing and melting of the Arctic surface (best with at least 6-hourly forcing and forcing that doesn't have strong temperature biases) were important to capture. 2) Hunke and Holland (2007) showed the effect of using two forcings on ice-ocean hindcasts: the original and modified AOMIP forcing. The modified AOMIP forcing had reduced wind forcing and colder summertime temperatures when compared to the original. As a result, the modified forcing hindcasts had thinner ice due to reduced ridging from winds. This thinner ice emerged in spite of reductions in the heat content due to colder temperatures. Next, the record 2007 melt season was discussed including the observed timing of ice loss, NCEP-NCAR wind strength, and flux observations from Barrow Alaska. During 2007, the largest ice extent loss happened from June to July. In fact, 2008 beat 2007 for all other monthly mean changes in extent. During 2007, southerly winds in the Chukchi/E. Siberian Sea were very strong from June through October, but were strongest from August through October. At Barrow, the radiometer-measured SW radiation anomaly was largest in June and July, consistent with satellite observations over the Beaufort and Western Arctic. Early ice loss and cloud reductions led to strong ice-albedo feedbacks during the 2007 melt season. Jen next discussed published hindcasts for 2007, and some limitations related to these experiments. One point raised was the large known biases in NCEP-based surface fluxes, temperatures, and winds. Another point raised was the inability of the atmospheric temperature to respond to the ice state in hindcast simulations. Thus, the forcing used for the surface air temperatures has a strong influence on the hindcast ice loss. A related issue is when the atmospheric temperature is fixed by the

forcing, surface turbulent fluxes can compensate for errors in the radiative fluxes, a point also discussed by Hunke and Holland (2007). Jen closed with a slide presenting 2007 hind-cast experiments that she is starting with Marika. These experiments will be motivated and informed by ideas in Jens presentation.

Sea ice

Ben Blazey, University of Colorado

Sea ice sensitivity to initial conditions, atmospheric forcing, and precipitation in CSIM

The sensitivity of Arctic Ocean sea ice to different atmospheric conditions, precipitation regimes, and initial ice conditions is examined. The Los Alamos sea ice model (CICE), the active ice component of the Community Climate System Model (CCSM) is used for multi-year integrations. Atmospheric conditions are found to quickly dominate initial conditions with regards to areal extent, but total volume is slower to react. Increases in precipitation are found to have nominal effect on ice extent and volume under most scenarios, but produces significant increases under a scenario comparable to current and forecast conditions in the Arctic.

Eric DeWeaver, University of Wisconsin, Madison

Reemergence of sea ice cover anomalies and the role of the sea ice-albedo feedback in CCSM simulations

The extent to which sea ice cover anomalies are determined by past sea ice conditions is of interest for assessments of the short-term predictability and long-term decline of Northern Hemisphere sea ice area (NH SIA). In an ensemble of 20th-century simulations from climate models, NH SIA anomalies show strong persistence, quantified as the lagged autocorrelation (LAC) of anomalies between in a base month and a later month, from roughly June through November. Following a period of decorrelation during the winter, LAC values increase in the summer of the following year to a maximum of 0.4 to 0.5, so that NH SIA anomalies formed in one year can “reemerge” in the next. A similar reemergence of SIA anomalies also occurs between consecutive winters. The summer-to-summer reemergence commonly found in climate models is not seen in the detrended NH SIA observations, although the observations show some winter reemergence. Further examination suggests that some of the extreme LAC behavior in models can be related to aspects of the mean SIA seasonal cycle.

To understand the underlying mechanisms of SIA persistence and reemergence, simulations are performed with a climate model in which the ocean component model is replaced by a “slab ocean” with fixed heat flux convergence. The removal of ocean processes eliminates winter reemergence but has little effect on summer reemergence, suggesting that the

memory for summer reemergence resides in the sea ice thickness and its slow response to atmospheric forcing. An additional simulation in which the sea ice-albedo feedback (SIAF) is disabled shows that SIAF causes SIA variance to increase by a factor of two, but the SIAF impact on persistence and reemergence is small by comparison. These results can be understood in part as a consequence of the response of turbulent heat fluxes to the enhanced ice cover anomalies caused by the SIAF: when SIAF causes large open water anomalies in the fall months, heat loss through turbulent fluxes removes much of the heat added by SIAF-enhanced insolation during the melt season.

Marika Holland, National Center for Atmospheric Research
Using CCSM3 to assess Arctic sea ice predictability

Marika discussed aspects of seasonal Arctic sea ice predictability in the context of a rapidly changing Arctic environment. This included an assessment of the role of preconditioning of the ice cover versus intrinsic atmospheric variations for determining the end of summer ice extent. From an analysis of the standard 20th-21st century CCSM3 integrations, it was determined that these relationships are influenced by the changing mean sea ice state. Additionally, results from a set of perfect initialization ensemble experiments were presented. These integrations were initialized with identical ice, ocean and terrestrial states and run for 2 years, allowing us to assess the inherent predictability in the sea ice system. These results suggest potential predictability in Arctic ice thickness and summer extent for up to two years.

Kyle Armour, University of Washington
A simple model for arctic sea ice: Variability and trends in the September minimum ice extent

We develop a simple, physically motivated model for Arctic sea ice in which the total ice area in September is separated into its first-year and multi-year ice components. The September minimum ice area is shown to be a function of the previous year's summer minimum area, the maximum area in winter, and the survivability of first-year and multi-year ice through the summer melt season. Using this simple model, in coordination with a simulation of 1978-2006 sea ice conditions using the Los Alamos sea ice model CICE, several aspects of Arctic sea ice are investigated. We propose that this separation of total ice area into its first-year and multi-year ice contributions provides a useful framework for understanding Arctic sea ice and for comparing model results to observations.

Oksana Guba, University of New Mexico
The Material-Point Method for sea ice dynamics modeling

The Material-Point Method (MPM) is a meshfree numerical scheme, which is applied

to problems in fluid and solid mechanics. MPM has been recently used for modeling sea ice. In this talk, we discuss the MPM ice model developed and implemented by Deborah Sulsky, Kara Peterson, and others. Also, we focus on some aspects of working with satellite data, which is used as an input and a criterion for verification.

Cecilia Bitz, University of Washington

Towards a prognostic salinity model in CICE for biogeochemistry in CCSM

Salt in sea ice is captured in liquid inclusions known as brine pockets. The brine volume adjusts so the brine salinity depresses the freezing point to the brine temperature, assuming the sea ice is in thermodynamic equilibrium. The same principle is exploited when salting icy roads. In a global climate model, we would like to model the brine volume and hence the salinity of sea ice for sea ice biogeochemistry, light scattering, and melt pond drainage. Salinity can be modeled by incorporating an equation for salt conservation in the thermodynamic scheme. The heat equation in the existing thermodynamic scheme must also be modified to capture the heat transported with brine motion and the heat exchanged from phase changes driven by salt transport. The primary mechanisms for salt transport are meltwater flushing, flooding at the ice-snow interface, and convection driven by gravitation instability. Convection is proving to be the most challenging to model at the scale necessary for climate modeling. We are investigating a method based on mixing-length theory and assuming the eddy velocity can be modeled from Darcy's law. Hence we treat convection as a diffusive process with a diffusivity that is a function of the sea ice Rayleigh number.

Biogeochemistry

Clara Deal, University of Alaska, Fairbanks

A brief introduction of the DOE EPSCoR project: Influence of sea ice on arctic marine sulfur biogeochemistry in CCSM

An EPSCoR-State/National Laboratory Partnership Grant was recently awarded to Clara Deal and Meibing Jin at the University of Alaska Fairbanks. The overall research objective is to improve the treatment of arctic marine sulfur biogeochemistry in CCSM. DOE laboratory partners include Scott Elliott, Elizabeth Hunke, Mathew Maltrud and Nicole Jeffery of the Los Alamos National Laboratory. The motivation for this project is that global climate models (GCMs) have not effectively considered how responses of arctic marine ecosystems to a warming climate will influence the global climate system. A key response of arctic marine ecosystems that may substantially influence energy exchange in the Arctic is a change in dimethyl sulfide (DMS) emissions, because DMS emissions influence cloud albedo. This potential feedback is closely tied to sea ice through its impacts on marine ecosystem carbon and sulfur cycling, and the ice-albedo feedback implicated

in accelerated arctic warming. This research first involves model development to improve the representation of marine sulfur biogeochemistry in the Arctic, where disproportionate warming is expected. The ice edge and marginal ice zone are of particular interest. Initial phases will be followed by global-scale simulations to understand and diagnose the control of sea-ice-related processes on the variability of DMS dynamics. This study will help build GCM predictions that quantify the relative current and possible future influences of arctic marine ecosystems on the global climate system.

Scott Elliott, Los Alamos National Laboratory

Arctic validation of several algal biogeochemistry models run in stand-alone CICE

Specialist organisms inhabiting high latitude ocean waters and sea ice control regional major and minor element geochemical cycles, fluxes to and from the sea of direct/indirect greenhouse gases, plus the structure of both ice surfaces and stratus clouds. The Climate Ocean Sea Ice Model team at Los Alamos (COSIM) has formed collaborations with IARC biogeochemists and others in order to develop coding required in coupled POP/CICE for the representation of polar geochemical processing. The group strategy will be to set existing global ecodynamic models aside at the outset in order to focus attention on the rich layer of biological activity present in the bottom few centimeters of the pack the so-called skeletal layer. From this starting point, development will branch out to consider pathways in neighboring ecosystems including the congelation or interior ice mass, and mixed layer waters both below the ice and in the marginal ice zone. Ultimately the completed high latitude schemes will be rationalized with global biogeochemistry mechanisms then embedded in the Community Climate System Model so that local and global feedbacks can be assessed. Sulfur cycle and DMS to cloud albedo projects are cited as examples. Global POP simulations of the surface ocean distribution of volatile sulfur are coming of age in the tropics and subtropics, but toward the poles undershoot remains a problem and a likely major reason is omission of the ice algae. Detailed process studies now being conducted in and on the pack ice are cited as the source of information for defining a precise organosulfur reaction set in the skeletal layer. Early simulations of DMS in open waters of the ice domain match ship-based measurement data in several aspects including variability on the subgrid scale. The sulfur driven CLAW hypothesis feedback loop has recently been inserted into CCSM so that DMS feedbacks may be evaluated in a warming world, but ice algae and high latitude specialists such as *Phaeocystis* are still lacking. It is demonstrated that they will be critical if the effects on high latitude ice and cloud structures are to be predicted with fidelity. Finally, the arguments demonstrated for sulfur are extended to all the other well known elemental cycles including those of nutrients, carbon and the major/indirect greenhouse gases. Effects of perturbations to the carbon cycle upon ecosystem structure are explored, along with the potential for destabilization of the ice column through the generation of rich upper level pigment layers.

Nicole Jeffery, Los Alamos National Laboratory
Modeling ice algae using sea ice microstructure

The highest algal concentrations in oceanic polar regions occur in sea ice. This important source of primary production, formerly neglected in coupled climate system models, plays a multifaceted role in the high latitudes through ecosystem dynamics, cloud formation and, potentially, sea ice evolution. Arctic ice bottom or skeletal layer algal models have been developed which exploit the link between sea ice extent and thickness and algal growth. However, these models say nothing of internal ice or surface ice algal communities which can dominate production in the Southern Ocean or regionally under varying sea ice evolution histories. In this talk, I present preliminary results from a vertically resolved ice algal model which includes the effects of sea ice micro-structure and evolution history. The model distinguishes between processes which transport bulk quantities, such as congelation, melting and large scale sea ice dynamics, and the vertical transport of intrinsic (brine) concentrations, which depends upon sea ice porosity, permeability, and brine density. Simulations of the ice algal model embedded in CICE (the LANL sea ice model) are compared.

Meibing Jin, University of Alaska, Fairbanks
Development of a sea ice ecosystem model in the coupled POP-CICE model: Questions and plans

The new, standalone CICE-ecosystem model is working and being examined. The standalone POP-ecosystem model was been developed previously; some modifications to account for biogeochemical cycling via sea ice have been made. The coupled model is now running, producing very preliminary results and many questions.

Discussion

How do we transfer knowledge from non-CCSM research projects into CCSM?
Suggestions included expanding NCAR's visitor program (in particular, targeting visitor program funds to facilitate model development), having postdocs at NCAR with joint university advisors, and working directly with observational programs such as ARM. The Climate Process Teams included both observationalists and modelers, and were very successful in getting new parameterizations into the model (at least into the ocean component), but apparently they self-organized. The NCAR summer school that teaches graduate students how to experiment with the atmospheric model has been successful. Documentation for each of the component models could be improved, and we need new tools for comparing model output with observations. An EOS article was suggested as a way to publicize the resources that are available and to ask the community what it needs.

What diagnostics should be added?

There is a diagnostics package for the sea ice component on the web that needs to be made more visible. Observationalists might prefer other diagnostic variables than those available. Specifically for the sea ice model, participants suggested snow melt, more category-dependent information such as surface temperature, and history files written at various time resolutions (daily in addition to monthly, for some variables).

Is there any interest in modeling ice bergs for CCSM?

Elizabeth Hunke has developed a model for ice berg – sea ice dynamic interactions, and is looking for collaborators.