Report of the CCSM Polar Climate Working Group Meeting

Sixth Annual Community Climate System Model Workshop

Co-Chairs: Dick Moritz and Elizabeth Hunke

The Village at Breckenridge, 27 June 2001

The CCSM Polar Climate Working Group met on Wednesday, 27 June 2001, in Breckenridge, Colorado, as part of the Sixth Annual CCSM Workshop. Lists of attendees and acronyms are at the end of this report.

I. Studies of Sea Ice Using CCSM

A. Status of the current CCSM sea ice model (CSIM)

J. Schramm (NCAR) brought the working group up to date on changes to the sea ice model over the past year; the model components have not changed significantly, but the code has been cleaned up to remove redundant subroutines and converted to a standard F90 format. It has been tested on the gx3 and gx1v2 grids and verified for exact restarts.

There have been a few improvements to the physics, including

- wavelength-dependent penetrating radiation formulation
- albedo parameterization tuned to match SHEBA data
- thermo-only functionality using prescribed ice concentration data
- mixed layer can obtain deep-ocean forcing data directly

An outline of the User's Guide and CSIM Model Documentation are available at http://goldhill.cgd.ucar.edu/csm/models/ice-csim4.

Efforts to resolve remaining bugs and other problems, validate the model, and test its sensitivities are ongoing. The CSIM is archived along with the rest of the CCSM coupled model system, with scripts, using CVS.

B. CSIM thermodynamic model validation

J. Weatherly (CRREL) presented simulation results using the CSIM thermodynamic model, compared with data from the SHEBA field experiment. The model performs well when initialized for the "Pittsburgh" ice observation site at SHEBA, and then forced using SHEBA meteorological data, turbulent oceanic flux data, and snow observations.

Bottom ablation results at other SHEBA ice observation sites are not simulated as well as they are at the Pittsburgh site. The model results are better when the date of onset of snow melting is prescribed instead of simulated. Using the SIMIP2 precipitation data set, the modeled snow is too thin and begins melting too early, resulting in low ice volume.

II. Studies of the Polar Atmosphere Using CCSM

A. Atmosphere model biases

B. Briegleb (NCAR) highlighted some biases in atmospheric forcing fields output from the Community Atmosphere Model (CAM), including absorbed solar radiation (summer average: 20 W/m^2 low) and downward longwave radiation (too high in winter due to too much cloud). In a sensitivity study, he increased the downward solar radiation by a factor of 1.3 to compensate, resulting in less simulated ice thickness in summer. Currently the CAM uses temperature to partition cloud droplets between ice and liquid phases. Bruce suggests using separate equations for each phase to improve cloud simulations in the polar regions.

A. Rivers (UW) expanded on the CAM biases in the Arctic using Single Column Model (SCM) versions of CCM forced and verified with SHEBA data:

- poor annual simulation of clouds, particularly too much low cloud in winter
- longwave radiation too high
- downward shortwave radiation too low
- lower atmosphere temperatures too low
- these biases occur in both diagnostic and prognostic cloud water versions of the CCM

B. Alternative dynamical cores

C. Bitz (UW) showed results posted on her web site, derived from analyses by Bitz and Moritz of the Atmosphere Model Working Group (AMWG) simulations using different dynamical cores and convection schemes. All of the candidate models exhibit qualitatively similar bias in sea level pressure over the Arctic Ocean (Beaufort ridge/high displaced toward the pole; trough extending from Icelandic Low does not penetrate the Arctic Basin). The resulting surface geostrophic winds push the sea ice against the coast of eastern Siberia instead of against Greenland and the Canadian Archipelago (as the NCEP winds do). Of the models compared, the Lin-Rood finite-volume dynamical core had the smallest bias in Arctic SLP.

C. Related discussion notes

R. Moritz cautioned against blindly tuning climatological model output to match SHEBA data, since it is only a single year, not a climatology, and there was a large amount of melting and warm air advection in that year.

Working group members noted the importance of melting the Arctic snow cover completely in summer to obtain better simulations of ice melt and growth.

The CAM does not incorporate latent heat of fusion when water vapor changes phase, while the ice model does, resulting in a spurious source/sink of energy.

III. Coupled Model Simulations

M. Holland (NCAR) presented preliminary results from recent coupled simulations, just begun in early May. These simulations include the atmosphere (CAM), land (CLM), ocean (POP), and sea ice (CSIM4) model components. The ice volume increases steadily due to snow not melting fully in summer, related to radiative biases in the atmosphere model. Further experiments were run with a decreased cloud liquid water path (CCN number density was reduced over sea ice from 150 to 10), which removes the increasing ice volume trend in summer; however winter ice extents are still too large. Furthermore, Arctic ice is too thin and the CAM sea level pressure bias remains, resulting in an erroneous thickness pattern.

C. Bitz (UW) presented the results of fully coupled experiments using the Parallel Climate Transition Model (PCTM). Addition of ocean mixing parameterizations (KPP and GM (Visbeck version)) yielded warmer surface layers and greater northward heat transport in the North Atlantic. The ice edge in this area was greatly improved, and the ice in the Arctic was much thinner (unaffected in the Antarctic). Cecilia hypothesized that the ocean is compensating for the lack of ice surface ablation associated with atmosphere radiation problems and lack of snow melt.

IV. Development of Improved Physics of Polar Processes for CCSM

E. Hunke (LANL) presented a new EVP formulation that includes metric terms, which uses bilinear basis functions for a more accurate approximation to ice velocity and internal stress components. Simulations with constant ice strength showed the relative size and importance of the metric terms within the dynamics component. Varying ice strength includes feedbacks from thermodynamics, advection, and ridging; these simulations showed that the divergence may be significantly different in summer, when ice strength is low. Metric terms associated with the internal ice stress are relatively large but do not play as important a role, since the wind stress controls the ice motion in winter months, and in summer months the internal stresses are insignificant. Ice concentration differences between the new formulation and that currently in CSIM reach a few percentage points in summer; thickness differences at the end of a one year run can be as large as 10 cm or more. Elizabeth recommended that the PCWG adopt the new formulation for CSIM.

J. Hutchings (UAF) presented a split operator method that ensures pressure-velocity coupling is resolved in a segregated solution of the viscous-plastic sea ice model.

Essentially, the method is a pressure implicit correction scheme, and it incorporates a transport equation to ensure conservation of ice pressure. In comparisons between a stand alone sea ice model and satellite radar altimeter ice thickness estimates, the VP model overestimates ice thickness in the Beaufort Sea by 1 to 3 meters. Jennifer finds that up to 0.5 meter of this error might be attributed to unresolved pressure-velocity coupling in the line relaxation solution of the VP model (Zhang and Hibler, 1997).

W. Hibler (UAF) spoke on modeling high frequency variability and oriented features in Arctic Pack Ice. Under high ice pressure, higher frequency inertial oscillations are not possible. Bill asserted that the CSIM neglects the effects of ice convergence on pressure and recommended a different boundary formulation for coupling with the ocean model. He also recommends the teardrop shaped yield curve instead of the ellipse.

W. Lipscomb (LANL) presented a new algorithm for horizontal advection that uses a remapping scheme similar to that used for the ice thickness distribution in CSIM. He compared the scheme with MPDATA, currently used in CSIM, and found the remapping scheme to be second order accurate and positive definite (like MPDATA), more efficient for multiple tracers, and monotone (MPDATA is not monotone). The code needs more testing but he recommends that the PCWG consider it as an alternative to MPDATA in the CSIM.

V. A Potential Collaboration

Bob Grumbine (NCEP) gave an overview of the model setup he uses to provide "guidance" for ice forecasters. They are expecting to move to higher resolution models, particularly for simulating regional ice conditions (e.g., Great Lakes, Bering Sea). He is interested in evaluating the CSIM for use at NCEP.

VI. Future Plans

A. Metric terms for ice dynamics

B. Use saline ice for computing melt/growth for fresh water and salt fluxes between the ice and ocean models

C. The PCWG will consider CSIM code release prior to CCSM2 official release

When? How much? We agreed to continue this discussion after the meeting. Voiced concerns included:

- incomplete documentation
- incomplete test suite
- whether or not to release forcing data and full AIO framework (which includes the coupler)

- user support prior to official release
- limiting release to PCWG members (or those who ask for it)

D. Web sites

There are currently several CSIM-related web sites, which need to be consolidated into one site that includes diagnostic output from model runs and information about changes to the model (particularly physics). The CSIM site should also include links to other sites with pertinent data, such as ARM and POLES. Dick Moritz will pursue this with the CCSM Program Office (Lydia Harper), Julie Schramm, and Mark Stevens.

Members of the PCWG are asked to submit suggestions for sea ice and polar climate diagnostic variables and plot formats to be considered for inclusion in the new diagnostic web site.

VII. List of Attendees

First Name	Last Name	Email address
Michael	Alexander	maa@cdc.noaa.gov
Todd	Arbetter	todd.arbetter@colorado.edu
Cecilia	Bitz	bitz@apl.washington.edu
Bruce	Briegleb	bruceb@ucar.edu
Anthony	Craig	tcraig@ucar.edu
Gokhan	Danabasoglu	gokhan@ncar.ucar.edu
Peter	Gent	gent@ucar.edu
Robert	Grumbine	Robert.Grumbine@noaa.gov
Matthew	Hecht	hecht@ncar.ucar.edu
Bill	Hibler	billh@iarc.edu
Keith	Hines	Hines.91@osu.edu
Marika	Holland	mholland@ucar.edu
Elizabeth	Hunke	eclare@lanl.gov

Jennifer	Hutchings	jenny@iarc.uaf.edu
Robert	Jacob	Jacob@mcs.anl.gov
Philip	Jones	pwjones@lanl.gov
William	Large	wily@ncar.ucar.edu
William	Lipscomb	lipscomb@lanl.gov
JoAnn	Lysne	jlysne@lanl.gov
Mathew	Maltrud	maltrud@lanl.gov
Mark	Stevens	stevens@ucar.edu
Joe	Tribbia	Tribbia@ucar.edu
John	Walsh Jr.	walsh@atmos.uiuc.edu
Bernard	Zak	BDZak@sandia.gov
Xubin	Zeng	xubin@atmo.arizona.edu

VIII. List of Acronyms

AIO	Active Ice Only
ARM	Atmospheric Radiation Measurement program
CAM	Community Atmosphere Model
CCM	Community Climate Model
CCN	Cloud Condensation Nuclei
CCSM	Community Climate System Model
CLM	Community Land Model
CRREL	Cold Regions Research and Engineering Laboratory
CSIM	Community Sea Ice Model
CVS	Concurrent Version System

EVP	Elastic-Viscous-Plastic ice dynamics model
GM	Gent-McWilliams
LANL	Los Alamos National Laboratory
KPP	K Profile Parameterization
MPDATA	Multi-dimensional Postive Definite Advection Transport Algorithm
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
PCTM	Parallel Climate Transition Model
PCWG	Polar Climate Working Group
POLES	Polar Exchange at the Sea Surface (a component of NASA's EOS program)
POP	Parallel Ocean Program
SCM	Single Column Model
SHEBA	Surface Heat Exchange Budget for the Arctic
SLP	Sea Level Pressure
SIMIP2	Sea Ice Model Intercomparison Project 2
UAF	University of Alaska, Fairbanks
UW	University of Washington
VP	Viscous-Plastic