SGER: Coupling a Slab Ocean and Sea Ice Model to the Community Atmosphere Model

Project Participants

Senior Personnel

Name: Bitz, Cecilia
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Graduate Student

Undergraduate Student

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

National Center For Atmospheric Research
I worked closely with Jim Hack and Jim Rosinski at NCAR to develop the slab ocean version (SOM) capability of the NCAR Community Atmosphere Model (CAM). We shared many emails, phone calls, simulations, diagnostics, and results. Jim Hack and I are writing a paper about the model for the Journal of Climate special CCSM edition.

NCAR Scientific Computing Division
NCAR's SCD provided a computing allocation grant that allowed me to develop and test the model and experiment with it.

Other Collaborators or Contacts

Activities and Findings

Research and Education Activities:
This SGER supported my work to develop the sea ice portion of a slab ocean model (SOM) that is part of the Community Atmosphere Model (CAM). This functionality within CAM is necessary to estimate the equilibrium sensitivity of the climate, as simulated by CAM. This new capability has been crucial to the development of cloud physics in CAM because it provides the ability to quickly test cloud feedbacks. The SOM version of CAM is also widely used by university investigators on computers at their own institutions.
Sea ice in the SOM has the same sea ice thermodynamics that is in the fully coupled Community Climate System Model (CCSM), so this version of CAM provides an opportunity to investigate the equilibrium sensitivity of sea ice thermodynamics, as simulated by CCSM. I conducted 2 pairs of experiments with carbon dioxide either fixed at the 1990s level or a factor of two higher. In the first pair the sea ice was coupled as usual to the other components (interactive sea ice), and in the second pair the sea ice was prescribed to match the sea ice coverage in the simulation with 1990s CO2 (noninteractive sea ice).

These experiments yielded somewhat surprising results: the sea ice in CAM is responsible for 40% of the equilibrium temperature change due to doubling CO2. Meanwhile a parallel set of experiments (for another of my research projects) with the fully coupled CCSM attributed only 20% of the transient temperature change to sea ice. This tantalizing result suggests that sea ice alters heat uptake by the ocean, which is not represented in the SOM. This result needs further investigation for two reasons: (1) sea ice in CCSM has ice dynamics while ice in the SOM experiments is motionless and (2) fixing the sea ice interrupts global energy conservation in the model. Consequently I developed an improved CAM-SOM model -- one that includes sea ice dynamics by utilizing the CCSM flux coupler. I call this model CCSM-SOM. I then repeated my four experiments but this time I only fixed the sea ice albedo, which maintains energy conservation while still severely reducing sea ice feedbacks.

Findings:
My first experiments show that sea ice accounts for about 40% of the equilibrium temperature change due to doubling CO2 in CAM. These experiments evaluate the effects of all sea ice feedbacks together, including albedo feedback and the lesser-known feedback due to the insulating effect of sea ice (thinner sea ice conducts more heat to the surface, which then warms and contributes to thinning the ice). As discussed in the previous section, I repeated these experiments with a model that includes ice dynamics. However, this time I only evaluated the effect of ice albedo feedback alone and found it accounts for about 20% of the equilibrium temperature change. I believe that the difference, between 20 and 40%, is a measure of the ice insulating feedback, not the effect of including ice dynamics to the model. I will need to show this explicitly before I can publish the results, which will be possible when computing time is available later this summer. My parallel simulations with the full CCSM are currently underway. If ice albedo feedback accounts for far less of the temperature change in experiments with a full ocean GCM, I will have shown that sea ice influences ocean heat uptake.

This work feeds into my current project to study polar amplification that is also funded by NSF Atmospheric Dynamics. This SGER provided the model capability and the preliminary experiments for my continuing research. The work conducted with this SGER will be included in at least three papers in a special edition of the Journal of Climate on CCSM. This work is on course for the due date in November, 2004.

Training and Development:
Outreach Activities:
I am a member of two committee that are related to this project, and both conduct considerable public outreach. The committees are the CCSM Scientific Steering Committee and the US National committee to plan the International Polar Year in 2007.

Journal Publications

Books or Other One-time Publications

Web/Internet Site
URL(s):
http://www.ccsm.ucar.edu/models/atm-cam/index.html#documentation
Description:
The homepage for the Community Atmosphere Model (CAM3) provides a general introduction to the model, detailed documentation and users guides, and diagnostics of model output from a control simulation. The software I developed for this SGER is freely available from this website.

Other Specific Products

Contributions within Discipline:
This SGER supported my time to develop a model capability that yields an estimate of the equilibrium climate sensitivity. The new model capability enables researchers to run a climate model on computers that are common at most universities.

My own research with this model has shown that ice albedo feedback accounts for about 20% of the equilibrium climate sensitivity in the model, although sea ice itself only covers about 6% of the planet at any time. I have further found that all sea ice feedbacks together account for about 40% of the equilibrium climate sensitivity, yet ice albedo feedback is the only widely recognized sea ice feedback.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:
I have developed a version of CAM that enables researchers and teachers to conduct research that may lead to training and development. For example this new model version may allow university researchers to conduct experiments on their institution’s own computers. The model I have developed may be used in a university or summer school course as well. The model and full documentation can be downloaded from the internet.

Contributions Beyond Science and Engineering:
The equilibrium climate sensitivity, which is estimated with a slab ocean version of a climate model, can now be estimated. This result will certainly be given in the IPCC, 2007.
Categories for which nothing is reported:

Activities and Findings: Any Training and Development
Any Journal
Any Product
Contributions: To Any Other Disciplines
Contributions: To Any Human Resource Development