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Award ID: 0004261
Organization: U of Washington
Title: SGER: Modeling the Atmospheric Circulation Over the Arctic

**Project Participants**

**Senior Personnel**
- Name: Moritz, Richard
  - Worked for more than 160 Hours: Yes
  - Contribution to Project:

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

**Post-doc**

**Graduate Student**

**Undergraduate Student**

**Technician, Programmer**
- Name: Runciman, Kay
  - Worked for more than 160 Hours: Yes
  - Contribution to Project:
    Programmer, Mathematician

**Other Participant**

**Research Experience for Undergraduates**

**Organizational Partners**

**National Center For Atmospheric Research**

**Lawrence Livermore National Laboratory**
helping with a T170 simulation

**Other Collaborators or Contacts**

Byron Boville (co-PI, NCAR)
Jim Hack (NCAR)
Bruce Briegleb (NCAR)
Warren Washington (NCAR)
Phil Duffy (LLNL)
Jeffrey Yin (UW, JISAO)
Eric DeWeaver (U. Wisc. - Madison)
Activities and Findings

Research and Education Activities:
The objective of our project is to investigate features of the arctic atmospheric circulation that are poorly simulated by current General Circulation Models (GCM's), and that are crucial to the coupled global atmosphere-land-ice-ocean system. These features include the mean annual cycles and variability of arctic atmospheric circulation, with special emphasis on the position and amplitude of the mean Arctic Ocean surface anticyclone (cold season) and the mean Arctic Ocean surface cyclone (warm season). We hypothesize that these GCM biases are caused by (i) insufficient resolution of flow over orography, especially Greenland, (ii) insufficient horizontal resolution of surface heat and moisture supply to cyclogenesis and cyclone evolution in the storm tracks of high northern latitudes, (iii) poor simulation of arctic clouds and radiation budgets associated with model physics parameterizations, and (iv) oversimplifications in the prescribed surface boundary conditions over sea ice. We are investigating the effects of horizontal resolution on simulated arctic circulation, using the CAM (CCM). Community Atmosphere Model (formerly the CCM--NCAR Community Climate Model). We proposed to begin by analyzing the sea level pressure in a simulation at T170. If the arctic circulation is not satisfactory with dynamics, topography and surface heat exchange resolved at T170 (the highest horizontal resolution we are considering), then we would have direct evidence to contradict hypotheses (i)-(ii) above, without needing to run additional experiments at T85, or varying it.

We began our project by first analyzing a simulation at T170 that was done by Phil Duffy of Lawrence Livermore, in collaboration with Jim Hack who tuned the model to achieve top of atmosphere energy balance. Jim Hack also tuned the same model for T85 for our use.

While waiting for the tuning process to be completed, we diagnosed the Arctic climate and atmospheric circulation in the suite of new physics that were tested for the new atmosphere model. We also improved the sea ice formulation in the model for our simulations by implementing the thermodynamic routines from CCSM and allowing a fractional sea ice coverage within each gridcell. The atmosphere modeling group adopted our changes in CAM2 and it has remained in all subsequent versions of CAM. We provided our code and assisted in testing and evaluating the changes to CAM. We documented these new routines in the CAM technote and Bitz is now a contributing author. Phil Duffy also adopted the improved sea ice formulation in his T170 run.

We also modified the diagnostics computed at runtime and the output consistent with AMIP2 guidelines and to produce output needed for a linear stationary wave model. We subsequently ran 20 year simulation with the model at T42 and T85 to complete a set of integrations with standard resolution and double and quadruple standard resolution. We also ran a pair of sensitivity experiments at T85: the first had the orography smoothed to the standard model resolution and the second had the surface boundary
conditions over ocean (i.e., sea surface temperature and sea ice concentration) smoothed to the standard model resolution. A manuscript describing the results from the three model resolutions and the two sensitivity experiments is near completion.

Presentations:

Presentation to the CCSM Polar Climate Working Group January, 2003. ‘Effects of horizontal resolution of orography on arctic circulation’ C.M. Bitz, and R.E. Moritz


Presentation to the CCSM Atmosphere Working Group April, 2002. ‘The high latitude climate in CAM and CCSM using new sea ice model physics’ C.M. Bitz

Invited Presentation at American Meterological Society meeting May, 2001. ‘Sea ice response to wind forcing from general circulation models’ C.M. Bitz, J. Fyfe, G. Flato, R.E. Moritz

Poster, ARCSS OAII Meeting, November, 2001: ‘Towards Improving the Arctic Atmospheric Circulation Simulated by GCMs with High Resolution’, by C.M. Bitz, R.E. Moritz, J. Yin, and P.B. Duffy

Poster, European Geophysical Society Meeting, April, 2002: ‘Understanding controls on mid- and high-latitude atmospheric circulation using high-resolution GCMs’ by C.M. Bitz, R.E. Moritz, and J. Yin

Findings:
The major finding from our analysis of the suite of new physics that were tested for the new atmosphere model showed that the bias in sea level pressure during winter is cut in half in the simulation with the Lin-Rood dynamical core. We prepared a web site showing our analysis (See link under ‘diagnostics’ category at http://www.ccsm.ucar.edu/csm/working_groups/Atmosphere/). We shared our findings with the AMWG at the December 2000 meeting. In May 2001 the AMWG announced the configuration that they recommended to the CCSM scientific steering committee, and unfortunately it does not use the Lin-Rood dynamical core. For this reason we proceeded with the rest of our project using the spectral dynamical core version of the model. It is worth noting that the Lin-Rood dynamical version of the model has been subsequent tuned to eliminate a bias in the strength of the midlatitude westerlies to the detriment of the Arctic sea level pressure pattern. This relationship between the strength of the midlatitude westerlies and Arctic circulation is consistent with the results from our resolution experiments as well.

Our effort to improve the formulation of sea ice in the model yielded the most benefit from including a lead fraction, which warms the troposphere in winter. Because the influence is only noticeably below the inversion height, sea level pressure is only
at most a few millibars lower. In addition, with prognostic snow depth and an independent calculation of the surface temperature, the model exhibits more variability on all timescales from synoptic to interannual. These results are documented in a manuscript that is near completion.

We have found that horizontal resolution has a significant effect on the wintertime Arctic atmospheric circulation in simulations with the NCAR CCM3.6 using a spectral dynamical core with triangular truncation. Our analysis of simulations at T42, T85, and T170 indicates that the position and amplitude of the wintertime Beaufort high is improved in the higher resolution simulations. We can attribute a significant portion of the improvement to the resolution of orography. Storms enter the northern North Atlantic and Barents Sea more frequently in the higher resolution models, in better agreement with observations. Kinetic energy and meridional heat transport are higher in the storm tracks in the higher resolution runs. In addition, the relative magnitude of the Pacific and Atlantic storm tracks is more realistic, and there is evidence that more storms track across North America, where GCMs have typically failed to capture the observed path of storms. The influence of synoptic-scale eddies on the mean flow is both stronger and at smaller length scales at high resolution. The high resolution models also yield improvements in the summertime circulation, although the model still has an anticyclonic circulation over the Arctic Ocean where observations show a cyclone. The strength of the anticyclone decreases dramatically with resolution and the magnitude of the bias in vertical motion near the pole is greatly reduced. These results are documented in a manuscript that is near completion.

Training and Development:

Outreach Activities:
We have brought our results before the substantial community of scientists interested in CCSM and Arctic climate through presentations (Atmospheric Modeling Working Group meeting, February, 2001; Polar Climate Working Group meetings, January, 2003 and 2001; and CCSM Workshop, June, 2001), and through presenting our results on the web (http://www.atmos.washington.edu/~bitz/arctic/arctic.html).

Journal Publications


Contributions within Discipline:
Our results to date indicate that horizontal resolution is an important factor, perhaps the primary factor, that is limiting the accuracy of simulations of arctic SLP and surface winds using CCM. Our results were cited by the CCSM Climate Change Working Group as one of the principal reasons to use T85 resolution for upcoming IPCC simulations with CCSM.

The improved sea ice physics implemented with support from this project is now part of the released CCSM Atmosphere Model and it is documented in the CAM Science Guide (An NCAR technical note).

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Contributions to Resources for Research and Education:

Contributions Beyond Science and Engineering:

Categories for which nothing is reported:
Activities and Findings: Any Training and Development
Any Product
Contributions: To Any Other Disciplines
Contributions: To Any Human Resource Development
Contributions: To Any Resources for Research and Education
Contributions: To Any Beyond Science and Engineering