Climate sensitivity to the mean state of sea ice

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Project Summary

How sensitive are projections of greenhouse warming to the mean state of the sea ice? According to a study by Rind et al. (1997), *thickness* rather than the extent of sea ice in the Northern Hemisphere is the key parameter affecting the climate sensitivity controlled by sea ice. In contrast, they find that ice extent dominates in the Southern Hemisphere. Their study was conducted with the GISS climate model tuned to achieve a variety of different initial conditions. We propose to repeat and expand upon their analysis with an across-model study of the climate sensitivity relating the simulated sea ice in the CMIP2 models. We will intercompare the CO_2 induced increase in global temperature and its latitudinal dependence with the mean state of the sea ice under present day conditions. We will focus on sea ice behavior including the spatial distribution and hemispheric mean thickness and coverage.

Background

Summaries of the results of CMIP models in chapters 8 and 9 of the IPCC (2001) and our own analysis of CMIP2 models that are archived by the IPCC DDC indicate that present day sea ice extent explains little of their climate sensitivity. For example, the simulated sea ice extent in the present day climate of HadCM3 and CGCM2 are approximately the same and yet polar amplification and global warming due to increased CO_2 in CGCM2 is about double that of HadCM3. In addition sea ice is absent from the central Arctic during summer in CGCM2 by about the time of CO_2 doubling, while sea ice in HadCM3 is present at all times throughout the 21st century. The mean sea ice thickness in present-day simulations of CGCM2 (available from the CCCma web site) is about half of the thickness of our best estimates of observed ice thickness (Bourke and Garrett, 1987; Rothrock et al., 1999). The IPCC DDC archive does not include ice thickness, so we cannot yet say whether thicker ice occurs in the present-day simulations of HadCM3 and this results in a smaller sensitivity to climate change.

At the time when CO_2 concentration have doubled in CMIP2 climate change experiments, the location of the maximum warming relative to present day varies widely among models (Räisänen, 2001). However, the models can be stratified by those with a maximum warming somewhere in the central Arctic (e.g., CCCma, GFDL-R30, GISS, and MRI) or somewhere near the present day ice edge in the Greenland/Iceland/Norwegian Seas (e.g., HadCM2 and 3, NCAR-CSM and PCM, and LMD/IPSL). Among the five CMIP models

archived by the IPCC DDC, there is a stronger poleward amplification of the warming in the Northern Hemisphere as well as a greater global warming among those models that also have a maximum warming in the central Arctic. Information about the sea ice formulation in the models from the CMIP web site and sea ice extent summarized in the IPCC (2001) does not reveal any aspects of the model that can explain the separation into these two types of behavior. Instead we hypothesize that the mean sea ice thickness and its pattern in the present day climate in these models is at least partly responsible for this high-latitude climate sensitivity.

Proposed objectives and their relation to other CMIP subprojects

Our proposal is complementary to the two subprojects exploring high-latitude phenomena in the CMIP models. Both are devoted to identifying aspects of the models that influence the quality of the simulated sea ice and snow. Kattsov et al. are focusing on linkages between the models' sea ice and atmospheric forcing fields, while Greg Flato is examining particularly the features of the parameterizations that affect the cryosphere. Flato is also working on relating the simulated snow and ice to biases in the climate system. Recent presentation by both groups (Walsh in Finland and Flato in Sweden), summaries in the IPCC (2001), and at least one submitted paper (Walsh, personal communication) identify the wide range of atmospheric conditions (surface temperature, precipitation, clouds, sea level pressure, etc.) and sea ice conditions (extent) that are simulated by CMIP models. We will make use of these results to pursue our goal to understand specifically the relation among sea ice thickness, polar amplification, and climate sensitivity. We also aim to explain why the peak warming in about half of the models is at the present day ice edge while it is in the central Arctic in the other half.

References

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