The effect of sea ice, land snow, and cloud changes on the TOA radiation balance in coupled GCMs

Project investigators: Gorodetskaya I., M.-A. Cane, L.-B. Tremblay

Contact information:
Irina Gorodetskaya
Lamont-Doherty Earth Observatory of Columbia University
61 Route 9W
Palisades, NY 10964
Phone: (845) 365-8708
Fax: (845) 365-8736
email: irina@ldeo.columbia.edu

Project Summary

How will the TOA albedo respond to changes in the ice/snow cover given that they might be accompanied by changing cloud cover? In previous work (Gorodetskaya et al. 2004) we showed in an analysis of satellite data that while snow and ice concentrations are well correlated with TOA albedo, the TOA albedo change is only about 20% as the snow/ice concentration goes from zero to 100%. The presence of clouds over open oceans greatly reduces the response of the TOA albedo to sea ice changes. Over land, both clouds and vegetation reduce the effect of land snow on the TOA albedo. We propose to analyse the response of the TOA albedo to the sea ice, land snow, and cloud cover changes in coupled GCMs and compare them to the satellite data results.

Background

The ice/snow-albedo feedback is believed to contribute significantly to the amplification of projected warming at high latitudes (Rind et al. 1995; Groisman et al. 1994) and to be one of the principal mechanisms in paleoclimate models triggering glacial cycles (Gildor and Tziperman 2000). Sea ice, land snow and clouds have a similarly large impact on the TOA albedo due to their high reflectivity. Clouds can also compensate for the effect of the ice/snow cover variations on the TOA albedo. For example, retreating ice implies more open water and thus an increase in the air humidity, which could lead to an increase in cloud cover over the area thus reducing the effect of the ice retreat on the TOA albedo.

We have examined the radiative effectiveness of NH and SH sea ice concentrations from passive microwave data and NH land snow concentrations from digitized visible satellite images with respect to the TOA albedo produced by ERBE from November 1984 to February 1990 (Gorodetskaya et al. 2004). Correlation coefficients between ice/snow concentrations and TOA albedo calculated using 2.5^0 monthly gridded data are around 0.8, but the range of the TOA albedo change as sea-ice/land-snow concentrations vary from 0% to 100% is only about 0.2, which is significantly smaller than the expected range of the albedo changes in the absence of an atmosphere. The presence of clouds increases the TOA albedo over open oceans and land but has little effect over 100% ice/snow concentration. This greatly reduces the radiative effectiveness of sea-ice/land-snow cover with respect to the TOA albedo.

Proposed work

We plan to analyse the TOA albedo response to the sea ice, land snow and cloud changes in the CMIP2 models. First, we will compare the model results together and with satellite observations. Second, we will analyse the observed relationship between surface/atmosphere and TOA albedo in terms of the corresponding "mean climate" (cloud properties, sea ice and land snow cover, surface and air temperatures, position of storm tracks, moisture/heat advection, etc.) Also, we will study the coupled variance of sea ice concentrations and clouds. Finally, we will compare the results to the new satellite data available from the NASA's Earth Observing System program.

The CMIP2 model ouput of interest for us are monthly (CMIP2+) and daily data for both the present-day and increasing CO2 climate runs of the TOA and surface radiative fluxes (incoming and outgoing SW and LW radiation), surface conditions (sea ice concentrations, land snow concentrations, ice and ocean surface temperatures, etc), and atmospheric conditions (cloud properties, water vapor, air temperature, humidity profile, wind, vertical velocity, etc)

References

Gildor H. and E. Tziperman, 2000: Sea ice as the glacial cycles' climate switch: Role of seasonal and orbital forcing. Paleoceanography, 15, pp. 605-615.

Gorodetskaya I. V., M.-A. Cane, L.-B. Tremblay, A. Kaplan, 2004: Sensitivity of the planetary albedo to changes in sea ice and land snow concentrations: A satellite data study. Submitted J. Climate

Groisman P. Ya., T. R. Karl, and R. W. Knight, 1994: Observed impact of snow cover on the heat balane and the rise of continental spring temperatures. Science, 263, pp. 198-200.

Rind D., R. Healy, C. Parkinson, D. Martinson, 1995: The role of sea ice in 2 x CO2 climate model sensitivity. Part 1: The total influence of sea ice thickness and extent. J. Clim., 8, pp. 449-463