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Exploring the Southern Ocean Response to Climate Change: Final Report

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Purpose

The purpose of this project was to couple a regional (Southern Ocean) ocean/sea ice model to the existing GISS atmospheric GCM. This modification recognizes: 1) the relative isolation of the Southern Ocean, 2) the need to account, prognostically, for the significant air/sea/ice interaction through all involved components and 3) the advantage of translating the atmospheric lower boundary (typically the rapidly changing ocean surface) to a level that is consistent with the physical response times governing the system evolution; that is, to the base of the fast responding ocean surface layer. The deeper ocean beneath this layer varies on time scales several orders of magnitude slower than the atmosphere and surface ocean, and therefore the boundary between the upper and deep ocean represents a more reasonable fixed boundary condition.

The primary objective of the work was to realize this coupling. If the coupling proceeded smoothly so that time allowed, we would also utilize and test it by addressing three specific issues related to the climate impact questions discussed above:

1. Explore the feasibility of estimating the magnitude and location of deep water ventilation in the Southern Ocean through examination of the large scale (satellite resolved) spatial and temporal distributions of sea-surface temperature (SST), sea ice and parameters involving combinations of integrated property distributions. The latter include: the amount of in-situ ice growth at any location required to induce deep convection; water column stability; mixed layer thickness; potential ocean heat flux; and depth of the pycnocline. Estimating such parameters from the existing data base would provide a foundation against which we could gauge the magnitude of perturbations required in the large scale property distributions to alter significantly the stability at any particular location.

The feasibility of deducing convection from the large scale property distributions would be assessed predominantly through a series of sensitivity studies. These would test the sensitivity of the system (and model parameters) to anticipated perturbations consisting of random fluctuations as well as short and long term systematic variations. In this respect we hoped to gain necessary insights into the sensitivity of the vertical processes to the large scale fields.

2. Investigate the nature of the ocean/sea ice response to predicted change in the climatic forcing. Here we would focus on isolating the nature of the Southern Ocean change directly forced by a greenhouse induced climate warming. Again through sensitivity studies, we hoped to determine whether large scale (satellite resolvable) surface properties (e.g. SST or sea ice distribution) can provide predictive indicators of climate change. For example, if some aspect of the sea ice seasonality is very sensitive to climatic forcing, then we might expect to resolve changes in this parameter subject to a given magnitude of climate change which may be otherwise difficult to measure. Isolation of such a sensitive characteristic would thus provide an early indication of actual climate change.

3. Test the climate response to increased concentration of atmospheric greenhouse gases. The coupled model allows more accurate testing than heretofore possible, because of incorporating a significantly better treatment of the sea ice field. Also, the Southern Ocean represents a direct conduit to the global deep ocean reservoir which represents a

ice did not melt back - instead, the ice showed less than a 5% change in total ice mass produced each year. We are currently running this doubled CO_2 experiment now using the GCM with the coupled thermodynamic sea ice model, to see the influence of the thermodynamic-only feedbacks.

Finally, we have developed a variety of integrated ocean property distributions and parameters that are related to the stability of the water column. These have been derived, computed and plotted for the Atlantic sector of the Southern Ocean where we have the most thorough data set. They provide a reference against which we can gauge the destabilizing influence of climate perturbations generated during our experiments to examine the sensitivity of the air-sea-ice system to climate change.

Publications (in press and in preparation):

Martinson, D.G., in press. Ocean Heat and Sea Ice Thickness in the Southern Ocean, in Ice in the Climate System, W. Peltier, ed., NATO Volume.

Rind, D., R. Healy, C. Parkinson and D.G. Martinson, in preparation. The Role of Sea Ice in Simulated Climate Sensitivity, Part 1: The Influence of Sea Ice Thickness and Extent.

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Martinson, D.G., in preparation. Ocean-Sea Ice Interaction in the Antarctic, Part 1: Model

Martinson, D.G., in preparation. Physical Property Distributions Influencing Ocean-Sea Ice Interaction in the Weddell Region.