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A General Circulation Experiment with a Coupled Atmosphere, Ocean and Sea Ice Model

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ABSTRACT

This paper describes the construction and results of a comprehensive, three-dimensional general circulation model (GCM) of the earth's climate. The model, developed at the National Center for Atmospheric Research (NCAR), links separate existing models of the atmosphere, ocean and sea ice. The atmospheric model is a version of the third-generation NCAR GCM which has a relatively complete treatment of physical processes. It uses a generalized vertical coordinate with eight layers (~ 3 km thick) and 5° horizontal grid spacing over the entire globe. The ocean model, using the primitive equations and the hydrostatic and Boussinesq approximations, was changed to the world domain from an earlier model developed by Bryan (1969) and reprogrammed by Semtner (1974). The model has four unequally spaced vertical layers and 5° horizontal grid structure. The sea ice model is a simple thermodynamic model using a simplified calculation of heat flux through sea ice (Semtner, 1976).

The method of coupling the atmosphere and ocean models is an attempt to deal with the two different time scales of the atmosphere and ocean in a computationally efficient fashion. By means of four relatively short integrations, the atmospheric model provides samples (10–30 days in length) of four seasonal months—January, April, July and October. The data from the four atmospheric model months are fitted to annual and semiannual harmonics and are used to drive the ocean model for five years. The process is iterated for a number of cycles to achieve an approximate equilibrium.

The atmospheric circulation in the coupled model is similar to that obtained previously by Washington *et al.* (1979) with climatological ocean forcing. The simulated ocean surface temperature pattern is reasonably similar to the observed pattern, but the calculated ocean temperatures tend to be as much as 3°C too cold locally in the tropics and up to 4°C too warm in the midlatitudes. Possible reasons for these discrepancies are discussed. The major mean ocean current gyre systems are reproduced in the ocean model second layer where effects of non-geostrophic Ekman drift and short-term wind-stress averaging bias are not felt. These effects, however, tend to complicate somewhat the computed surface current pattern. The computed horizontal oceanic heat flux compares favorably with

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the observed of Oort and Vonder Haar (1976) in phase and amplitude. Vertical velocities at the bottom of the 50 m surface layer, which can be considered a simple mixed layer, have the same general pattern as those calculated using observed wind stress. The simulation of sea ice thickness and seasonal geographical extent is closer to the observed in the Arctic than in the Antarctic region.

The experiment described here must be regarded as preliminary; even though many first-order aspects of the climate system are simulated, improvements are still needed.