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Consistent with our objectives to extract as much as we could from existing models on the role of the oceans in the greenhouse effect and to improve various aspects of the coupled system, we made significant progress in three areas. (1) In a series of manuscripts, we documented how the El Niño-Southern Oscillation operates in the model and how it is enhanced with increased carbon dioxide. Although not all aspects are well simulated, most major features are as shown in comparison with observations. (2) In studies with collaborators Branstator, Karoly, and Karl, we explored the possible carbon dioxide "fingerprint" in zonal mean temperatures, the effects of changes in extratropical teleconnections, and the regional effects of low-frequency variability and climate change. The latter is of special interest to policymakers since a separation is necessary between natural and anthropogenic change and variability. (3) We experimented with an advanced version of the NCAR community Climate Model (CCM0) that also includes the Ramanathan and Collins cirrus albedo feedback mechanism. This model was run with a mixed layer and was tested with the 1° 20-level Semtner and Chervin ocean model. The latter includes the Arctic Ocean and dynamic sea ice, both showing realistic results. The model was configured in a multitasking mode and will be coupled to the CCM2 for a series of tests.

We completed the coupling of the advanced models. The dynamical ocean model was a 1°x1° version of the Semtner-Chervin ½°x ½° ocean model with 20 vertical levels. The 1°x1° version of the Semtner-Chervin model used in this research explicitly resolved some aspects of the mesoscale eddies as did the parent model. Research has shown that observed ocean features sufficient for climate experiments can be simulated at this resolution.

The sea-ice component made use of the Flato-Hibler dynamical sea-ice model with a new three-layer thermodynamical sea-ice component from Semtner. The coupling scheme was synchronous in that the atmospheric model provided wind stress, precipitation minus evaporation, and the sum of the surface energy balance to the ocean. The ocean provided surface temperatures and sea-ice distribution to the atmosphere. The coupled experiment was started from separate runs of the new models, each "forced" with the appropriate observed climate conditions, e.g., the observed sea-surface temperature for the spin up of the atmospheric model. This allowed separate diagnosis of any model problems before coupling.

We tested the effects of cirrus albedo changes as a function of deep tropical convection, as suggested by V. Ramanathan in the atmospheric model that now includes a mass flux convective scheme. Results show that the increased sensitivity of the model with the mass flux convective scheme was moderated by increased tropical cirrus albedos.

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The new coupled model system for greenhouse gas simulations on climate change was tested on multidecadal runs. We were capable of keeping the climate reasonably close to observed without the normal flux correction methods. The transient experiment was conducted by the same method as other modeling groups that took part in the Intergovernmental Panel on Climate Change (IPCC) 1995. It should be noted that the ocean model components made use of the documented Semtner-Chervin model at 1° and the sea ice used the Flato-Hibler dynamical method and the improved thermodynamics approach of Semtner. Coupling to the released NCAR CCM2 was ongoing. We studied changes in interannual variability in comparison to microwave sounding unit data, and compared the mixed-layer and coupled-model changes in variability.

Several publications have been completed covering the following subjects: greenhouse warming sensitivity to cirrus albedo effect, documentation and comparison of ocean models of 1° and 0.5° resolutions, monsoon variability changes with climate change, extratropical regional climate change, etc.

NCAR/DOE CO_2-Related Bibliography (By Year, 1979 to 1996)

The following summary of NCAR publications, resulting totally or in part from DOE funding, can be divided into several broad areas—(1) obtaining climatic response from coupled model experiments, (2) verifying model, (3) improving and documenting cloud-radiation treatment, (4) documenting model, and (5) developing methods for applying model experiment results to climate impact studies.

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