15.2 COUPLED OCEAN-ATMOSPHERE VS. PRESCRIBED-SST SIMULATIONS: EFFECT OF A "PERFECT OCEAN"

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1. INTRODUCTION

Results from several atmospheric general circulation models, run with sea surface temperature and sea ice amounts set to observed values, can be compared with "control run" simulations by the same atmosphere models coupled to ocean and sea ice models. The simulations with prescribed SST and sea ice are available from the Atmospheric Model Intercomparison Project (AMIP; see Gates et al. 1999), and coupled ocean-atmosphere simulations are available from the Coupled Model Intercomparison Project (CMIP; see Covey et al. 2001).

2. MODEL SIMULATIONS

The AMIP simulations have sea surface temperature and sea ice amounts prescribed to observed values for the period 1979-1994. CMIP control run simulations are run with external climate forcing (solar "constant", carbon dioxide concentration, etc.) held constant. Thus the CMIP simulations represent long term climate equilibria and—in contrast to the AMIP simulations—cannot be matched with specific calendar years and months.

In preliminary work, we have compared CMIP runs from both the NCAR Climate System Model (CSM) and the US Department of Energy – sponsored Parallel Climate Model (PCM) with an AMIP run of their common atmosphere model, the NCAR Community Climate Model Version 3 (CCM3).

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3. RESULTS

All three simulations have common weaknesses that presumably orginate in the atmosphere model. Replacement of the CCM3's "perfect ocean" with either the CSM's or PCM's ocean model degrades the level of agreement with observations for most fields, but errors in atmospheric variables from the coupled simulations are surprisingly similar to those from the simulation in which SST and sea ice are prescribed to observations.

3.1 *Root-mean-square Errors*

Examining RMS model errors in spatial and time variations, we find prominent among these (in AMIP and CMIP runs in general, in addition to the simulations examined for this study) errors in cloudiness, meridional and vertical wind velocities, and tropopause temperatures. The largest RMS errors occur in simulated tropopause temperatures, which are systematically colder than observed, especially in the Southern Hemisphere. The smallest errors occur in simulated near-surface temperatures and 500-hPa heights outside the tropics.

As expected, replacement of the CCM3's "perfect ocean" with either the CSM's or PCM's ocean and sea ice models degrades the level of agreement with observations for most fields. Nevertheless, for the annual mean and the seasonal climatology components of the 24 atmospheric fields examined, the increase in RMS error that results from switching from a "perfect ocean" to a coupled model is typically less than 30% in extratropical latitude bands. In the tropics, however, the RMS error increase is often several times greater.

The unexpectedly small error increases in the coupled models occur even for some aspects of interannual variations.

This occurs despite the fact that the coupled simulations represent long-term climate equilibrium without reference to particular calendar years and months. The coupled models are of course substantially (> 30%) more erroneous in their simulation of interannual variations of near-surface temperature, when compared with the CCM3 in which SST is prescribed to follow its observed month-to-month values. The coupled models also exhibit substantial error increases in the interannual components of many tropical fields, including tropopause temperatures and 500-hPa heights. On the other hand, coupled model errors for the interannual components of many fields increase by less than 30% over the errors in the CCM3. The interannual components of some fields, notably latent heat flux at the surface, are *less* erroneous in the coupled models. In this case, however, the observational uncertainty is so large that it would be premature to deem the coupled model simulation "better".

3.2 *Error Components*

We use a technique devised by Taylor (2001) to resolve RMS error into two components: one associated with space-time variance and another associated with space-time pattern correlations. (The ratio of simulated to observed variance, the pattern correlation between simulation and observation, and the pattern error component of RMS error are related by a simple equation, allowing all three quantities to be displayed in a two-dimensional graphic.) The seasonal cycle climatologies of many fields have more accurate pattern correlations in the prescribed-SST CCM3 simulation than in the coupled model simulations, particularly in the tropics.

For interannual variations, the space-time pattern correlation between the coupled model simulations and observations is necessarily zero. For latent heat flux at the surface, however, the CCM3's error in the magnitude of interannual variance is so great that the coupled models (particularly the CSM) exhibit a smaller interannual RMS error despite their having zero pattern correlation with observations. The significance of this result is questionable, because the RMS difference between alternate observational data sets (from ECMWF and NCEP reanalysis) is nearly as great as the RMS difference between observations and models.

4. CONCLUSIONS

Neither the CSM nor the PCM employs "flux adjustments" at the ocean-atmosphere interface, and the variables examined in this study are taken from the end of 300-year simulations by these models. Thus, for the error metrics used in this study, modern coupled ocean-atmosphere models without flux adjustments can provide simulations of comparable quality to those provided by atmosphere models driven by observed ocean and sea ice boundary conditions. Furthermore, the climatology simulated by the coupled models can be stable for several centuries. Our future work will examine other pairs of AMIP and CMIP simulations as they become available.

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References

Covey, C., and Coauthors, 2001: An overview of results from the Coupled Model Intercomparison Project (CMIP), *Global and Planetary Change*, submitted (http://www-pcmdi.llnl.gov/cmip/Overview_MS/ms_text.html).

Gates, W. L., and Coauthors, 1999: An overview of the results of the Atmospheric Model Intercomparison Project (AMIP I). *Bull. Amer. Meteor. Soc.*, **80**, 29-55.

Taylor, K. E., 2001: Summarizing in a single diagram multiple aspects of model performance. *J. Geophys. Res.*, in press (PCMDI Report No. 55: http://www-pcmdi.llnl.gov/pcmdi/pubs/ab55.html).