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OCEAN-ATMOSPHERE INTERACTION AND INTRASEASONAL OSCILLATIONS IN THE MODIFIED NCAR CAM2.0.1 COUPLED TO SLAB OCEAN OF VARYING DEPTHS

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1. INTRODUCTION

Sensitivity of tropical intraseasonal variability to oceanic mixed layer depth is examined in the modified National Center for Atmospheric Research Community Atmosphere Model 2.0.1 (NCAR CAM2.0.1) with relaxed Arakawa-Schubert convection (Moorthi and Suarez 1992), coupled to a slab ocean model (SOM), whose mixed layer depth is fixed and geographically uniform, but varies from one experiment to the next.

We are able to explain some interesting qualitative features of the MJO's amplitude dependence on mixed layer depth using GCM sensitivity studies and comparisons with a much simpler model. These results shed some light on the basic dynamics of the MJO in this GCM. The surface flux feedback (wind-induced surface heat exchange, or 'WISHE') turns out to be important in the GCM we use.

2. MODEL

The modified NCAR CAM2.0.1 with relaxed Arakawa-Schubert convection scheme is coupled to a simple slab ocean model that is formulated as follows:

$$\rho_o C_o h \frac{\partial T}{\partial t} = F + Q \qquad (1)$$

where T is the slab ocean temperature, ρ_o is the density of sea water (constant), C_o is the heat capacity of seawater (constant), h is the slab ocean depth, F is the net atmosphere to ocean heat flux, and Q is the oceanic mixed layer heat flux. Q is calculated as the oceanic heat flux satisfying the heat balance in (1) using climatological monthly surface heat fluxes derived from a control simulation forced by observed climatological SSTs. This framework is similar to that employed in Maloney and Kiehl (2002).

A 15-year CAM2.0.1 control simulation forced by observed climatological seasonal cycle SSTs was conducted. The climatological surface fluxes from this simulation were used to determine the oceanic Q-flux for 15-year SOM simulations with ocean depths of 50 meters, 20 meters, 10 meters, 5 meters, and 2 meters. An additional 15-year CAM2.0.1 simulation was conducted that used observed seasonal cycle SSTs in which latent heat fluxes are set to the climatological seasonal cycle from the control simulation ("No-WISHE" simulation).

3. RESULTS

Intraseasonal west Pacific precipitation variations during boreal winter are enhanced relative to a fixed-SST (infinite mixed layer depth) simulation for mixed layer depths of 5 to 50 meters (Figure 1 and 2), with a maximum at 20 meters, but are strongly diminished in the 2 meter depth simulation. This non-monotonicity of intraseasonal precipitation variance with respect to mixed layer depth was predicted by Sobel and Gildor using a highly idealized model. Figure 2 shows additional results with the model of Sobel and Gildor in a direct comparison to the GCM results. The simple model of Sobel and Gildor (2003) in this case is forced by

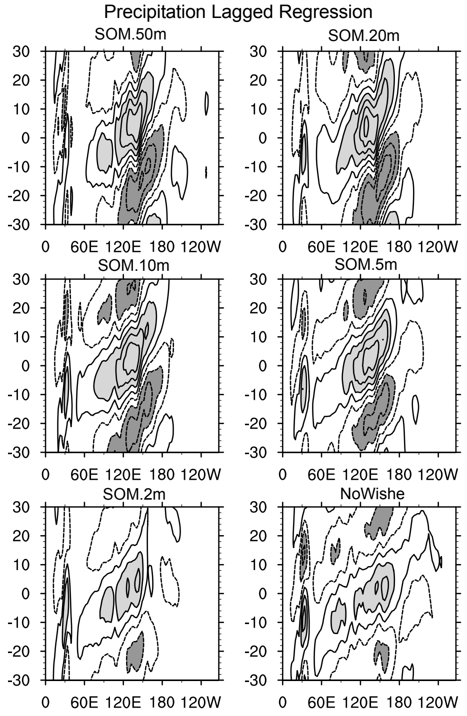

Fig 1. Lagged regression plot of equatorial 30-90 day precipitation during December-May. Fields are regressed onto the principal component timeseries of the leading equatorial 850 hPa extended EOF mode, and correspond to a 1s value of the reference timeseries. Precipitation contours are plotted every 0.4 mm day^{-1}, starting at 0.2 mm day^{-1}. Neg. values dashed.

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intraseasonal variations in surface wind speed.

SST variations are stronger in the 2 meter CAM2 than in any other simulation, similar to the behavior predicted by the simple model. However, these SST variations are phased in such a way as to diminish the amplitude of equatorial latent heat flux variations, a trend seen in Figure 3. This behavior is essentially reproduced by the simple model as well. Reducing the mixed layer depth is thus nearly equivalent to eliminating WISHE, which in this model reduces intraseasonal variability. The WISHE mechanism in the model is nonlinear, occurring in a region of mean low-level westerlies (not shown).

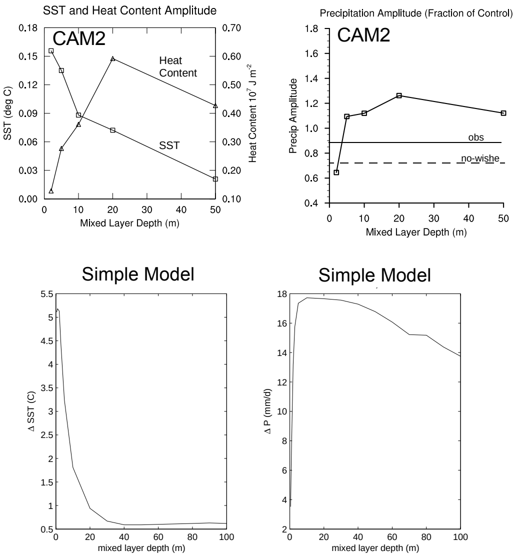

Fig 2.The magnitude of SST and precipitation variations as a function of mixed layer depth in the a,b) CAM2 and the c,d) simple model of Sobel and Gildor. The magnitude of oceanic heat content anomalies are also shown for the CAM2.

The behavior of subseasonal variability in the simple model can be explained as follows. At very small mixed layer depth (small thermal inertia), surface evaporation must balance the net "surface forcing" (net surface radiative energy flux plus ocean heat transport divergence), which varies only weakly for modest cloud-radiative feedback strength. Surface evaporation variations must thus become small. The moist static energy budget implies that precipitation variations are approximately proportional to evaporation variations in the simple model, so the precipitation variance must also go down. Since the mean state has sizeable precipitation, the variance reduction implies that the MJO cycle no longer has periods of zero precipitation; the convective adjustment scheme and “weak temperature gradient” approximation then together imply that the surface air humidity becomes approximately constant. With evaporation and surface air humidity nearly constant while surface wind speed varies substantially, the only possibility is for SST variability to increase. The SST fluctuations configure themselves so as to maintain nearly constant surface evaporation.

Since a very shallow mixed layer is effectively similar to wet land, it is suggested that the mechanism described here may explain the local minimum in MJO amplitude observed over the Maritime continent region

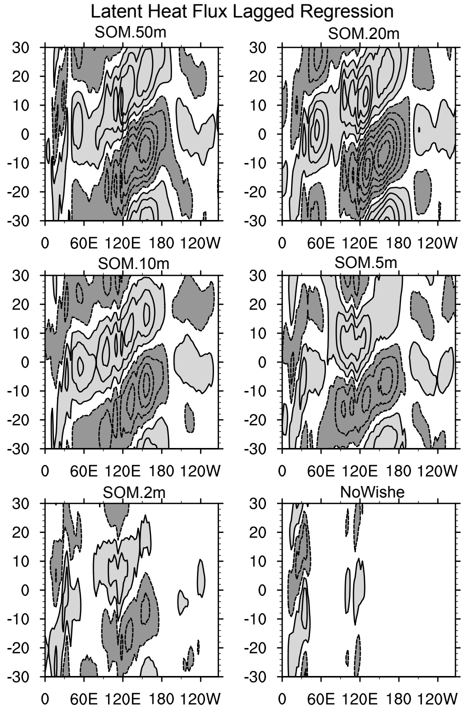

Fig 3. Same as Fig 1, except for surface latent heat flux. Contours are plotted every 2 W m^{-2}, starting at 1 W m^{-2}.

Further details of these experiments can be found in a paper submitted to *Journal of Climate* (Maloney and Sobel 2004).

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4. REFERENCES

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