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EASTERN PACIFIC INTRASEASONAL PRECIPITATION AND SST VARIATIONS IN A GCM COUPLED TO A SLAB OCEAN MODEL

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1. INTRODUCTION

Maloney and Kiehl (2002, hereafter MK02) found that the Madden-Julian oscillation (MJO) significantly modulates eastern Pacific intraseasonal sea surface temperatures (SSTs) during June-November. SST variations during an MJO lifecycle are on the order of 0.4-0.5 ^{o}C, as determined from Reynolds SST data. SST variations just to the south of Mexico and Central America (the eastern Pacific hurricane region) are 180^{o} out of phase with those on the equator. Off-equatorial SSTs lead enhanced convection by approximately 10 days. Surface latent heat and shortwave flux variations were found to largely explain the SST variations over the eastern Pacific hurricane region. Equatorial east Pacific SST anomalies are likely caused by ocean dynamics.

This study uses an atmospheric general circulation model (GCM) coupled to a slab ocean model (SOM) to determine 1) whether intraseasonal SST variations of magnitude close to observed can be simulated over the eastern Pacific hurricane region during a model intraseasonal oscillation lifecycle, and 2) whether these SST variations importantly modulate intraseasonal convection. Studies using GCMs coupled to oceanic mixed layer models have suggested the importance of SST variations to MJO convection over the equatorial Indian and western Pacific Oceans (e.g. Waliser et al. 1999).

2. MODEL

The GCM used here is a modified version of the NCAR Community Climate Model version 3.6 (CCM3, Kiehl et al. 1998). CCM3 simulations in this paper are conducted at T42 resolution with 18 vertical levels. The model is modified by replacing the standard CCM3 deep convection scheme of Zhang and McFarlane (1995) with the relaxed Arakawa-Schubert scheme of Moorthi and Suarez (1992). This replacement was done to improve tropical intraseasonal variability in the model.The equation that forms the basis for the CCM3 SOMl is:

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

where T_o is the ocean mixed layer temperature, ρ_o is the density of ocean water, C_o is the heat capacity of ocean water, h_o is the mixed layer depth, F is the net atmosphere to ocean heat flux, and Q is the oceanic mixed layer heat flux, which simulates deep water heat exchange and ocean transport. F includes latent heat, sensible heat, shortwave radiation, and longwave radiation fluxes.Mixed layer depths used in the model vary spatially and employ an annual mean mixed layer depth.

A 15-year control simulation of the CCM3 with fixed climatological SSTs was conducted. Fluxes from this run were used to compute Q in (1) for use in a simulation where the CCM3 is coupled to the SOM described above. The SOM run was initiated by a 20 year spin-up period to ensure that the model reaches a stabilized climate. The 15 years of the simulation immediately following the spin-up period are analyzed in this paper.

3. EAST PACIFIC DURING JUNE-NOVEMBER

Model June-November intraseasonal oscillation (ISO) events are composited in a similar manner to observed MJO events in MK02. Figure 1 shows composite intraseasonal precipitation anomalies for the control and SOM simulations during peak eastern Pacific ISO convective periods in both simulations. A composite ISO lifecycle in the SOM simulation exhibits stronger, more coherent, and more widespread eastern Pacific warm pool convective anomalies than in a control simulation using climatological SSTs. SOM simulation precipitation anomalies are close in magnitude to observed. SOM precipitation anomaly magnitudes are even stronger relative to the control simulation when examining suppressed convective periods (not shown). Competing convective forcings over land and ocean make eastern Pacific low-level circulation anomalies more complex in the SOM simulation than in the observed MJO, however (not shown).

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Off-equatorial eastern Pacific SST variations of more than 0.6^{o}C are associated with the June-November SOM simulation ISO. Figure 2 shows composite SSTs during the period of peak positive SST anomalies in the SOM simulation.These variations are similar to those observed with the MJO. No significant equatorial east Pacific SST anomalies occur in the model, supporting the contention that observed MJO SST anomalies on the equator are caused by ocean dynamics.

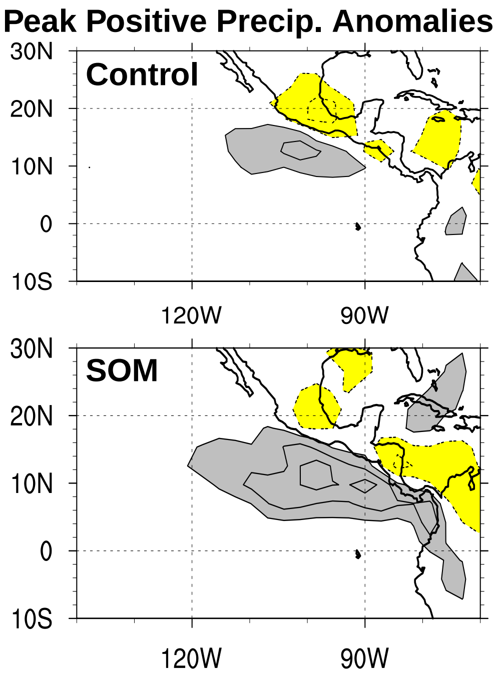

Figure 1. Composite ISO intraseasonal precipitation anomalies during the phase of maximum enhanced convective for the SOM and control simulations. Contour interval 1.2 mm day^{-1} starting at 0.6 mm day^{-1}. Values greater than 0.6 mm day^{-1} shaded dark. Negative contours dashed.

Positive off-equatorial SOM simulation SST anomalies lead convective anomalies by fewer days than in the observed MJO. Latent heat flux and shortwave flux anomalies are the dominant term in controlling east Pacific intraseasonal SST in the SOM simulation. Positive latent heat flux and shortwave radiation anomalies (positive defined as downward into the ocean) lead enhanced SST by about 10 days during significant ISO events in the SOM simulation. Minimum shortwave flux tends to lag maximum precipitation slightly, and precipitation anomalies explain only 20% of the variance in shortwave anomalies.

Model SST anomalies most likely modulate convection by directly altering low-level moist static energy, although anomalous SST gradients may also force low-level circulation anomalies that affect convection.

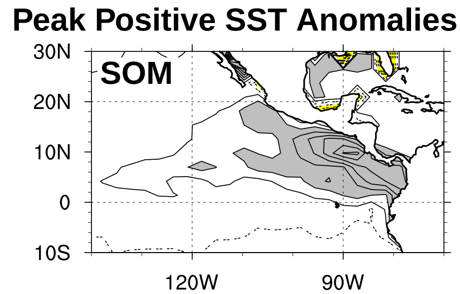

Figure 2. Composite intraseasonal SST anomalies during the phase of highest SST in the SOM simulation. Contours plotted every 0.06^{o}C, starting at 0.03. Values greater than 0.09 are shaded.

4. CONCLUSIONS

An atmospheric GCM coupled to a slab ocean model produces more realistic east Pacific intraseasonal convective variability during NH summer than a control simulation using fixed climatological SSTs. Off-equatorial SST variability is also reproduced realistically in the SOM simulation. A dynamical ocean model is needed to reproduce the equatorial SST signal in the observed MJO.

5. REFERENCES

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