14C.3 SENSITIVITY OF A COUPLED SINGLE COLUMN MODEL IN THE TROPICS TO TREATMENT OF THE INTERFACIAL PARAMATERIZATIONS

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## 1. INTRODUCTION

Interactions between the tropical atmosphere and ocean have now been established to be of fundamental importance to the evolution of the El Niño-Southern Oscillation, intraseasonal oscillations such as the Madden-Julian oscillation, and monsoons. Experiments using atmospheric general circulation models have shown that the atmospheric circulation is very sensitive to small changes in sea surface temperature (SST) in the tropical western Pacific Ocean warm pool region. At the same time, the SST and the ocean mixed layer structure in the warm pool are very sensitive to changes in the surface heat, momentum, and freshwater fluxes that are driven by the atmospheric circulation. The mutual sensitivity of the ocean and the atmosphere in the warm pool region places stringent requirements on models of the coupled ocean-atmosphere system, and coupled climate simulations commonly show significant drift in sea surface temperature if the surface fluxes are not forced towards climatology.

This study addresses the local thermodynamic interactions between the atmosphere and upper ocean in the warm pool. The interaction between the tropical atmosphere and the Pacific Ocean warm pool consists of intense but episodic exchanges of heat, momentum, and fresh water. We focus here specifically on short timescale atmosphere/ocean interactions. Given the apparent sensitivity of the tropical climate system to small variations in SST (and resultant variations in surface fluxes), much work has been devoted to understanding the mechanisms by which the interfacial (or skin) temperature differs from temperatures below. Several models of the bulk-skin temperature difference based on surface renewal have been formulated. In addition, a number of models for determining the surface turbulent flux exchange between the ocean and the atmosphere have been formulated. Recently Brunke et al. (2001) have evaluated the differences between these models and found that long-term differences in latent heat fluxes can be on the order of 20 W $m^{-2}$. It is still unclear as to what effects changes in surface fluxes over these ranges have on the coupled atmosphere-ocean system, especially over short time scales.

This study extends the previous research on short-term air/sea interactions during TOGA COARE by using observed and modeled data to evaluate the effects of interfacial parameterizations on the coupled system in the tropical Pacific. In order to address the thermodynamic coupling of the ocean-atmosphere system in the western Pacific, this study uses a coupled single-column atmosphere/ocean model to evaluate the variability of the model results dependent upon the use of various bulk and skin temperatures as the interface temperature and variations associated with differing flux models.

## 2. MODEL DESCRIPTION

The model used in this work consists of a coupled atmosphere/ocean single column model, as described in Clayson and Chen (2002). The ocean component of the coupled model consists of the one-dimensional ocean model described by Kantha and Clayson (1994) and Kantha and Clayson (2002). This model uses second moment turbulence closure and includes a skin surface temperature parameterization that has been modified to include the effects of precipitation. Parameterizations for Langmuir circulation and wave breaking effects have also been included. The ocean mixed layer model has been evaluated over many time scales and in many locations. The vertical resolution of the ocean model is 1 m; temporal resolution is 15 min. The data for initialization of this model is from the WHOI IMET buoy.

The atmospheric component of the model used for this study is the single column version of the NCAR Community Climate Model (CCM3; Kiehl et al. 1996) known as SCCM 1.2. The SCCM 1.2 contains physical paramaterizations that are identical to those used in the full scale CCM3. The SCM has 18 vertical levels, with a rigid lid at 2.917 mb, and uses a time step of 15 minutes. As described in Clayson and Chen (2002), we have modified the SCCM 1.2 by changing the paramaterizations of cloud amount and cloud optical properties, which are now calculated as a function of the cloud water path and the effective cloud droplet radius. The changes were shown to provide greatly improved simulations of cloud parameters during the TOGA COARE IOP. The SCCM is forced using data from the TOGA COARE Intensive Flux Array (IFA) region from the data analysis of Lin and Johnson (1996).

In the coupled model, the atmospheric model provides the near-surface horizontal wind speeds, air mixing ratio, air temperature, precipitation rate, and downwelling shortwave and longwave radiation to the ocean at each timestep. These values, combined with the sea surface (skin) temperature previously determined by the ocean model, are used as inputs to a turbulent flux model (described in Clayson et al. 1996). The modeled turbulent fluxes drive the evolution of the ocean mixed layer. In response to the surface fluxes, the ocean model determines a new profile of temperature, salinity, and horizontal velocity. The newly determined SST is used to provide the atmosphere model with an updated surface moisture and latent heat flux, sensible heat flux, and upwelling longwave radiation flux.

## 3. SURFACE FLUX SENSITIVITY

In order to evaluate the effects of the surface turbulent flux parameterizations on the coupled model, three flux parameterizations are used. The first is the baseline simulation with the turbulent flux model of Clayson et al. (1996). The second flux parameterization is that of Fairall et al. (1996), developed using TOGA COARE data (hereafter referred to as the COARE algorithm). The COARE algorithm (like the Clayson et al. algorithm) is based on surface renewal theory, but differs in some key elements in that it uses different specifications of the roughness-stress relationship (with no inclusion of roughness due to capillary waves) and roughnes lengths for heat and moisture, and a gustiness velocity to account for the additional flux induced by boundary-layer-scale variability. The third surface flux parameterization used for comparison is that provided with CCM3 (Kiehl et al. 1996). These three algorithms were shown to have systematic differences in the work of Brunke et al. (2001), and as such should give a good indication of the sensitivity of the coupled model to the surface turbulent flux algorithm. The skin temperature differences between the baseline simulation and the simulations using the COARE algorithm and the CCM3 algorithm are shown in Fig. 1. These differences between the model simulations can reach nearly 1 $^{o}$C on an hourly basis;

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daily-averaged sea surface temperature differences reached maximum values of 0.5 $^oC$. The largest daily-averaged SST differences are generally seen during the low-wind periods in November and early December, with slightly smaller differences in early January. These differences are correlated with changes in oceanic mixed layer depth; when the mixed layer depth is shallower in one simulation, the sea surface temperature is warmer. As will be discussed in the presentation, these differences are caused mainly by differences in the resulting cloud properties between the simulations.

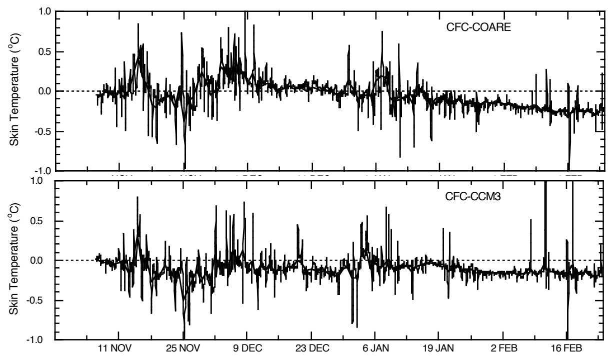


Fig 1. Skin temperature differences between baseline and COARE algorithm (top) and CCM3 algorithm (bottom). Bold line is daily average.

## 4. SURFACE TEMPERATURE SENSITIVITY

In this section we test the sensitivity of the results of the coupled model to the temperature that is used for determining the upwelling fluxes. In order to evaluate the effects on the coupled system of using the 4.5 m temperature as the "surface" temperature, a simulation which calculated all ocean temperatures (including skin) were calculated, but the temperature used for calculating the surface fluxes for coupling to the atmosphere was 4.5 m temperature. The original skin and 4.5 m temperatures are shown in Fig 2. The differences in the resulting skin temperatures can be seen in Fig. 3. Again, the major differences between the two simulations occur during low wind periods, and are due to changes in solar radiation (Fig. 4). The average humidity and temperature differences during two of these periods of low winds are shown in Fig 5. As will be shown in the presentation, the majority of the differences are due to the reduced diurnal variability.

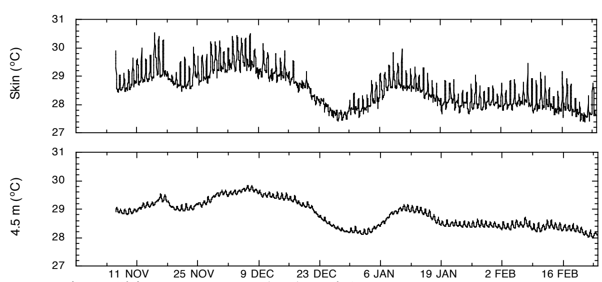


Fig 2. Skin temperature (top) and 4.5 m temperature.

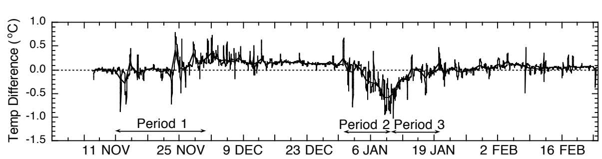


Fig 3. Skin temperature differences between baseline and 4.5 m temperature simulation. Bold line is daily average.

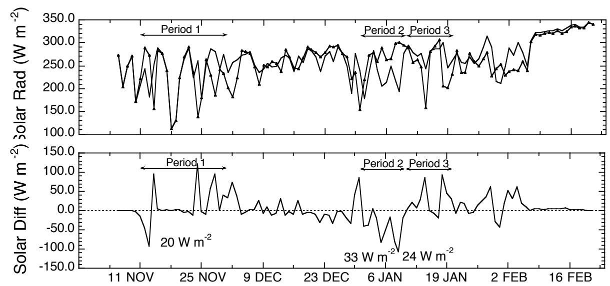


Fig 4. Solar radiation from skin simulation (solid line) and 4.5 m temperature simulation (solid line with triangles) (top) and difference between the two simulations.

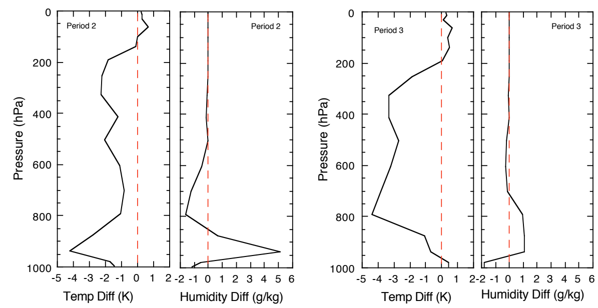


Fig 5. Differences between skin and 4.5 m simulations.

## 5. SUMMARY

The sensitivity of the model results to the turbulent flux model used in the coupled version is shown to produce daily-averaged sea surface temperature variations of over 0.5 °C. Of equal significance is the variation in model response to temperatures from different depths in the water column. Use of the typically cooler skin temperature as the interfacial temperature rather than the temperature at depth results in strong differences in the atmospheric profiles of heat, moisture, and cloud properties. These differences are not caused solely by the difference in temperature, but also due to the much-reduced diurnal variation in sea surface temperature at depth. The extent to which a daily-averaged sea surface temperature changes the resulting atmospheric profiles depends on whether the diurnal variability was strong; under low-wind conditions the differences are the most dramatic.

**Acknowledgments.** This work was supported by NSF Career program.

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