P1.54 Sensitivities of Cloud and Radiation to Changes in SST Over the Tropical Eastern Pacific: Results from Cloud-Resolving Simulations

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1. Introduction

Many different factors affect the conditions in the atmosphere and the overall climate in any given area on Earth. One such factor is the sea surface temperature (SST). Changes in SST can greatly influence the formation of cloud systems which can modulate climate change. Small-scale cloud-resolving numerical weather prediction (NWP) models can be a powerful tool for studying cloud formation and evolution, and their interaction and feedback processes with radiation. In this paper, the sensitivities of cloud cover and surface radiation to changes in sea surface temperature (SST) over the tropical eastern Pacific ocean were examined using cloud-resolving model simulations of a deep tropical convective system during the 1998 El Nino event.

2. Experimental Design

The model used in this study was the Advanced Regional Prediction System (ARPS, Xue et al., 2000a; Xue et al., 2000b; Wang et al., 2001), modified to include large-scale forcing data. The model was run in two dimensions with a horizontal domain (east-west) of 512 km and a vertical domain of 25 km. The horizontal grid spacing was 2 km, and the vertical grid space varied from 20 m at the surface to 980 m at the model top. The test area is located at latitude 5S-10S and longitude 150W-145W. The options for ice microphysics and atmospheric radiation transfer parameterization were both used in the model, so the most realistic picture of clouds and radiation could be studied. The large-scale forcing was the same for all test runs.

Three simulations were run for the 10-day period of March 17 through March 26, 1998. The first simulation was a control run (hereafter referred to as Control) using input data from the European Centre for Medium-range Weather Forecast (ECMWF) global analysis for the region. The other two simulations were run under the same initial inputs, but with varying SST conditions. These simulations used SST values of +2^{o}C and -2^{o}C from the initial SST value in the control simulation, and will hereafter be referred to as SST_{+2} and SST_{-2}, respectively. All three simulations started out at the same initial SST value of 29.62^{o}C. Over the course of two days simulation time, SST_{+2} and SST_{-2} were gradually changed to their final SST values of 31.62^{o}C and 27.62^{o}C, respectively.

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3. Preliminary Results and Discussion

3.1 Effect of SST on Cloud Cover and Precipitation

Figure 1 shows the time series of total cloud fraction for the three different SST runs. While the total cloud cover was high in all three simulations, this figure shows that cloud cover increases with decreasing SST values. Table 1 shows the domain and time averaged cloud cover differences between SST_{+2} and Control and between SST_{-2} and Control. The values in this table are averaged over the entire domain between day 3 (when the SST values reach on their equilibrium values in SST_{+2} and SST_{-2}) and the end of the simulation. The positive values for SST_{-2} minus Control again indicates that there were more cloud cover in SST_{-2} than in Control for all three cloud-levels: low-level, mid-level, and high-level clouds. The negative values in SST_{+2} minus Control show the opposite effect. The absolute domain and time averaged cloud fraction differences look quite small, with the highest averaged difference not exceeding +0.083 for the high-level cloud cover, but the relative change reaches 10%. The largest relative change increases by 18% for the low-level cloud cover in SST_{-2} case (see Table 1).

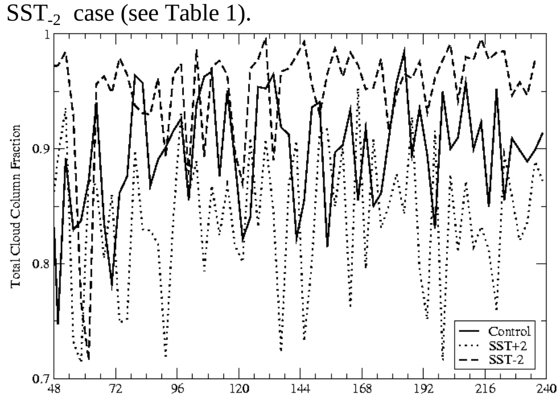

Figure 1: Time series of the total cloud fraction over 8-day period for Control, SST_{+2} and SST_{-2}

Table 1: Domain and time averaged differences between SST_{+2} minus Control and SST_{-2} minus Control for total, low-level, mid-level and high-level cloud fraction

	Cloud Difference			
	Total	Low	Mid	High
SST_{+2} minus Control (diff / Control, %)	-0.057 (-6%)	-0.031 (-12%)	-0.037 (-9%)	-0.080 (-10%)
SST_{-2} minus Control (diff / Control, %)	0.054 (6%)	0.045 (18%)	0.041 (10%)	0.083 (10%)

Although cloud fraction increased as SST decreased, the amount of total water in the air, including precipitation increased with increasing SST. Higher SST values can lead to higher air temperature values and larger moisture loading, which can force stronger convection. Therefore, the precipitation rate was highest for SST_{+2}, followed by Control, then SST_{-2}. Table 2 shows domain and time averaged air temperature at 10 m above sea level and the precipitation rate for each of the three simulations. These results for the averaged total cloud fraction, as well as the averaged precipitation rate, agree well with previous findings (Wu and Montcrieff, 1999).

Table 2: Domain and time averaged air temperature and precipitation rate for all three cases

	Air Temperature	Precipitation Rate
Run Name	**(^{o}C)**	**(mm/day)**
Control	25.60	22.91
SST_{+2}	26.69	23.77
SST_{-2}	24.50	22.22

3.2 Effect of SST on Surface Radiation

Varieties of cloud cover due to changes in SST values can modulate the amount of net radiation (both net shortwave radiation and net longwave radiation) at the surface. The domain and time averaged surface radiation fields for all three cases are summarized in Table 3. It shows that the net surface shortwave radiation increases with increasing SST. This is caused by the total cloud cover decreasing with SST, and hence allows more radiation reaching the surface.

Table 3: Domain and time averaged net shortwave, net longwave radiation and total net radiation at the surface

	Net Shortwave Radiation	Net Longwave Radiation	Total Net Radiation
Run Name	**(W/m^2)**	**(W/m^2)**	**(W/m^2)**
Control	219.06	-79.00	140.06
SST_{+2}	225.58 (3%)	-86.16 (-9%)	139.42(-0.5%)
SST_{-2}	208.99 (-5%)	-70.88 (10%)	138.11(-0.7%)

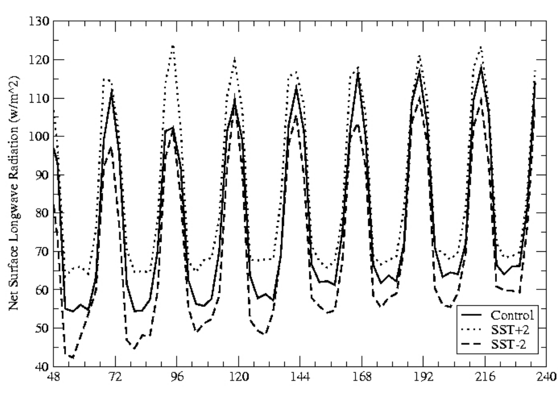

Figure 2: Time series of negative net surface longwave radiation over 8-day period for Control, SST_{+2} and SST_{-2}

The net surface longwave radiation was obtained by subtracting the net shortwave radiation from the total net radiation at the surface. From Figure 2, it can be seen that SST_{+2} gives off the most negative net longwave radiation, while SST_{-2} gives off the least; due to combined effects of increasing/decreasing SST with decreasing/increasing low cloud cover (see Table 1).

The total net radiation at the surface is the sum of the positive net shortwave radiation at the surface and the negative net longwave radiation at the surface. The total net radiation at the surface is almost the same for all three simulations due to compensating effect of shortwave and longwave radiation as seen in Table 3. This same result can also be obtained from Costa et al. (2001).

3.3 Effect of SST on Sensible and Latent Heat Flux

Both sensible and latent heat flux had their highest values for the SST_{+2} simulation, as seen in Figure 3. This positive correlation between heat fluxes and SST is to be expected. Since the surface was warmer in SST_{+2} and air temperature near the surface was also warmer but it increased at a smaller rate than SST (Table 2), these will lead to a larger sensible and latent heat flux value.

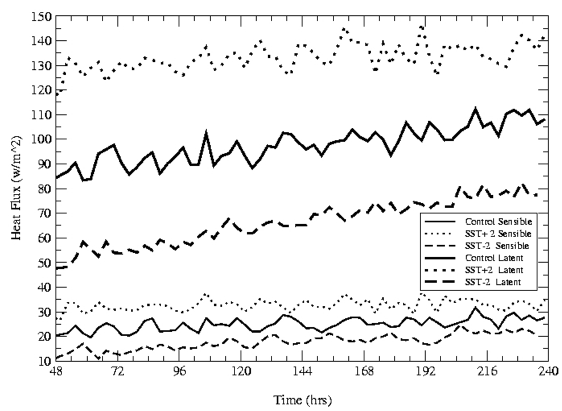

Figure 3: Sensible (lower panel) and latent (upper panel) heat flux over 8-day period

4. Summary and Conclusions

Using cloud-resolving numerical weather prediction models, this study examined three cases with identical initial conditions except for sea surface temperature. It was found that cloud cover increases with decreasing SST. However, the precipitation rate increases as SST increases. As a result of the higher total cloud fraction, less solar radiation reached the surface of the Earth for the SST_{-2} case. The opposite is true for the SST_{+2} case. Since both net surface shortwave and negative net surface longwave radiation increased (decreased) as SST increased (decreased), the total net surface radiation was relatively unchanged for all three cases. It was also found that the sensible and latent heat fluxes increased with increasing SST and decreased with decreasing SST.

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References *(available upon request)*