P8.16 Sea surface temperature and precipitation clouds for tropical oceans

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1. INTRODUCTION

An estimated two-thirds of the global precipitation falls in the Tropics. The energy released by precipitating water affects the entire global circulation. Convective cloud systems (CCS) carry heavy rainfalls and account for most of the rain amount. These clouds are one of the most complex elements of the climate system. The heating from CCS is the principle driver of regional and global-scale atmospheric circulations. This study investigates the sea surface temperature (SST) effect on the precipitation clouds, particularly CCS, using data between 30°S and 30°N of 1998 measured by the Tropical Rainfall Measuring Mission (TRMM) satellite.

2. DATASETS AND ALGORITHM

2.1 Datasets

The TRMM satellite flies in non-sun-synchronous orbits with a 35-degree inclination and carries five sensors. Data from three of them are used in this study. The TRMM Microwave Imager (TMI) is a 5-spectral (10.65, 19.35, 21.3, 37.0 and 85.5GHz), 9-channel passive microwave radiometer. Each spectrum has both vertically and horizontally polarized channels except the 21.3GHz spectrum that only has the vertically polarized channel. The spatial resolutions for these spectra are about 63x37, 30x18, 23x18, 16x9, and 7x5 km^2, respectively. The measured brightness temperature (BT) is used to retrieve cloud liquid water path (LWP), SST, and wins speed. The TRMM standard hydrometeor profile product provides surface and convective rains, and precipitation water and ice amount retrievals in 14 layers at the 85.5GHz resolution. Both BT and precipitation products were acquired from the Goddard Distributed Active Archive Center (DAAC).

The Clouds and Earth's Radiant Energy System (CERES) instrument is a 3-channel broadband radiometer with wavelengths covering 0.3-5 μm for shortwave (SW), 8-12 μm for thermal infrared window, and 0.3-200 μm for total spectra, respectively. The longwave (LW) measurements are obtained from the difference between the total and SW channels. The nadir field-of- view (FOV) of the instrument is about $10\times10 km^2$.

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The Single Satellite Footprint (SSF) product from the CERES project provides estimates of reflected SW and emitted LW fluxes at top-of-atmosphere and surface.

The Visible and Infrared Scanner (VIRS) is a 5-channel (0.63, 1.6, 3.75, 10.8, and 12μm) narrowband imaging spectral radiometer with 2km nadir FOV. It senses the surface or cloud top temperature under clear or cloudy conditions. The hourly VIRS and SSF data were acquired from the Langley DAAC. In this analysis, all previously mentioned four types of data sets (BT, rainfall, SSF, and VIRS) were collocated.

2.2 Retrieval Algorithm

The CERES project uses the VIRS data to derive cloud properties, which include cloud mask (clear or cloudy), height, temperature, layering, water path, optical depth, particle phase (water or ice), and effective particle size (Minnis et al., 1995, 1998, 2001). The visible infrared solar-infrared split-window (VISST) and solar-infrared infrared split-window (SIST) techniques are applied to day and nighttime measurements, respectively (Minnis et al 2002). The VIRS cloud temperature measurements generally represent the cloud top temperature.

A plane-parallel microwave radiation transfer model of Lin et al. (1998) was used as the forward model to simulate the BT for all TMI channels under various conditions of cloud temperature, LWP, column water vapor, wind speed, and SST. The BT measurements of horizontally polarized 37GHz and vertically polarized 85.5 GHz channels are used to retrieve LWP and cloud water temperature simultaneously. Because microwave radiation is not sensitive to non-precipitating ice particles on the top of multilayered cloud systems, its measurements reflect the averaged cloud water temperature, which is close to the cloud base temperature when the cloud water layer is not very thick.

From the collocated data, the BT values of 245K and 218K from the VIRS 11μm channel were chosen to classify the cloud clusters into cold or deep CCS, respectively. The separation of cold and warm rain pixels were made based on the BT threshold of 273K. One full year (1998) of cold and deep CCS, and cold and warm rain cells over the tropical oceans were identified.

3. ANALYSIS

Based on pixel level statistics, cloud top temperatures decrease and cloud base temperatures increase with SST (Figure 1a). The correlation coefficients are approximately 0.97 and -0.87, respectively, for the studied region. Cloud thicknesses and rainfall rate increase with SST and are peaked at the highest SST (Figure 1b). The correlation coefficients between SST and cloud thickness and rainfall rates are 0.97 and 0.96, respectively.

Although 68% of the tropical sky have clouds, the CCS covers only ~13%: most of them occur at SST higher than 300K. For the high SSTs, CCS could cover up to 30% of the area. The chances of cold rains are higher than warm rains (Figure 2b). The overall averages are ~4% and 2% for cold and warm rains, respectively. The average rainfall rate (Figure 2c) of cold clouds (2.71mm/h) is 4.5 times as high as that of warm clouds (0.62mm/h). For the rain amounts, cold clouds generate about nine times as much rainwater as warm clouds. More than 90% of the cold rains fall at the area with SST higher than 300K (figure 2d).

Based on raincell data, rainfall rates increase with SST (Figure 3a) and raincell radius (Figure 3b) when SST is higher than 298K. Furthermore, cloud clusters can be separated by the area coverage ratios of raincell and cloud. The clusters in developing stage (higher ratio) usually are smaller and have heavier rainfalls (Figure 4). Also observed are more reflected SW and less emitted LW from the cold cloud top of CCS than its surroundings.

4. SUMMARY

This study combines microwave, visible and infrared data to investigate the SST effects on the rain cells and CCS in the tropical oceans. Basic statistical relationships among these properties are obtained. Future study will be focused on the cloud responses to changing SSTs, i.e., cloud feedback analysis. Also, more data are needed, especially those from the Aqua satellite which has all similar instruments used in this study.

5. Reference

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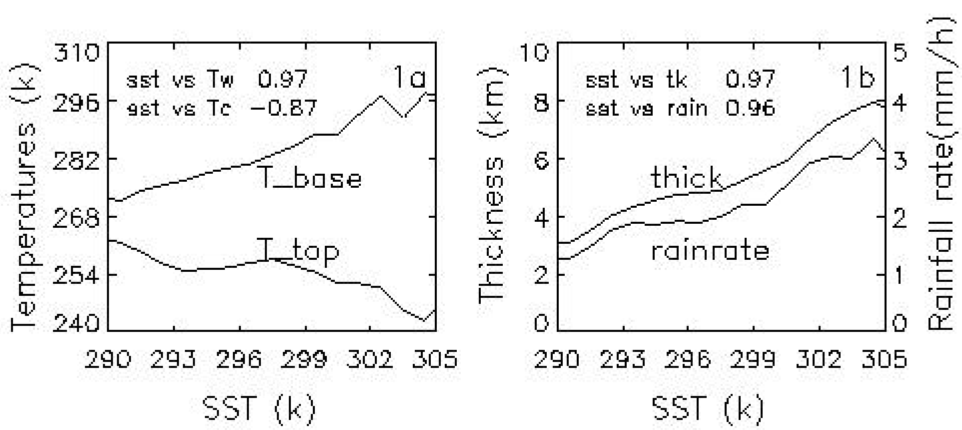

Figure 1. Pixel-based cloud base and top temperatures, thickness, and rainfall rate

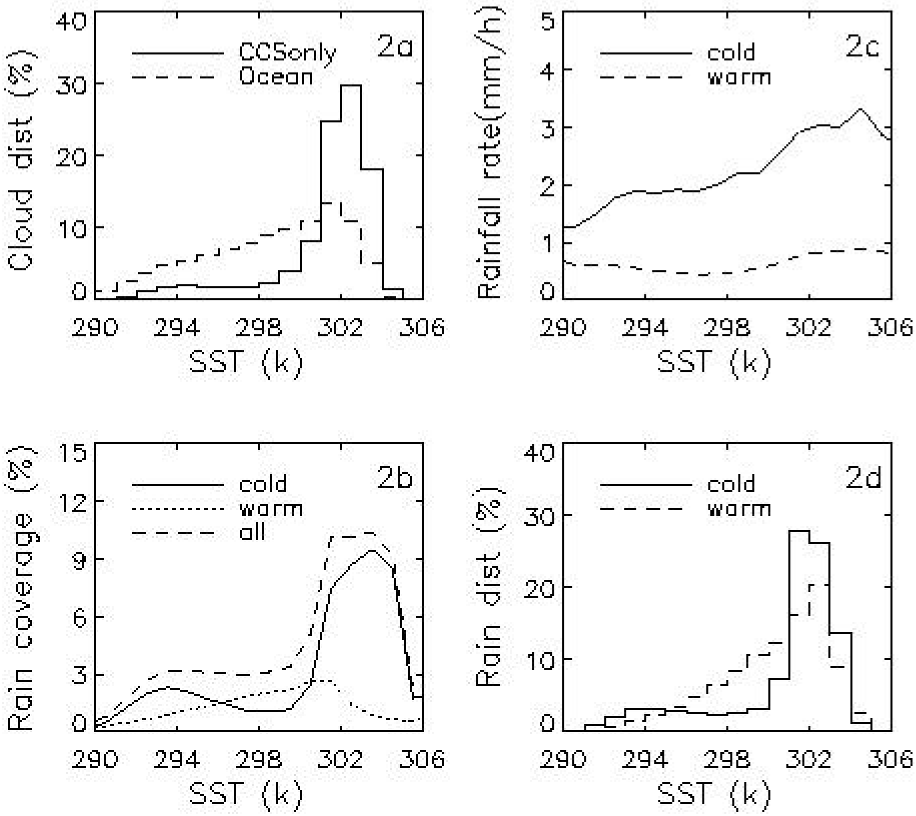

Figure 2 Pixel -based cloud and rain distribution

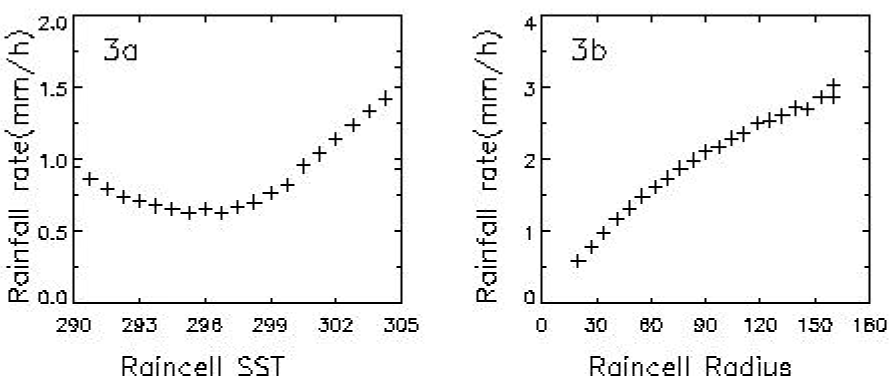

Figure 3. Raincell-based effective SST, rainfall rate, and raincell radius

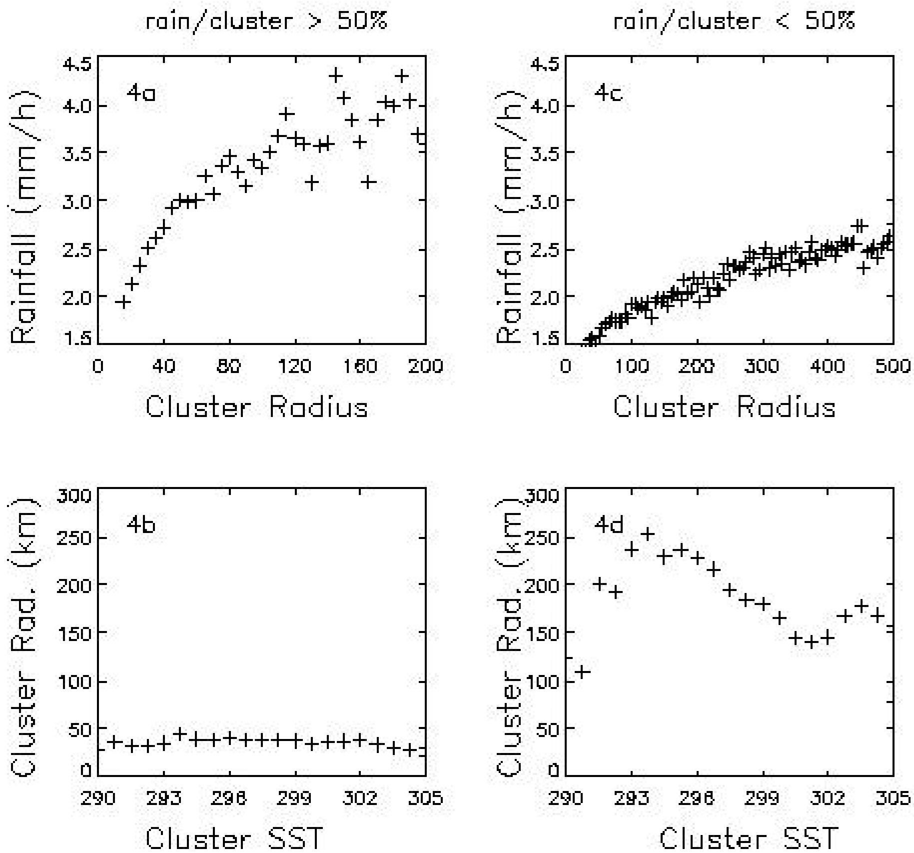

Fig. 4: Cluster-based effective rainfall rate, radius, and SST