JP4.17 COMPARISON OF LATENT AND SENSIBLE HEAT FLUXES OVER TROPICAL OCEANS OBSERVED BY TRMM AND DMSP SATELLITES

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1. INTRODUCTION

Part of the solar energy that reaches earth is absorbed and warms the surface. Water vapor is produced by evaporation from the warm surface. Rainfall is the condensation of water vapor into liquid water or ice. During the phase change, latent heat is released. Therefore, Rainfall is related to the amount of heat transported from surface to atmosphere. More rainfall indicating more heating of atmosphere, which gets three-fourths of its heat energy from the release of latent heat by precipitation. This heating is an energy source of the global atmosphere circulation. There is a north-south atmospheric circulation driven by latent heating in the equatorial region, named Hadley circulation. There is also another east-west atmospheric circulation, named Walker circulation, around Indonesia and the western Pacific. Sensible heat flux at the air-sea interface is due to the temperature difference between the cold skin and air temperatures. A falling raindrop is in thermal equilibrium with its surroundings, with a temperature corresponding to the web-bulb temperature of the atmosphere at its height. The temperature of the raindrop as it hits the ocean surface is equivalent to the web-bulb temperature of the atmosphere just above the surface. The difference between these two temperatures cloud range from small to larger depending on the nature of the rain. Both heat fluxes are important parameters in understanding the atmosphere/ ocean heat and fresh water transports. This study estimates these fluxes over tropical oceans (30N to 30S) using Tropical Rainfall Measuring Mission (TRMM) Microwave Image (TMI) data and compares the results to those of Goddard Satellite-Based Surface Turbulent Fluxes (GSSTF) version 2 products derived from SSM/I data collected by Defense Meteorological Satellite Program (DMSP) satellites.

2. DATASETS AND ALGORITHM

2.1 Datasets

The parameters required to calculate the surface turbulence flux include air and sea surface temperatures, air humidity, surface specific humidity, air density, and wind speed. Only satellites could provide global measurements of the required parameters, consisting of high spatial and temporal resolution and consistent quality. Although Infrared measurements could estimate surface temperature for clear sky, they can hardly determine wind speed and surface humidity, which on the other hand can be estimated by microwave imager data. Special Sensor Microwave Imager (SSMI) has been flown on DMSF satellite since 1990. They are a series of sun-synchronous meteorological satellites and measured brightness temperature at four frequencies 19.35, 22.235, 37.0, and 85.5 GHz. TRMM Microwave Imager(TMI) data set is from the TRMM satellite, which is a US-Japan joint space mission for tropical rainfall measurements. It flies in non-sun-synchronous orbits with a 35-degree inclination. It carries five sensors. One of them is the nine-channel passive microwave radiometer with dual polarized 10.65, 19.35, 37.0 and 85.5 GHz and vertically polarized 21.3 GHz channels. The spatial resolutions are 63x37, 30x18, 16x9, 7x5, and 23x18 km^2, respectively.

European Centre for Medium-Range Weather Forecasts (ECMWF) is an international organization supported by 23 European states. Their goal is to deliver medium-range weather forecasts. The data products used in this study are skin and 2m temperatures.

2.2 Retrieval Algorithm

The brightness temperature (BT) measurements from microwave radiometer are used to retrieve surface air specific humidity (Qa) and column water vapor (CWV) based on BT simulations of a microwave radiation transfer model (Lin et al. 1998). The sea surface temperature (SST) and near sea surface wind speed (WS) are estimated empirically from the TMI Tb values. They are determined by regressing with the BT for non-precipitating measurements. The bias of satellite-derived sea surface temperature and wind speeds is very small. Air temperature is obtained by adding the gradients between the skin and air temperatures of ECMWF to the TMI estimated SST. Surface pressure and near-surface air temperature are needed to determine the air density and latent heat of evaporation. The error caused by fixing pressure at 1013.25 mb is negligible. With these meteorological parameters, the bulk algorithm based on the stability-dependent aerodynamic model for TOGA COARE (Fairall et al. 1996) is used to calculate sea surface latent and sensible heat fluxes. The bulk flux algorithm of COARE used mean values of surface temperature, air temperature, wind, and humidity to calculate the turbulent fluxes. The standard bulk formulae for latent and sensible heat fluxes are:

$$LH = \rho L C_l\,(U-U_s)(Q_s-Q_a)$$
$$SH = \rho C_p C_s\,(U-U_s)(T_s-\theta)$$

Where ρ is air density, L is the latent heat of vaporization, C_l and C_s are the transport coefficients of moisture and heat, C_p is specific heat of air at constant pressure, U is

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Corresponding author address: Alice Fan, SAIC, Inc., Hampton, VA 23666; email: t.f.fan@larc.nasa.gov sea surface wind speed at a standard level of 10m, U_s is ocean surface current speed , Q_s an Q are water vapor mixing ratios at sea skin and 10 m levels, T_s and θ are potential temperatures at these two levels.

Surface humidity mixing ratio at 10m is calculated from the BT of the first three channels. Air and sea surface temperatures and the Clausius-Clapeyron equation are used to calculate the saturated vapor pressures at these two levels. They are in turn used to calculate the saturated mixing ratios. The surface mixing ratios is estimated as 98% of the saturated mixing ratios assuming a 34 psu salinity. The virtual temperature and air density are then calculated.

3. ANALYSIS

The TMI estimates are compared to the GSFC version 2 products of surface turbulent fluxes derived from SSM/I measurements onboard of DMSP F-8, F-10, F-11, F-13,and F-14 satellites. Both data sets are averaged into 1X1 degree gird boxes. Figures 1 and 2 reveal the zonal and grid level means of latent heat fluxes from these two data sets. They correlated well between 20N and 20S degree, although the TMI values are lower than those from SSM/I by 3 to 15 w/m^2. The TMI flux values are higher than those from SSM/I by 6- 17 w/m^2 at higher latitudes, because of higher wind speed estimations at the current estimation. The monthly zonal averaged latent heat differences for entire tropical oceans (30S to 30N) are very small, only about -6.6, -3.2, -2.9, -2.0, -7.2, 1.1, 2.9, and -2.4 w/m^2 for the first 8 months of 1998. Figures 3 and 4 show the sensible heat from TMI are lower than those from SSM/I across all compared latitudes by 6-7 w/m^2.

4. SUMMARY

Ocean surface fluxes of heat, moisture, and momentum have strong variation on small temporal and spatial scales. Only satellite–based observations could provide a comprehensive estimate based on the credible measurements of sea surface temperature, surface air temperature, wind speed, and humidity. Future studies on the diurnal and regional variations are needed.

5. Reference

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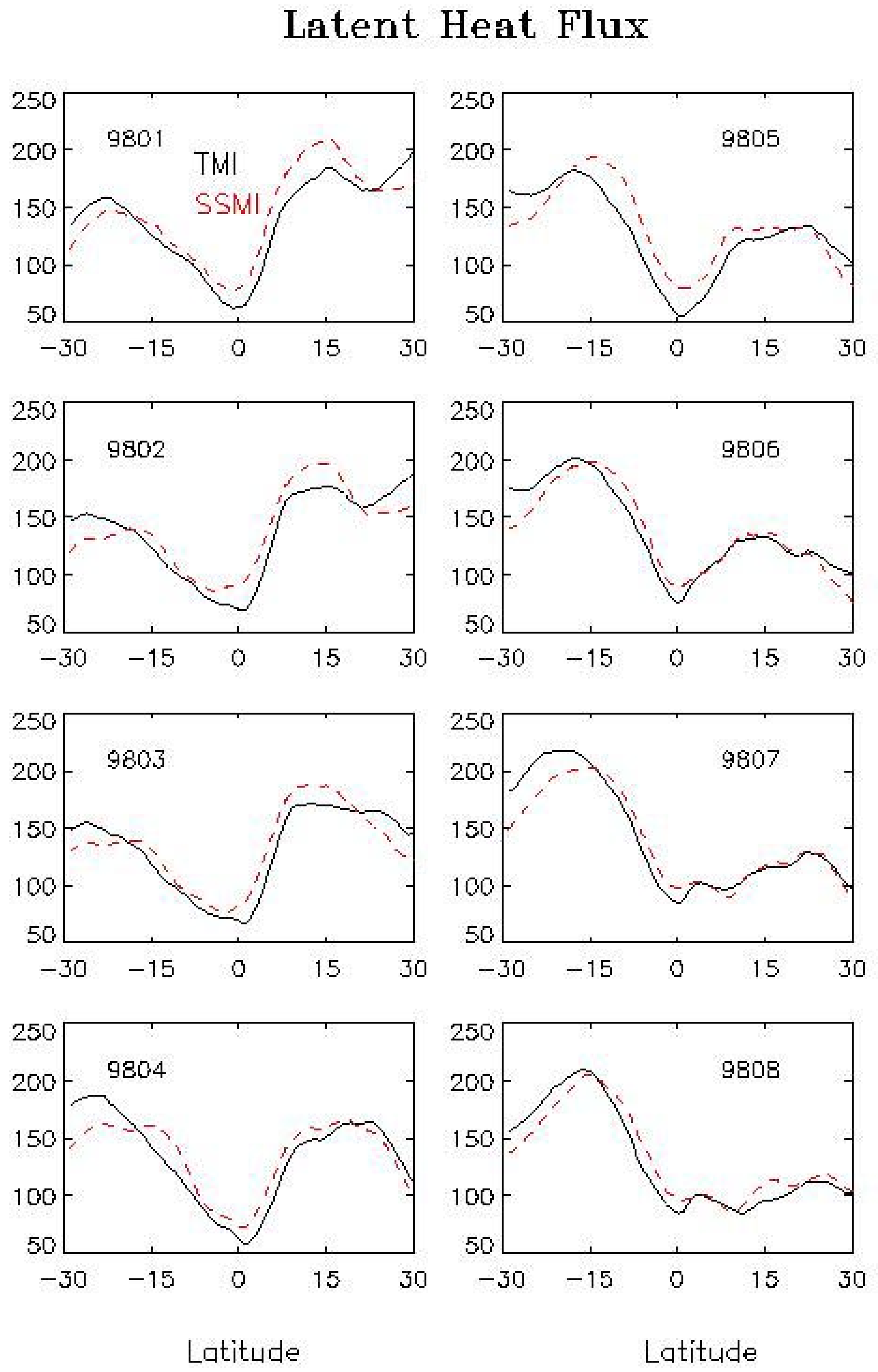

Figure 1: Zonal average of latent heat flux from TMI and SSMI

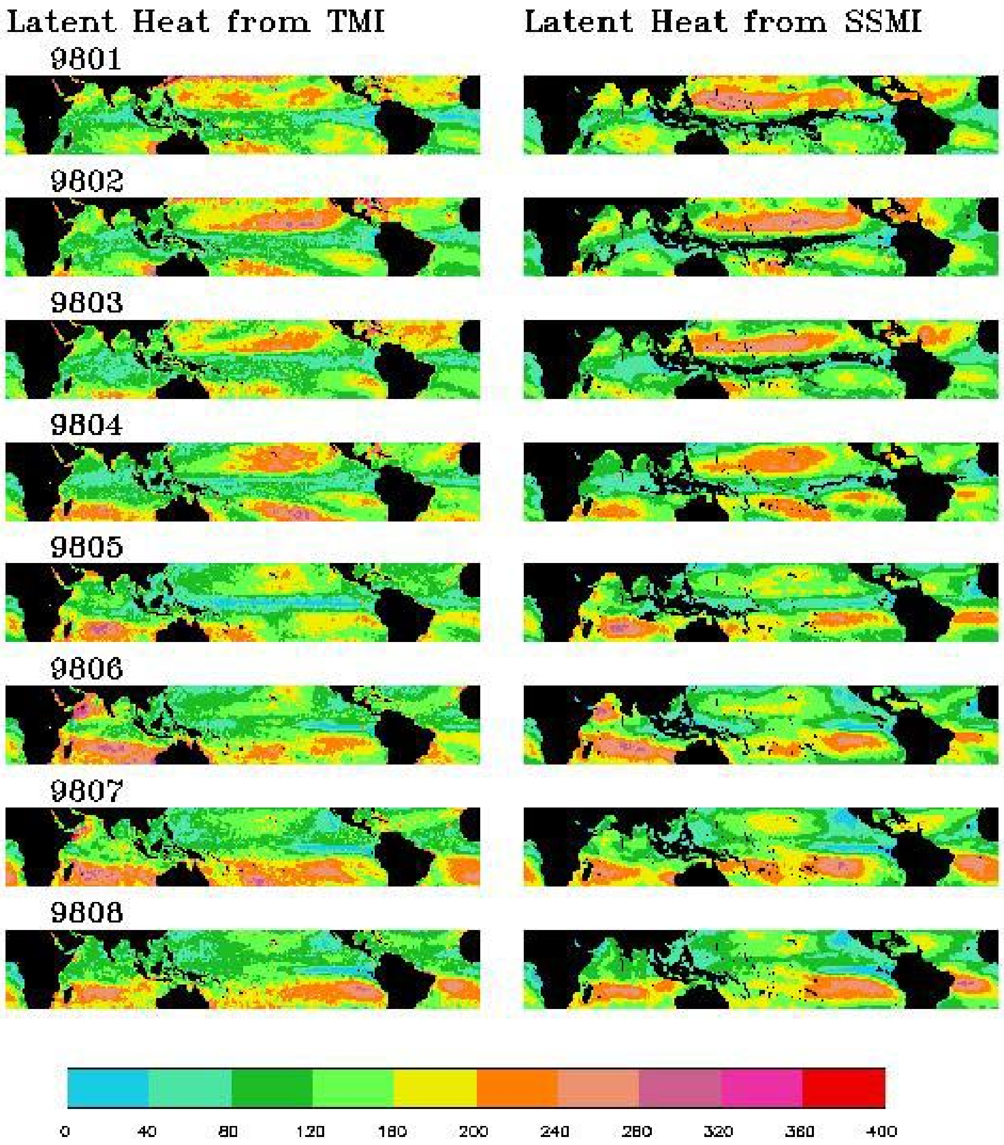

Fig. 2: Latent heat flux from TMI and SSMI

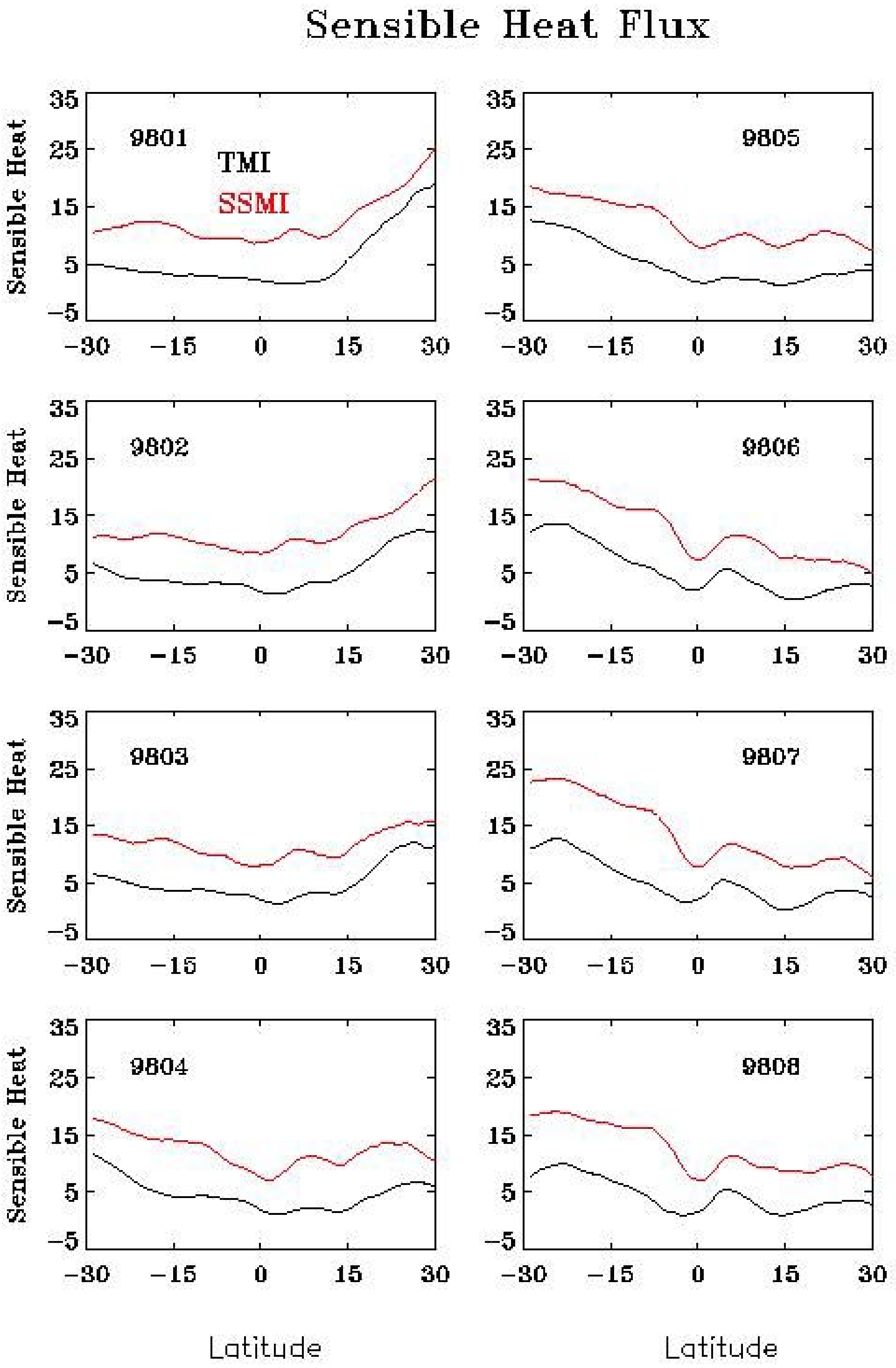

Figure 3: Zonal average of sensible heat flux from TMI and SSMI

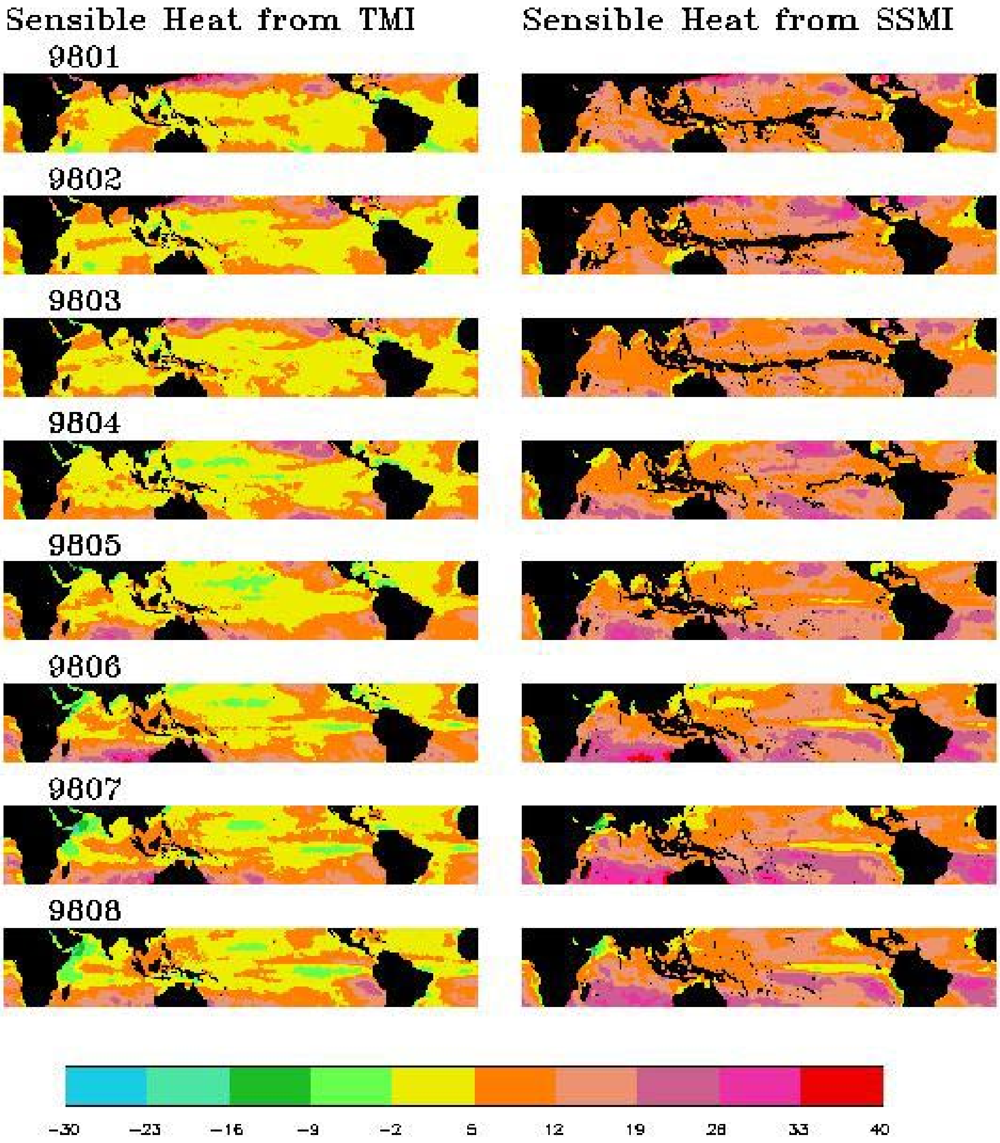

Figure 4: Sensible heat flux from TMI and SSMI