P3.1 VALIDATING of SATELLITE RETRIEVED LATENT HEAT FLUXES OVER TROPICAL OCENAS

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1. INTRODUCTION

The major heat components for air-sea interface include shortwave, longwave, latent, and sensible heat fluxes. Among them, shortwave and latent heat fluxes are the dominant factors over tropical oceans. In these regions, latent heat fluxes are comparable to the net shortwave fluxes. Currently, satellite remote sensing techniques start to provide global estimates of latent heat fluxes. This study uses brightness temperature (BT) measurements from the Tropical Rainfall Measurement Mission (TRMM) and the bulk algorithm of Fairall et al (1996) to estimate latent heat fluxes. It is critical to validate the satellite estimates with in situ measurements.

Because remote sensing cannot directly measure latent heat fluxes, an indirect approach through bulk formula using satellite retrievals of wind speed and humidity differences between sea skin and 10 m air level is used. The accuracy for each of these meteorological parameters is critical for the calculation of latent heat fluxes. Otherwise, the errors propagate through the bulk formula and lead to large uncertainties in the derived latent heat fluxes.

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. Among them, the TRMM Microwave Imager (TMI) is a 5-spectral (10.65, 19.35, 21.3, 37.0 and 85.5 GHz), 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 available ground measurements are from the NOAA Environmental Technology Laboratory (ETL) Research ships. They are from measurements for the projects such as the Joint Air-Sea Monsoon Interaction Experiment (JASMINE), the Nauru 99 (NAURU99), the Kwajalein Experiment (KWAJEX), the Pan-AMerican Climate Study (PACSF99), and the buoy service in the North Pacific (MOORINGS). These five cruises provided three latent heat estimates: direct covariance (COV), inertial-dissipation (ID) methods, and the bulk algorithm (BULK) using ship measured meteorological variables.

In this study, the TMI pixels were collocated with each of the ship measurements to be within 10 minutes and 20 km. Each ship measurement has 1 to 20 matched TMI pixels. The latent heat fluxes have been calculated using satellite estimated wind speed, water vapor, and sea surface temperature from the BT measurements from 1998 to 2000. The mean values of matched pixels were compared to the ship measurements.

2.2 RETRIEVAL ALGORITHM

The bulk algorithm used here is based on the stability-dependent aerodynamic model developed by the Tropical Ocean Global Atmosphere (TOGA) Coupled Ocean-Atmosphere Response Experiment (COARE; Fairall et al., 1996). The standard bulk formula for latent heat flux is:

$$H_{LAT} = \rho L\ C_L(Ua-Us)(Qs - Qa)$$

Where ρ, L, and C_L are air density, latent heat of vaporization, and drag transport coefficients of moisture, respectively. Ua is wind speed at 10 m above surface. Us is ocean surface current speed, which is much smaller than Ua and is assumed to be 0. Qa and Qs are air specific humidity at 10 m height and sea skin levels, respectively.

The sea surface temperature (Ts), Ua and Qs are estimated empirically by regressing with the BT measurements under non-precipitating conditions. The channels used for Ts are 10.65 GHz vertically and horizontally polarized channels, and 19.35 and 21.3 GHz vertically polarized channels. For Ua, this study uses 10.65, 19.35, and 37.0 GHz horizontally polarized channels and 37.0 GHz vertically polarized channel.

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Air temperature (Ta) is the most difficult parameter for satellite remote sensing. In this study, Ta is obtained by adding the temperature difference between the sea skin and air of ECMWF to the observed Ts. That is Ta = Ts + ECMWF (Ta - Ts). The air-sea temperature difference is generally very small (< 2K) over the tropical open oceans. Air density is calculated based on Ta and a fixed pressure of 1013.25mb. The error caused by fixing the pressure is generally negligible.

The determination of Qa is a challenge job for microwave remote sensing due to the fact that microwave radiation mainly emerges from entire thick planetary boundary layer. Since the integrated water vapor content of the lowest 500-meter of the atmosphere layer over ocean is highly correlated (r > 0.9) to the Qa near the sea surface, Schulz et al. (1993) estimated Qa values from the integrated total water vapor content sensed by passive microwave measurements and yielded an accuracy of ~1.2g/kg. Later, Schluessel (1995) combined this two-step approach into a one-step optimized approach for SSM/I measurements: relating Qa directly to the microwave BT values. Their Qa accuracy was about 1.1 g/kg. The equation for Qa used is:

$$Qa = -80.23 + 0.6295 (Tb19V) - 0.1655 (Tb19H) + 0.1495(Tb22V) - 0.1553 (Tb37V) - 0.06696 (Tb37H)$$

The saturation specific humidity (Qs) at sea surface is essentially a function of the sea surface temperature with a correction factor 0.98 to account for the reduction in the saturated vapor pressure for a 34 parts per thousand salinity (Fairall et al., 1996). The bias (rms) errors of these meteorological parameters (Figure 1) are 0.31 (1.69) m/s for wind speed, -0.36 (1.28)K for Ts, 0.50 (1.49)g/kg for Qa, and 0.04 (1.35) K for Ta.

3. ANALYSIS

Although, the satellite calculated latent heat fluxes have bias (rms) of -9.74 (37.08) W/m**2 when compared to the ship BULK results (Fig. 2a), the bias (rms) are 1.53 (54.30) W/m**2 (Fig. 2b) and 0.27 (50.0) W/m**2 (Fig. 2c) when compared to the ship COV and ID results. This is very promising. The bias (rms) are 10.0 (43.6) W/m**2 (Fig. 2d) and 8.21 (38.9) W/m**2 (Fig 2e) between ship BULK and ID and COV, respectively. The ship BULK results are higher than direct COV and ID methods by 8-10W/m**2. This is the same as the difference between the ship BULK and the satellite estimates.

The correlation coefficients between satellite estimated fluxes and surface BULK, COV, and ID are 0.63, 0.30, and.0.43, respectively. The main error sources in satellite flux retrievals are the uncertainties in air humidity and wind speed. The error sources for ship measurements are the ship motion, flow distortion, and the contaminating effects of marine environment. They produce major uncertainties in the flux estimates. Despite all these obstacles, the satellite measurements provide reasonable accuracy with global coverage. The seasonal maps are shown in Figures 3, 4, and 5.

4. SUMMARY

The latent heat fluxes are mainly correlated with atmospheric dynamics and thermodynamics, especially wind speed and humidity difference at sea skin and near sea surface levels. These properties have strong variations on small temporal and spatial scales. Only satellite-based observation can provide a comprehensive estimate of these parameters. The accuracy of satellite sensed latent heat is strongly dependent on the accuracy of the estimates of air and sea surface temperatures, air humidity, and wind speed and the bulk algorithms. The limitation of current microwave technique is that it may be less accurate under high wind situations than in normal conditions due to limited validation data and not be able to retrieve wind speed and air humidity under precipitating clouds.

5. REFERENCE

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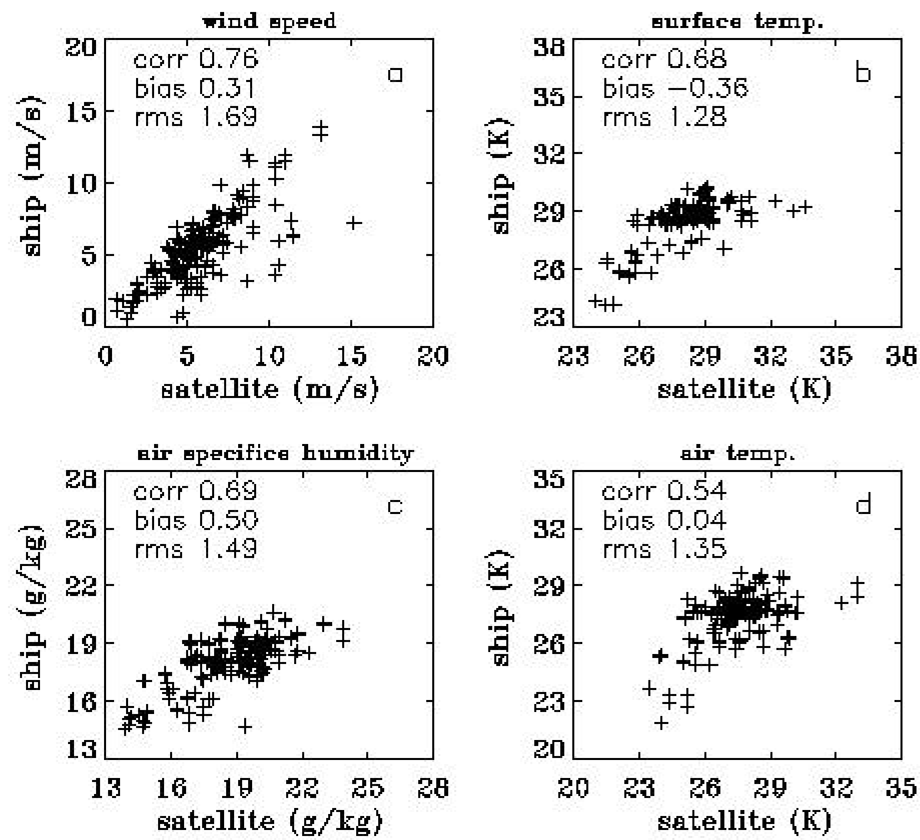

Figure 1: Comparison of satellite estimated meteorological parameters with ship measurements.

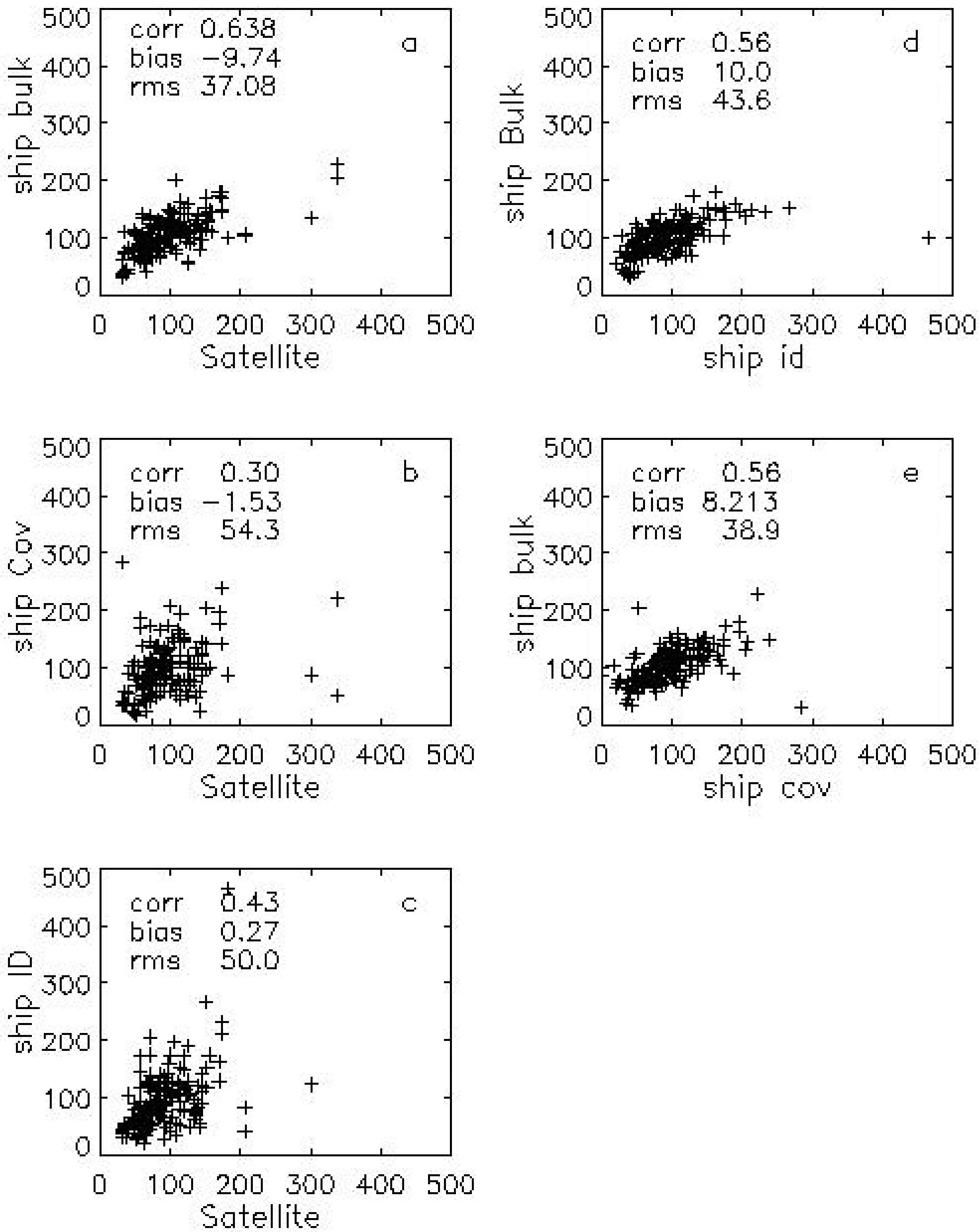

Figure 2: Comparison of satellite estimated latent heat fluxes with ship estimates.

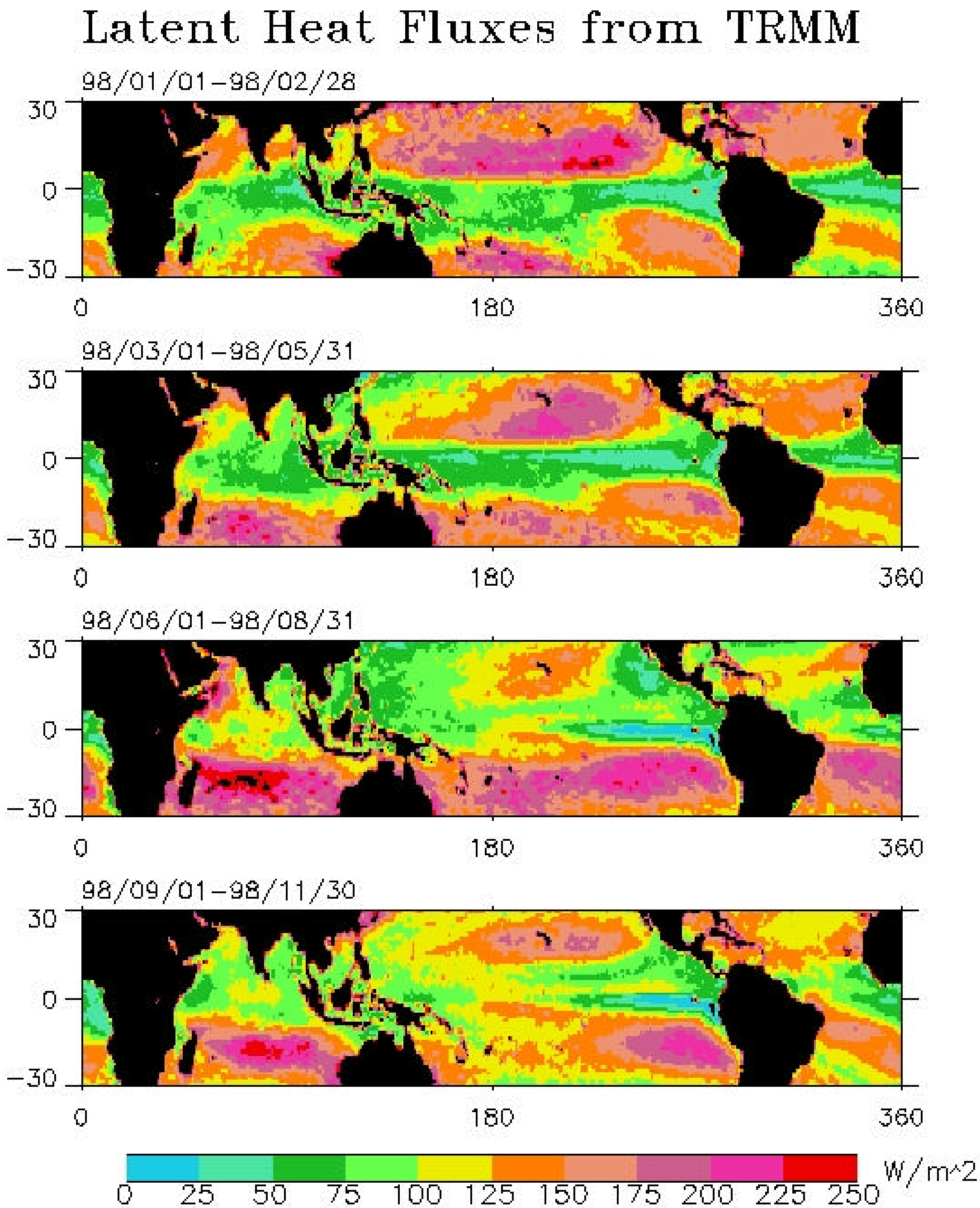

Figure 3: Latent heat fluxes from TRMM for 1998

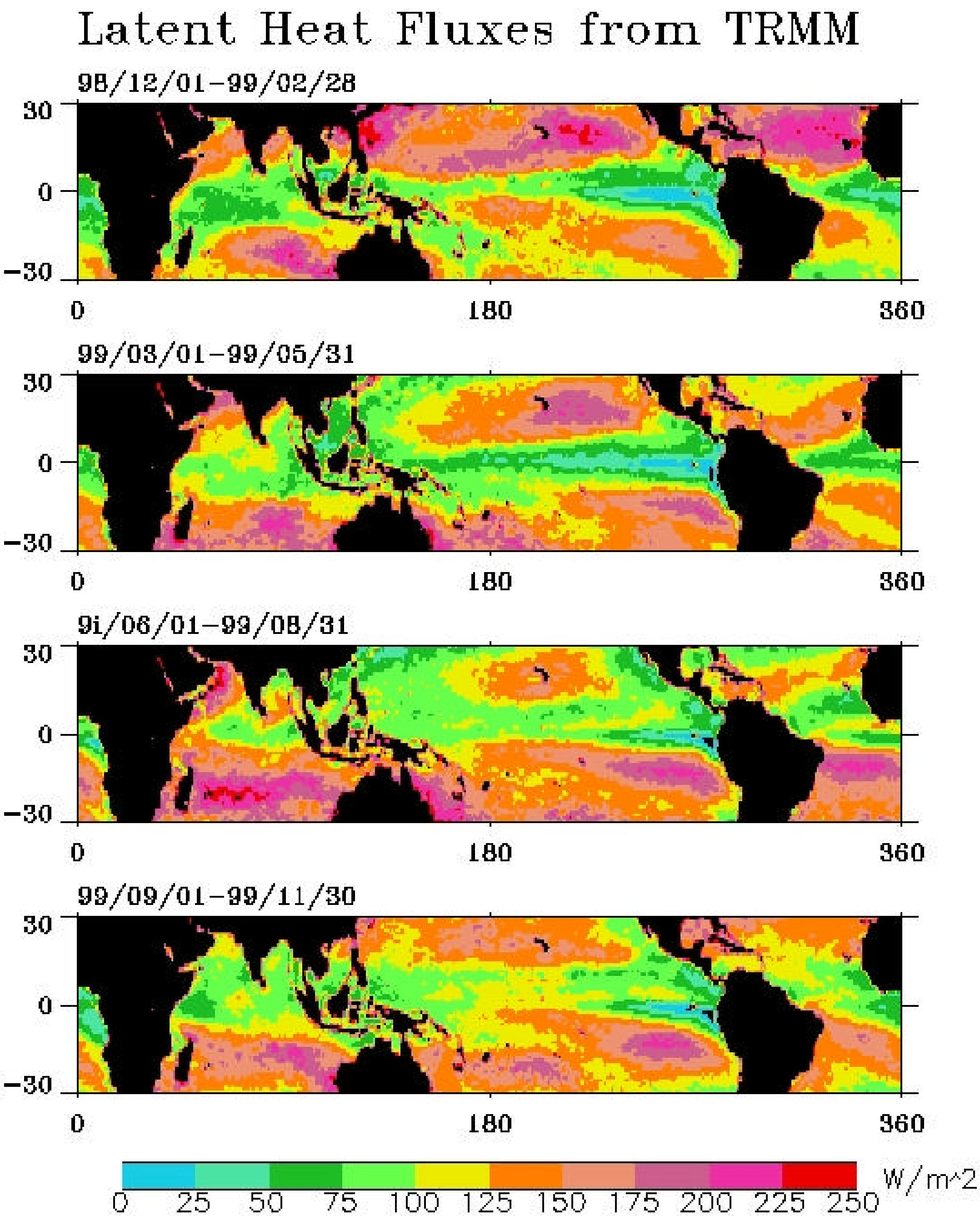

Figure 4: Latent heat fluxes from TRMM for 1999

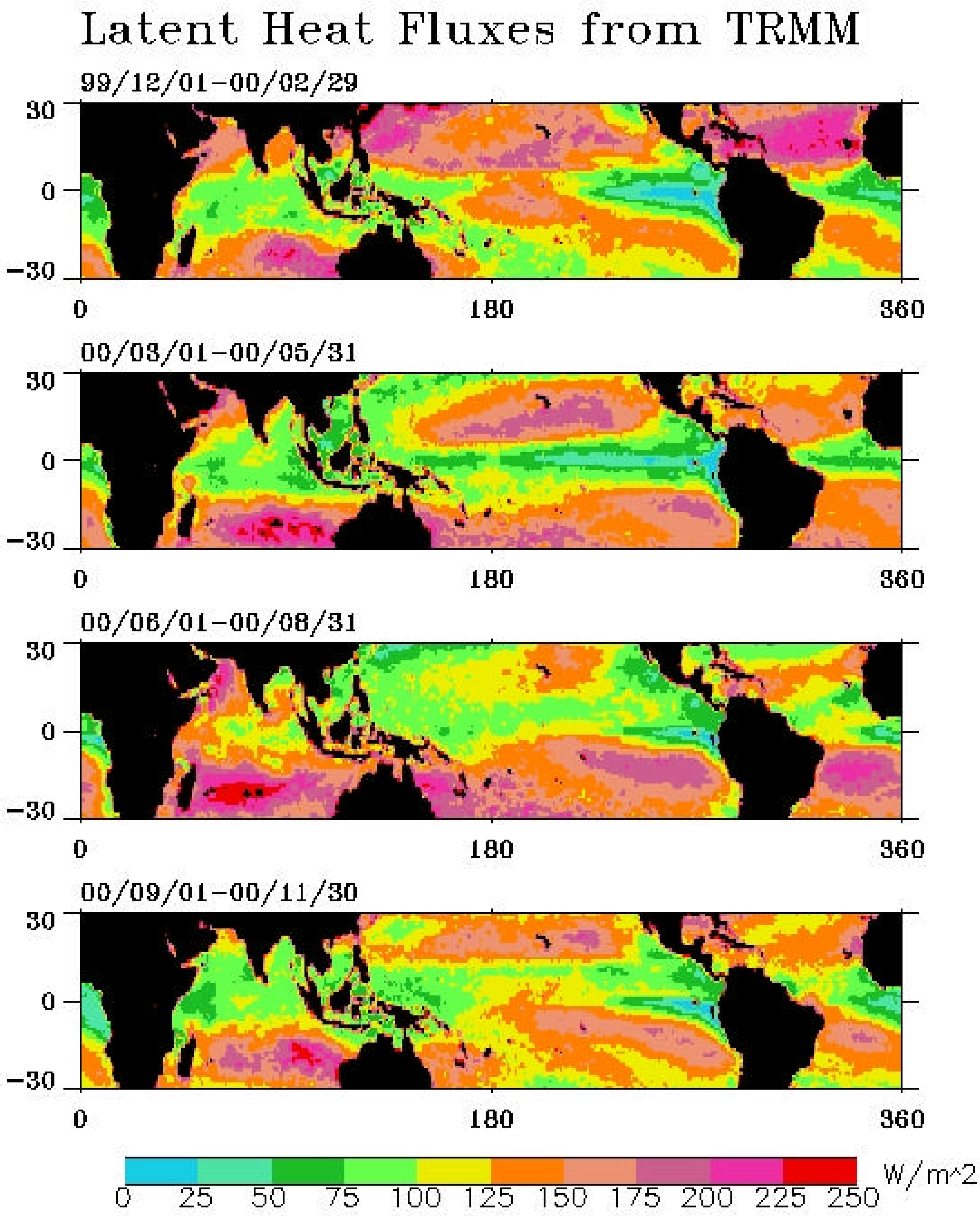

Figure 3: Latent heat fluxes from TRMM for 2000