P3.7 THE ATMOSPHERE HEAT BUDGET OVER THE TROPICAL OCEANS

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1. INTRODUCTION

The earth's energy budget gets its source from solar radiation. About one-third of them are reflected back to space. The rest are absorbed by atmosphere (~16%), clouds (3%), and surface (~51%). The net radiation flux (NRF) at top-of-atmosphere (TOA) is estimated as the incoming solar radiation reduced by the emitted longwave (LW) radiation. The surface NRF is the combination of SW and LW NRF absorbed by oceans. The difference between these two NRF is the atmosphere NRF. This flux is general negative, indicating the net cooling effect of atmospheric radiation. The climate system adjusts this imbalance mainly through the evaporation cooling at surface, release of latent heat by precipitation within atmosphere, and sensible heat transport in the low boundary of the atmosphere due to the temperature difference between the atmosphere and its underneath boundary. It is critical to measure these energy budgets in understanding the earth's climate system.

2. DATASETS AND ALGORITHM

2.1 Datasets

This study uses data of the Tropical Rainfall Measuring Mission (TRMM) satellite over the tropical oceans (30S to 30N) collected from 199801-199808 to examine the latitudinal and diurnal variations of the atmosphere heat budget. TRMM satellite carries five sensors covering spectra from visible, infrared, to microwave wavelengths. It has 46-day processing cycle orbits, which provides a unique opportunity to examine the diurnal variation of tropical hydrological and energy cycles. Data collected from Visible and Infrared Scanner (VIRS), Clouds and Earth's Radiant Energy System (CERES), and TRMM Microwave Imager (TMI) are used in this study.

CERES is a 3-channel broadband (0.3-5, 8-12, 0.3-50µm) radiometer. VIRS is a 5-channel narrowband (0.63, 1.6, 3.75, 10.8, and 12.0µm) radiometer. TMI is a 9-channel radiometer at spectra 10.65, 19.35, 21.3, 37.0, and 85.5 GHz. Each spectrum has vertically and horizontally polarized channels except the 21.3 GHz spectrum, which has only vertically polarized channel.

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2.2 RETRIEVAL ALGORITHM

The VIRS visible and infrared channels measure earth-reflected solar and thermal radiations. These data are used to detect cloud coverage, layering, water/ice particle size, optical depth, and water path by Visible Infrared Solar-Infrared Split-window techniques (Minnis et al., 1995, 1998, 2001)

CERES project uses the measured broadband radiation, Angular Distribution Model (ADM), and cloud properties from VIRS to calculate the radiation fluxes at TOA and surface. The retrieval biases are about 2W/m^2 and 3W/m^2 for LW and SW, respectively, at TOA, and 8W/m^2 and 15W/m^2 for LW and SW at surface for monthly mean data. For more information, please visit the CERES web site at http://asd-www.larc.nasa.gov/ceres.

The latent and sensible heat fluxes are estimated using standard bulk formula with satellite retrieved meteorology parameters. The bulk formula are obtained 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 and sensible heat fluxes are:

$$H_{LAT} = \rho L\, C_L(Ua\text{-}Us)(Qs - Qa)$$
$$H_{SEN} = \rho\, C_P C_S(Ua\text{-}Us)(Ts - Ta)$$

Where ρ and L are air density, latent heat of vaporization, respectively. C_L and Cs are drag transport coefficients of moisture and sensible heat, respectively. Ua is wind speed at 10 m above surface. Us is ocean surface current speed, Qa and Qs are the air specific humidity at 10 m height and sea skin levels, respectively. C_P is specific heat of air (1004J/kgK) at constant pressure of 1013.25mb.

The pixel level bias (rms) errors for latent heat flux are about 1.53 (54.30) W/m^2 and 0.27 (50.0) W/m^2

when compared to the measurements of ship direct covariance and inertial-dissipation methods. They are about -9.74 (37.08) W/m^2 when compared to ship bulk results. For sensible heat flux, the bias (rms) errors are around -1.77 (9.34), -3.66 (9.20), and -1.90 (8.23) W/m^2 compared to the results of ship direct covariance, inertial-dissipation, and bulk estimations, respectively.

3. ANALYSIS

Based on the latitudinal means (Fig. 1a) over the tropical oceans for 199801-199808, the TOA NRF (solid curve) varies from 0 to 70 W/m^2, and the surface NRF (dotted line) varies from 150 to 200 W/m^2. This results a negative atmosphere NRF (dash line) cooling from -100 to -150 W/m^2. Latent and sensible heat fluxes (Fig. 1-b and 1-c) contribute atmospheric heating 70 to 170 W/m^2 and 3 to 8 W/m^2 over the tropical oceans, respectively. After considering all these heat fluxes, the atmosphere heat budgets (Fig. 1-d) vary between -50 and 30 W/m^2 over the oceans. Note that the atmosphere heat budget and latent heat fluxes have similar latitudinal variations (Fig. 1b and 1d):both are low around equator and higher at higher latitudes. This indicates the important role of latent heat in atmosphere heat budget.

The seasonal variations of NRF at TOA, surface, and atmosphere are shown as dotted (9801-9803) and dash curves (9806-9898) in Figures 1e, 1f, and 1g. Summer hemisphere has significant higher NRF at both TOA and surface. Higher TOA and surface NRF may result less net atmosphere radiation cooling, which is about –100 W/m^2 and –120 to –150 W/m^2 for the summer and winter hemispheres, respectively (Fig. 1g).

Diurnal variations of NRF are shown in Figure 2a. Hourly means for both TOA (solid curve) and surface (dotted curve) radiation can reach 700W/m^2 at noontime but they are negative between 7PM and 6AM because of thermal emission to the space and the weakness or absence of solar radiation. The losses could be more than 200 W/m^2. The atmospheric NRF budget (dash curve) is mostly negative except between 10AM and 2PM.

Figure 2b shows the latent heat fluxes between the air-sea interface. They vary between 120 and 150 W/m^2. There are higher losses after 4PM. Figure 2c shows the sensible heat fluxes ranging between 4 and 6 W/m^2, with higher losses in the morning. Combining all these fluxes, atmosphere heat budget (Fig. 2-d) varies between 150 and –100 W/m^2 during day and night times. Atmospheric heat fluxes have similar diurnal variations as those of atmospheric NRF with approximately 150 W/m^2 higher. The result indicates radiation fluxes play the most important role in diurnal variation of tropical climate system.

4. SUMMARY

The negative atmospheric NRF is compensated by the moisture heat flux. Latent heat plays an important role in regulating the atmospheric heat budget. From zonal means, atmospheric heat budgets are negative between 10°S and 10°N. The biggest atmosphere heat loss and ocean heat gain are around the equator due to strong solar radiation and heavy rainfalls. Integrating the diurnal energy fluxes, the atmospheric heat gains during the day and heat losses during the night are about canceling each other.

From the TRMM satellite, both the radiation and humidity fluxes can be estimated with excellent collocation. This improves the local accuracy for estimating atmosphere and surface heat fluxes. These data could be useful for validating the atmosphere-ocean models.

5. REFERENCE

Fairall, C.W., E.F. Bradley, D.P. Rogers, J.B. Edson, and G.S. Young, 1996: Bulk parameterization of air-sea fluxes in TOGA COARE, J. Geophys. Res., 101, 3747-3767.

Fairall, C.W., E. F. Bradley, et al. 2003: Bulk parameter rization of air-sea fluxes: updates and verification for the COARE algorithm, J. Climate, Vol. 15, 571-591.

Fan, A. and B. Lin, 2004: Latent heat flux estimated from TRMM satellite, AGU fall meeting

Lin, B., and A. Fan, 2004: Validation of satellite retrieved latent heat fluxes over tropical oceans. AMS annual meeting.

Minnis, P. D. F. Young, D. P. Kratz et al. 1995: Cloud optical property retrieval in CERES Algorithm Theoretical Basis Document, Vol. 3, Rep. NASA RP 1376, NASA Langley Res. Cent., Hampton, VA

Minnis, P., D. P. Garber, D.F. Young et al 1998: Parameterization of reflectance and effective emittance for satellite remote sensing of cloud properties, J. Atmos. Sci, 55, 3313-3339.

Minnis, P., W. L. Smith Jr., et al. 2001:A near-real time method for deriving cloud and radiation properties from satellites for weather and climate studies, in Proceeding AMS 11th Conference on Satellite Meteorology and Oceanography, pp 477-480. AMS Boston, Mass.

Wielicki, B. A., B.R. Barkstrom, et al. 1996: Clouds and the Earth's Radiant Energy System (CERES): An Earth Observing System Experiment. Bull. Amer. Meteor. Soc., 77,853-86

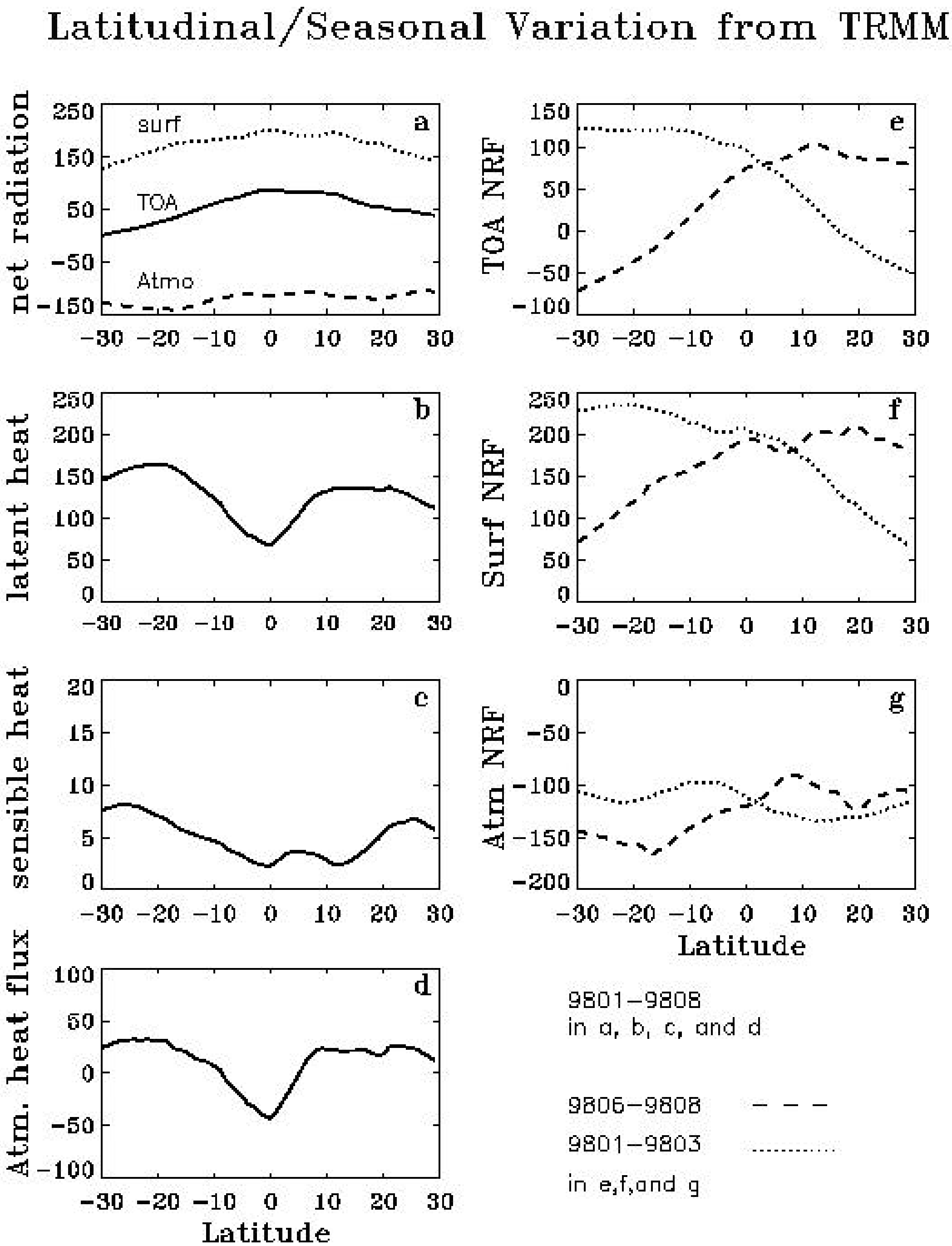

Figure 1: Latitudinal variations for (a) net radiation flux (NRF) at TOA, surface, and Atm. , (b) latent heat, (c) sensible heat, and (d) Atm. heat fluxes (including NRF, latent and sensible heat fluxes). Seasonal variations of NRF at (e) TOA, (f) surface, and (g) Atm., (dash line for 9806-9808, dotted line for 9801-9803)

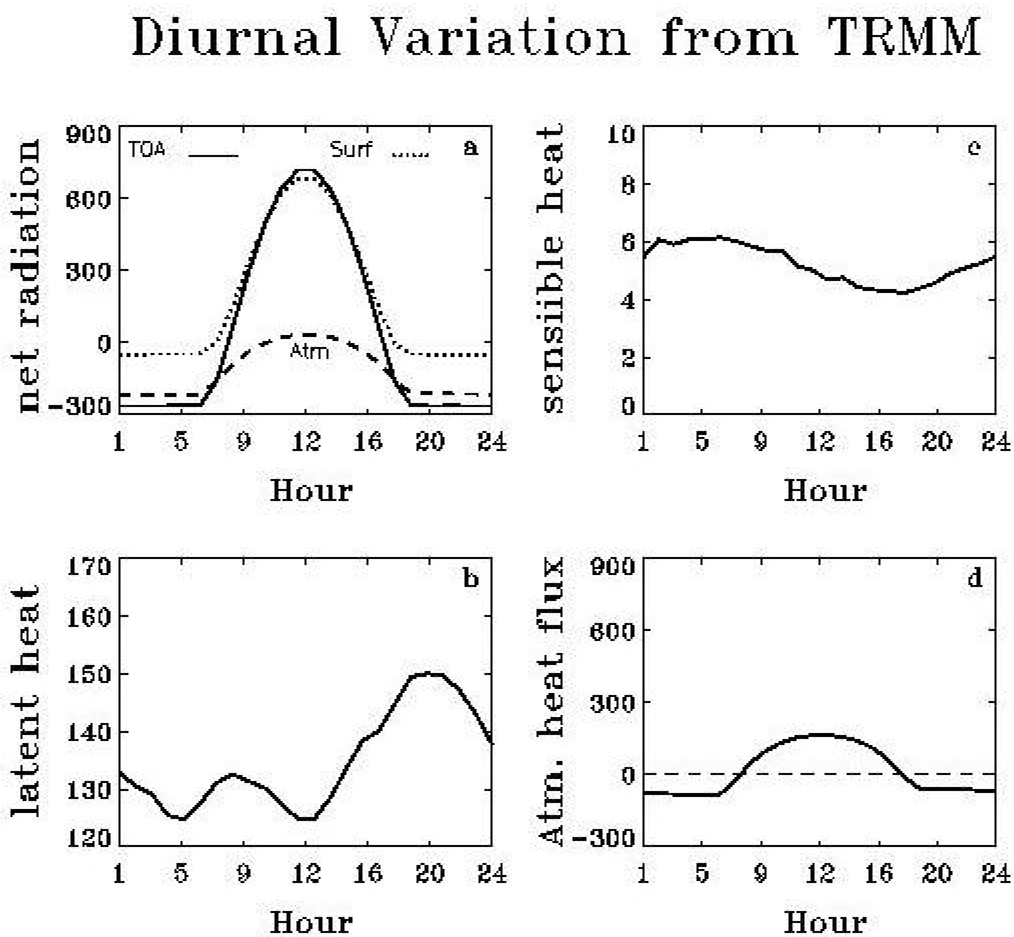

Figure 2: Diurnal variation for (a) net radiation flux, (b) latent heat, (c) sensible heat, and (d) Atm. heat fluxes