Diurnal Variability of Turbulent Fluxes in the Equatorial Pacific

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Introduction

During March and April of 1996, scientists from 13 national research institutions participated in the Combined Sensor Program (CSP) experiment. This program is a collaborative effort of the U.S. Department of Energy (DOE) and the National Oceanic and Atmospheric Administration (NOAA). The CSP 30-day cruise on the NOAA Ship Discoverer originated in American Samoa and traversed west along the equator to Manus Island, Papua New Guinea for intercomparison with the DOE Atmospheric Radiation and Cloud Station (ARCS) within the Tropical Western Pacific (TWP) Cloud and Radiation Testbed (CART) site. After a 10-day stay in the vicinity of Manus Island, the cruise reversed track and continued east along the equator to the International Dateline, ending in Honolulu. The NOAA Environmental Technology Laboratory (ETL) installed a variety of in situ and remote sensing systems on board the Discoverer, and the ETL air-sea interaction group provided instrumentation for bulk meteorological and turbulent flux measurements. A full description of the CSP can be found in Post et al. (1997) and at the ETL CSP web site (http://www4.etl.noaa.gov/csp.html).

The surface heat flux balance in the tropical central/western Pacific plays a fundamental role in large-scale cloud processes, water vapor distribution, and global climate processes. In particular, the diurnal variability of the surface heat flux and sea-surface temperature (SST) have been observed to have a strong effect on local convective processes (e.g., Fairall et al. 1996a). During the CSP, ETL instruments were deployed to measure the surface-layer heat and momentum fluxes, SST, air temperature and humidity, cloud statistics (see White et al. 1998), and radiative fluxes. We examine the diurnal variation of these important components of the air-land-sea system in order to provide a statistical, climatological description for the equatorial marine boundary layer. This information is instrumental for interpretation of the data sets obtained during the CSP from the large suite of remote sensing instrumentation deployed on the Discoverer and Manus Island.

Instrumentation and Processing

The surface layer turbulent fluxes of momentum, heat and moisture are fundamental descriptors of the state of the marine boundary layer. Their accurate estimation is essential for the interpretation of the remote sensing systems deployed during the CSP. The sonic anemometer/ thermometer and fast-response infrared hygrometer have become the standard instruments for making the turbulent flux measurements. ETL deployed these instruments at the top of a 20-meter mast on the foredeck of the Discoverer. The inertial-dissipation method (Fairall et al. 1990) was employed to estimate the turbulent fluxes on the 10-minute time scale. In addition, the mean atmospheric variables (SST, air temperature, humidity, solar irradiance, downwelling infrared irradiance, and rain rate) were measured with the standard suite of slow-response instruments (thermistor, thermometer, hygrometer, pyranometer, pyrgeometer, and optical rain gauge, respectively). For comparison, the 10-minute mean measurements were used as input to the Tropical Ocean Global Atmosphere-Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) Bulk Flux Algorithm (Fairall et al. 1996b). All of these products were then averaged with respect to the hour (UTC) of the day, providing us with a description of the diurnal behavior of each. In addition, standard errors were computed to demonstrate the variability of each atmospheric parameter. Finally, the products were also bin averaged with respect to mean wind speed, which allows us to view the condition-dependent behavior of the boundary layer.

Results

Figures 1 through 7 demonstrate the outcome of the diurnal averaging of the mean quantities and turbulent fluxes. Error bars are shown as vertical lines in the plots. In Figure 1, we see that the maximum wind stress appears in the middle of the day. This is consistent with the wind speed maximum and the observation in Figure 2 that the sensible and latent heat fluxes are maximum at the same time of day. In Figures 1 and 2, we show the comparison of the inertial-dissipation (solid lines) flux estimates with those obtained from the TOGA-COARE Bulk (dashed lines) Flux Algorithm (Fairall et al. 1996b). The stress estimates are consistent for both methods, but the sensible and latent heat flux estimates show significant differences. Figures 3 and 4 show the results from averaging the mean quantities and inertial-dissipation flux estimates within wind speed bins. Notice that the SST is coolest for strong winds, but that the heat fluxes are greatest for these same conditions.

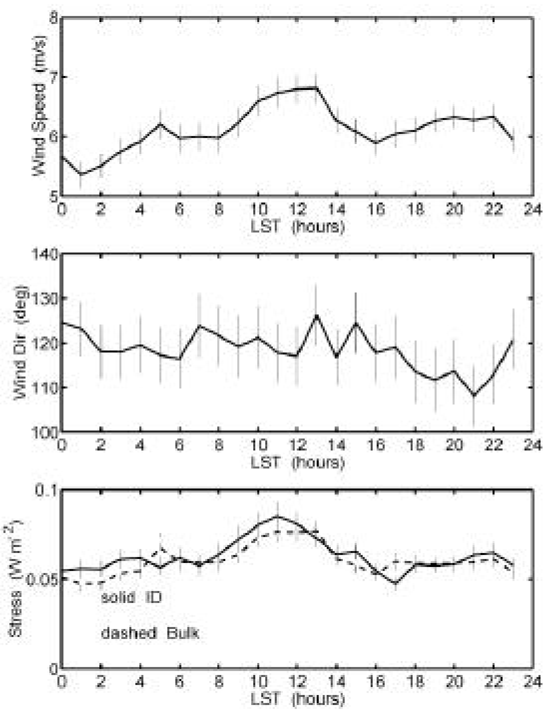

Figure 1. CSP wind and stress.

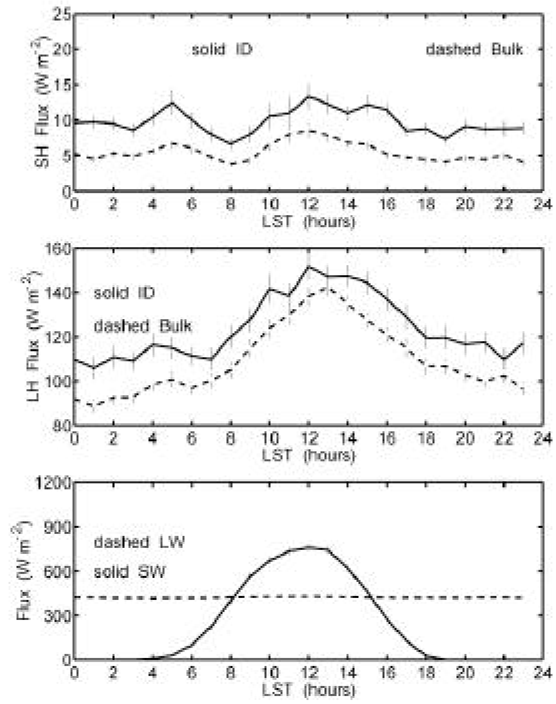

Figure 2. Sensible/latent heat, radiative flux.

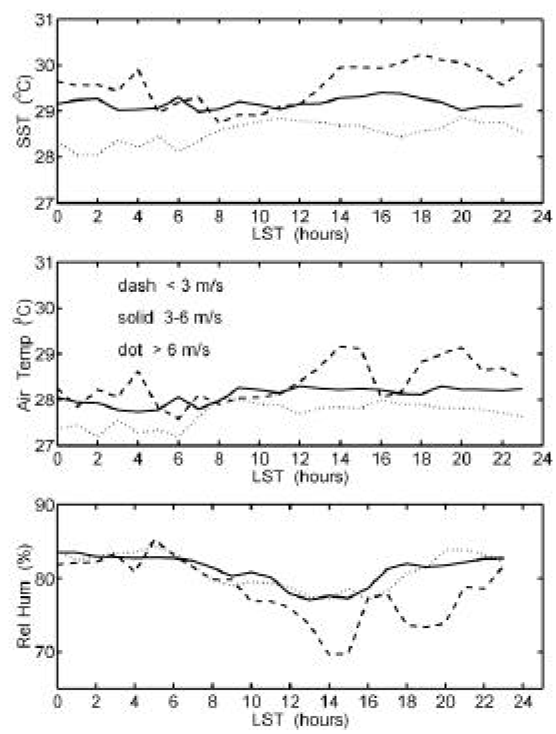

Figure 3. SST, air temperature and humidity averaged in wind speed bins.

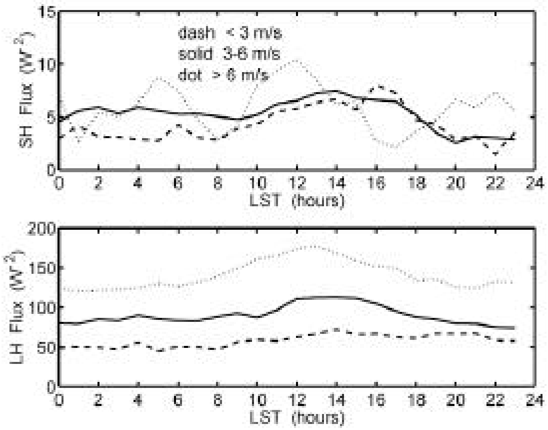

Figure 4. Sensible and latent heat fluxes averaged in wind speed bins.

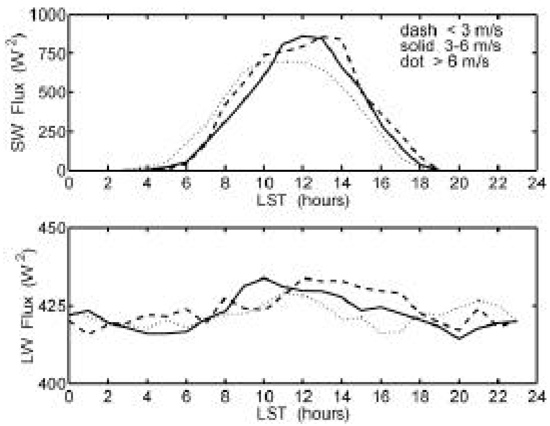

Figure 5. Shortwave and longwave radiative fluxes averaged over wind speed bins.

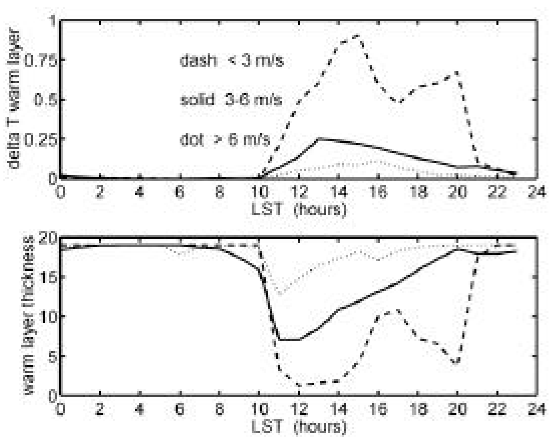

Figure 6. Warm layer characteristics output from the TOGA-COARE bulk algorithm.

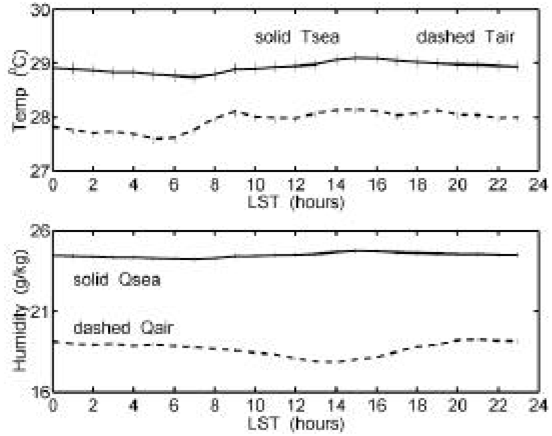

Figure 7. Diurnal equatorial SST, air temperature, sea surface specific humidity, and air specific humidity.

Conclusions

We have shown the diurnal characteristics of the marine atmospheric surface layer mean and turbulent quantities. The variability of the SST and surface heat fluxes are instrumental in the heat balance over the tropical ocean. The observations presented here are important to describe the climatological nature of the tropical marine boundary layer and to assist in the interpretation of the variety of remote sensing systems on board the R/V Discoverer and at the ARCS site on Manus Island.

References

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