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Surface Diurnal Variations — A Link Between Solar Heating and Diurnal Cycle of Tropical Convection?

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1. Introduction

The diurnal cycle of moist convection has been observed in many previous studies. It seems to be a function of geographic locations. The reason for the diurnal cycle of convection is not hard to understand over some locations where various localized circulations (e.g., sea-breeze, nocturnal-jet, etc.) are dominant. *The mechanism for the existence of the diurnal cycle in tropical oceanic convection are not well understood.* In this study, we examine the relationship between diurnal cycle of tropical oceanic convection and surface properties (e. g., SST, T_{air}, and surface humidity) over the western Pacific warm pool.

2. Data

Surface measurements from the TAO (Tropical Ocean and Atmosphere) and WHOI (Woods Hold Oceanography Institute) buoys collected during TOGA COARE (Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment, November 1992-February 1993) are analyzed to examine the surface diurnal variations. Hourly GMS infrared data with 10-km resolution is used to examine the diurnal cycle of clouds over the COARE domain (152°-180°E and 10°N-10°S).

3. Results

a. The diurnal cycle of deep convection

The percent high cloudiness (PHC, fractional coverage of cloud tops by various temperatures, 208 K, 235 K, and 260 K) are shown (Fig. 1) for the maritime continent and the COARE IFA (Intensive Flux Array, centered at 156°E and 2°S over the western Pacific Ocean). Over the ocean, the area coverage of very cold cloud tops (< 208 K) peaks in the early morning hours (0300-0600 LST). It is followed by a increase of successive warmer cloud tops (235 K and 260 K) after sunrise and through the afternoon. A similar observation in surface measured rainfall is shown by Janowiak et al. 1994. Over the maritime continent, this phase lag from very cold to warmer cloud tops is also evident, but with a much short time period (i.e., a few hours). These results indicate that the diurnal cycle of the cold cloudiness is associated with the lifecycle of convective systems (or cloud clusters) as they grow during the night and decay after sunrise.

Cloud clusters, defined as a closed contour of an IR temperature (208 K), are divided into four size quartiles over the COARE domain (Chen et al. 1995). The diurnal cycle of the cold cloudiness is stratified according to the size of the cloud clusters (Fig. 2). The smallest clusters had a very small amplitude of diurnal variation, while the largest clusters had a strong diurnal variation with a amplitude (dawn-to-dust ratio) of 10:1. Most of the diurnal cycle of PHC was contributed by the largest cluster quartile. Again, the size dependency of the diurnal cycle indicates the lifecycle of convective systems play an important role.

The cloud clusters are tracked in time (Williams and Houze 1987) so that the lifecycle of convective systems (contains one or more cloud clusters at a given instant) can be identified. The results of tracking show that most of large convective systems (Class 4 > 92,800 km^{-2}) were initiated in the afternoon and reached their maximum size during the night and early morning hours (Fig. 3b). The lifetime of these large systems are generally > 12 h (Chen et al. 1995). There are two maxima in the starting time (afternoon and predawn) for smaller convective systems (Class 1 < 6800 km^{-2}, Fig. 3a). The lifetime of most small convective systems are only a few hour. This result is not surprising given that some small convective systems are initiated in the afternoon for the same reason as the large systems and other small systems are either split from the large systems or triggered by cold pools of large systems during the night and early morning hours while the large convective systems are most active.

b. Surface diurnal variation

Spectral analysis of surface data from the TAO buoys shows a strong diurnal peak in SST, T_{air}, and RH. The diurnal cycle of other surface properties, such as specific humidity and air-sea fluxes, are relatively weak. In order to isolate the surface diurnal variability, without the influence of convection, we composite only the non-cloudy days from the four months TAO buoy data. Figure 4 shows the composite surface T_{air}, q (specific humidity), θ_e, and SST. The T_{air} and θ_e increase rapidly after sunrise and reach a diurnal maximum during the afternoon, while SST increases several hours later. Figure 5 shows the TOGA COARE composites from the WHOI buoy, including RH, T, SST, and solar flux, which have a consistent diurnal cycle compares to TAO buoy data. The increase of T_{air} follows the solar heating closely from sunrise to early afternoon, while SST changes rather slowly and several hours behind the solar heating. In comparison with Fig. 3, the frequency of initiation of new convective systems increases from 0900 to 1500 LST, which is consistent with the T_{air} variation.

c. Summary

The diurnal cycle of tropical deep convection over the COARE domain is related to the lifecycle of convective systems. Preliminary analysis of the buoy data suggest that the surface diurnal variability may play an important role in the initiation as well as the lifecycle of convective systems over the tropical ocean. The diurnal cycle of tropical convection and surface properties in relation to various large-scale flow regimes (e.g., convectively active and suppressed phases of the intraseasonal oscillation) is currently under investigation.

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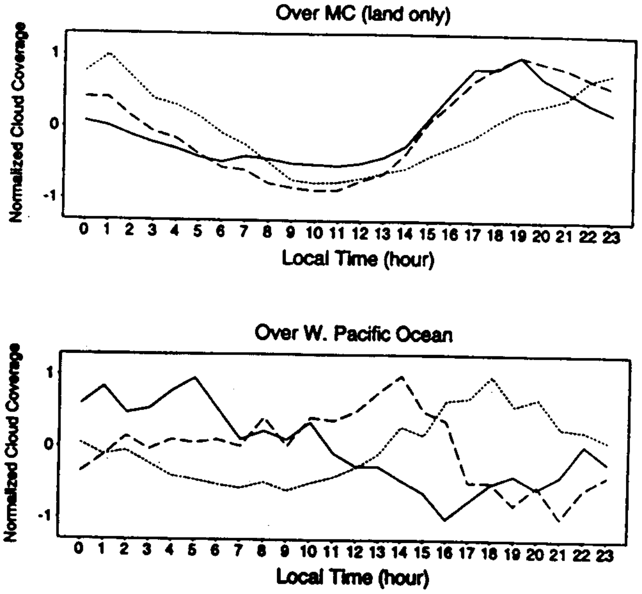

Fig. 1 Diurnal cycle of percent high cloudiness (PHC, the fractional coverage of cloud with IR temperature < 208 K, solid line; < 235 K, dashed line; and <.260 K, dotted line). (a) over the maritime continent and (b) over the ocean (152°-180°E and 10°N-10°S).

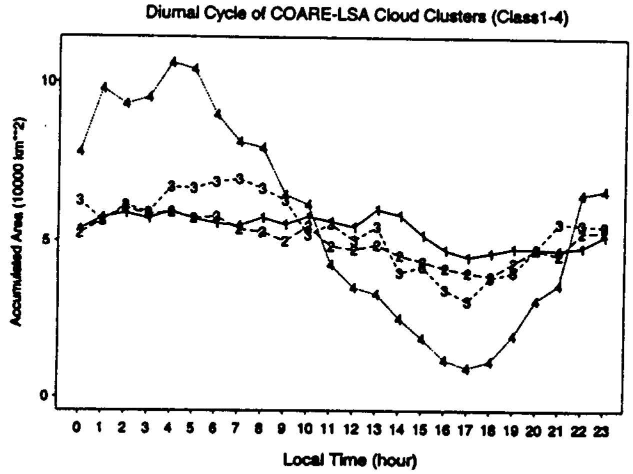

Fig. 2 Diurnal cycle the accumulated cloudy area covered by the 208 K cloud clusters over the domain of 152°-180°E and 10°N-10°S, for each of the four size classes.

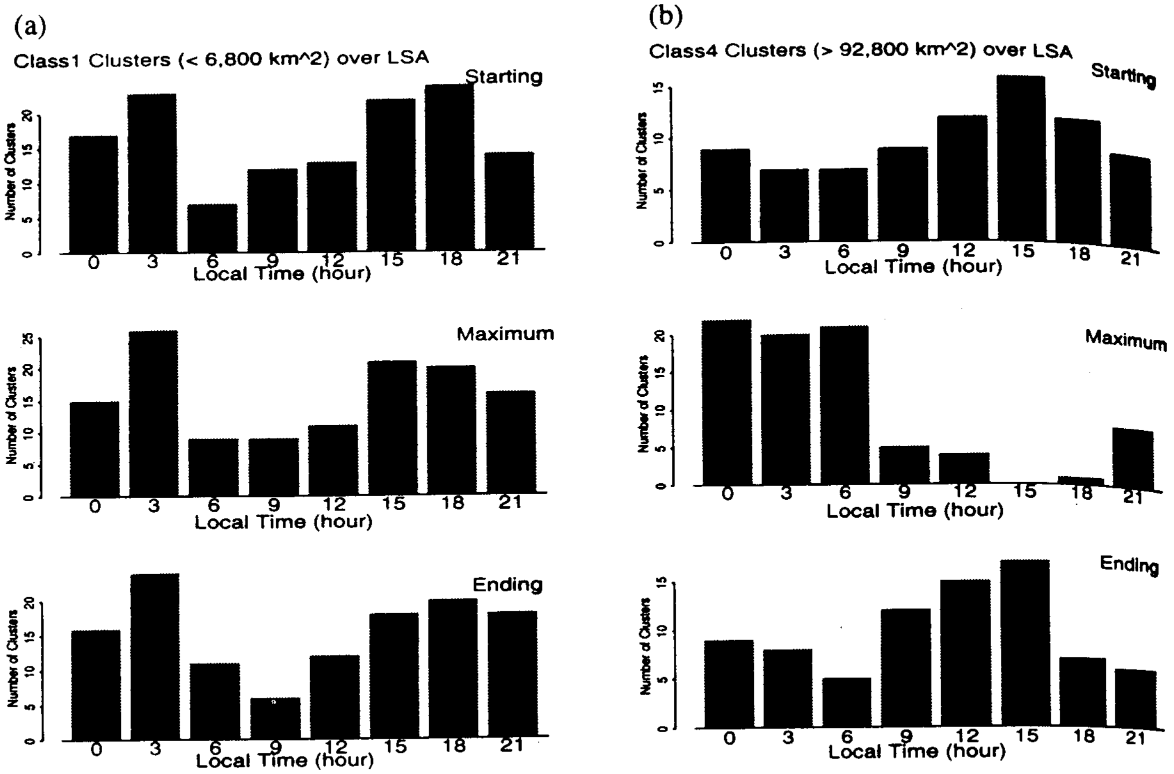

Fig. 3 Lifecycle (starting, maximum, and ending times) of convective systems tracked in time and space. (a) Class 1 systems, (b) Class 4 systems.

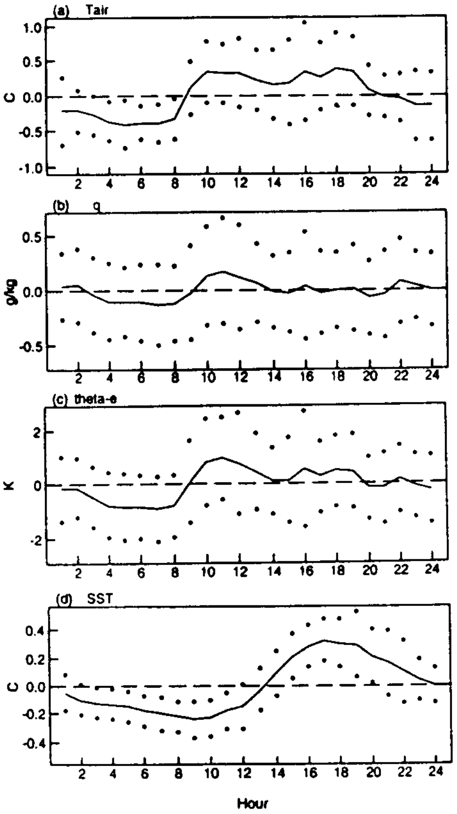

Fig. 4 Surface composite of diurnal variations (solid line; standard deviation, dotted line) from TAO buoys (156°E-2°S, 157°E-0°) for all non-cloudy days during TOGA COARE. (a) T_{air} , (b) q, (c) θ_e , and (d) SST.

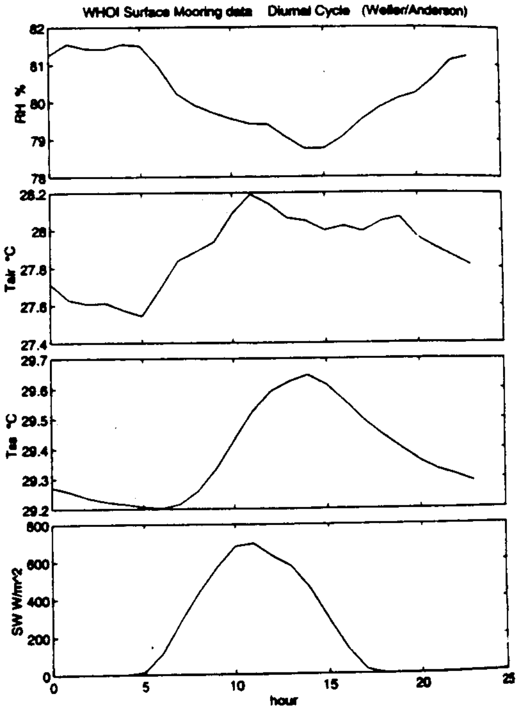

Fig. 5 Surface composite of diurnal variations from WHOI buoy (156°E-1.75°S). (a) RH, (b) T_{air}, (c) SST, and (d) solar flux.