Diurnal Cycle Characteristics During TiMREX: Disturbed vs. Undisturbed Periods

Chun-Chih Wang[1], Richard H. Johnson[2], Paul E. Ciesielski[2], James H. Ruppert[2]

INTRODUCTION:

It has been well documented that diurnal land-sea breezes have a strong influence on the precipitation pattern in Taiwan, especially during summer monsoon seasons (Johnson and Bresch 1991). The interaction between land-sea breezes and low-level southwesterly monsoon flows has created a noticeable precipitation pattern in Taiwan, with precipitation maxima over land during the daytime and a shift offshore during the nighttime. However, this diurnal characteristic is sometimes marred by the presence of fronts, convection, and cloud cover (Johnson and Bresch, 1991). Local topography also affects diurnal cycles and surface flows (Wallace, 1975). This research project investigates the influence of cloud cover on the degree of surface heating and strength of land-sea breezes. Since land-sea breezes and topography affect the intensity, timing, and location of rainfall, it is important to understand the complex relations between the surface flows and mountainous terrains of Taiwan (Yeh and Chen, 2000).

METHODS:

The percent cloud cover over the island was estimated by examining color-enhanced MTSAT infrared satellite images hourly from 00-06 UTC (08-14 LST) during the intensive observation period of the 2008 Terrain-influenced Monsoon Rainfall EXperiment (TiMREX) (Ciesielski et al. 2010). Clouds with apparent temperatures below 273 K were identified as cloud cover.

A list of field experiment days was divided into disturbed and undisturbed categories. Days (mornings) with >50 percent average cloud cover were classified as disturbed days and vice versa for the undisturbed days.

Instrument bias and data errors associated with the gridded upper air sounding data collected during the 2008 TiMREX field experiment were removed by using quality control methods developed by Ciesielski et al. (2010).

Sounding data from the TiMREX enhanced sonde network was objectively analyzed onto a 0.25 degree grid at 6 hr, 25-hPa vertical resolution, using multiquadratic interpolation (Nuss and Titley, 1994). QuickScat winds over the ocean and data from 168 surface sites over Taiwan were combined to create a 0.25 gridded product at the surface. (See Appendix I)

Diurnal potential temperature changes, surface winds and divergence, vertical motion near the surface, and six-hourly smoothed TRMM 3B42 rainfall rates for the undisturbed and disturbed periods were analyzed and plotted by using NCARGraphics visualization tool.[N1]

The fields were averaged for an area focused over Taiwan[D3] at 00, 06, 12, and 18 UTC to illustrate the differences between the undisturbed and disturbed periods.

Wind vectors normal to the coastline were computed for fourteen grid points along the western coast of Taiwan at 06 and 18 UTC for both periods to demonstrate land-sea breeze intensity differences.

RESULTS:

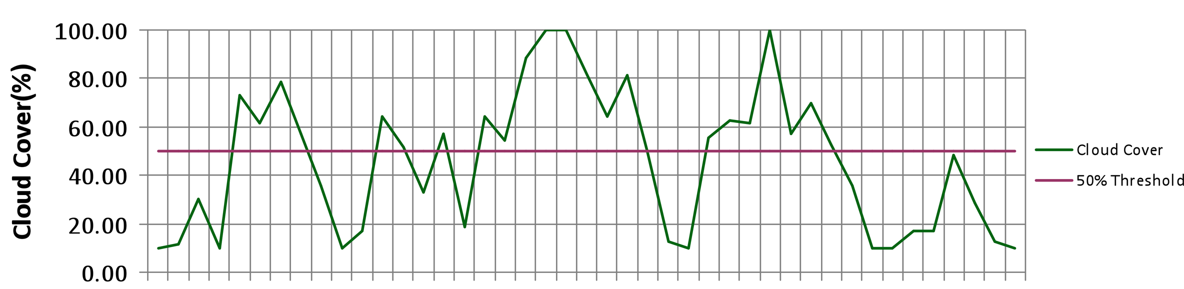


Fig. 1. A time series of 00-06 UTC cloud cover from May 15th to June 26th.

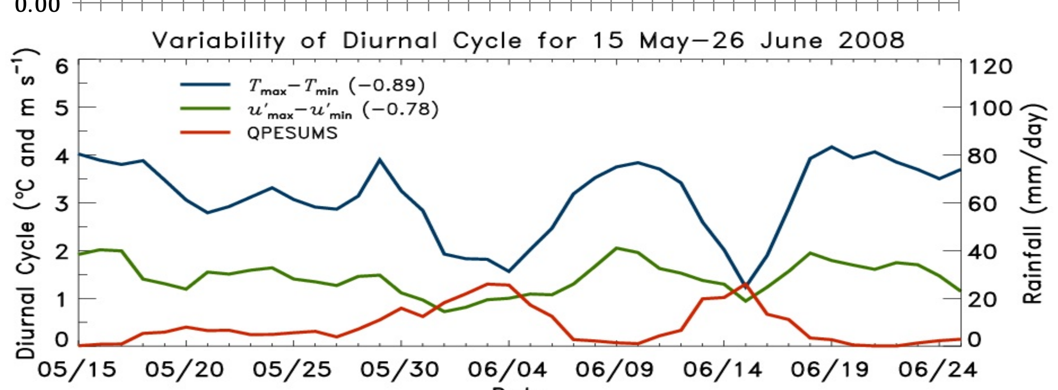


Fig. 2. A time series of diurnal temperature changes (blue), changes in u-vectors normal to the coastline (green), and QPESUMS rainfall (red). The actual correlation numbers in respect to QPESUMS rainfall are included in parentheses.

Fig. 2 courtesy of James Ruppert[4]

RESULTS (CONTINUED):

II. Surface Divergence (10 x 10^{-6} s^{-1} / contour):

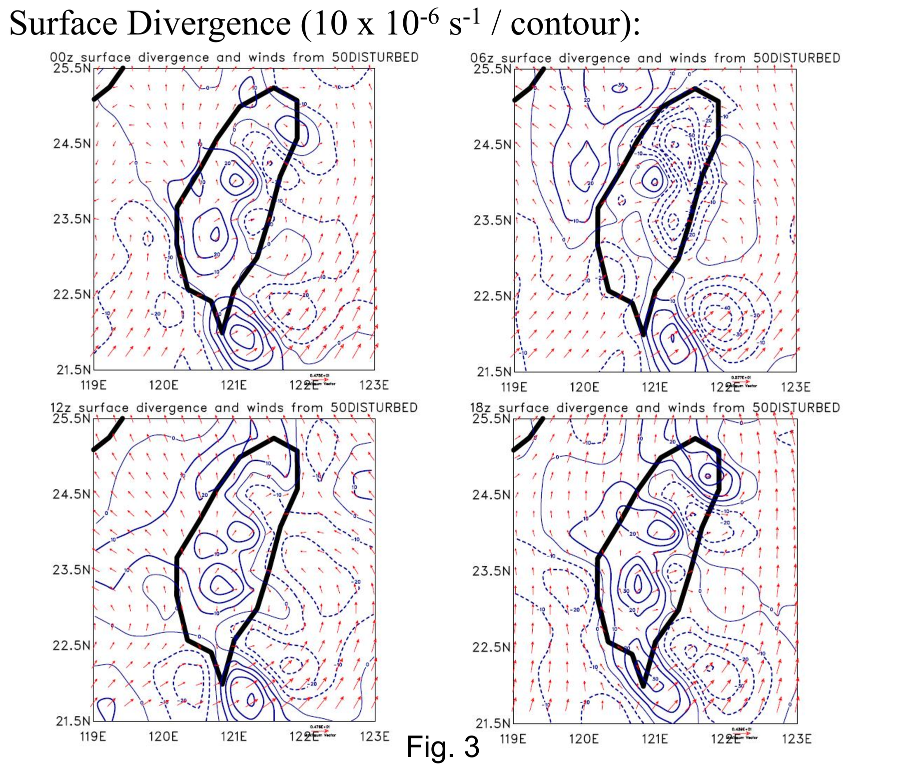


Fig. 3

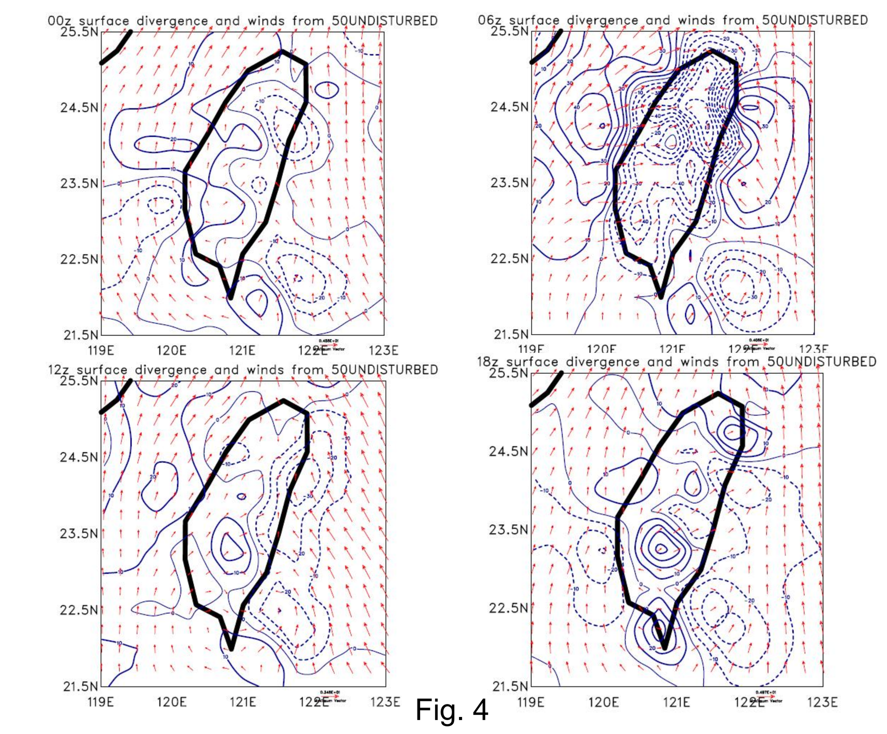


Fig. 4

Fig. 3 and Fig. 4 show the diurnal surface divergence during the disturbed and undisturbed periods. Note that the magnitude of daytime surface convergence was greater and the timing lasted well into the night during the undisturbed period.

III. Vertical Motion (2 mb hr^{-1} / contour)

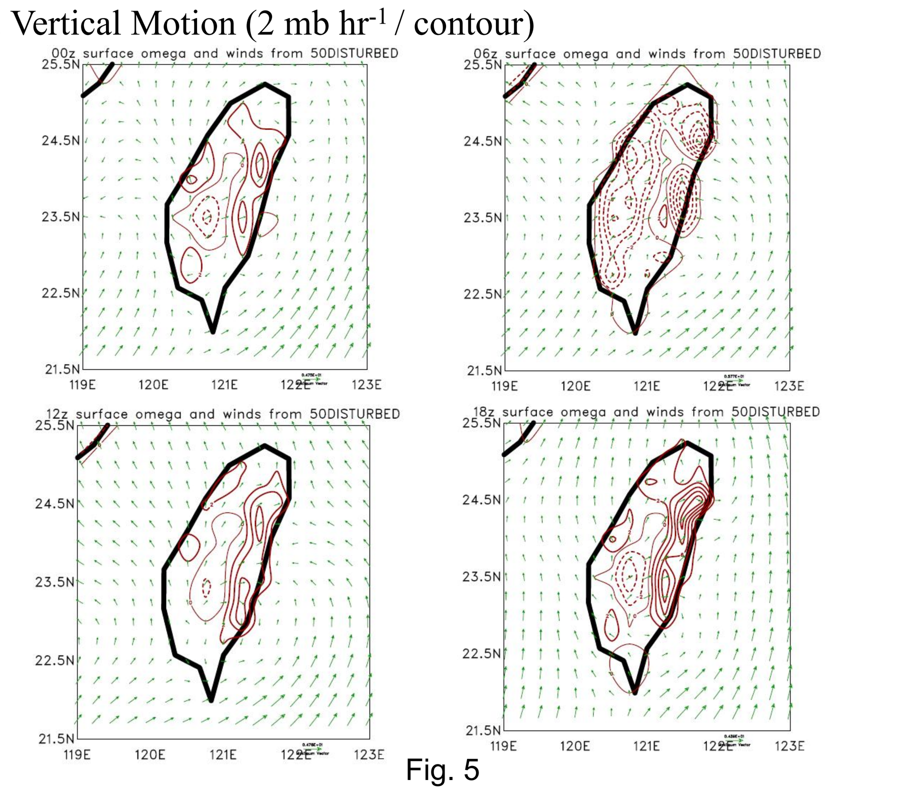


Fig. 5

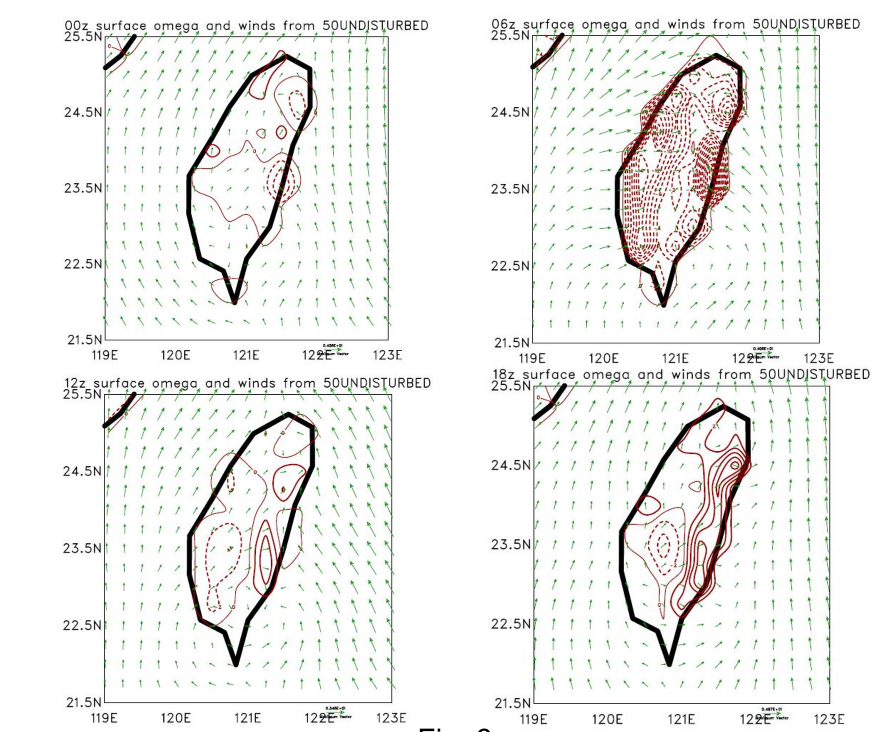


Fig. 6

Fig. 5 and Fig 6. show the diurnal vertical motion near the surface during the two periods. Note the earlier initiation of upward motion in the morning and delayed downslope flows at night for the undisturbed period.

IV. TRMM Rainfall and Surface Winds

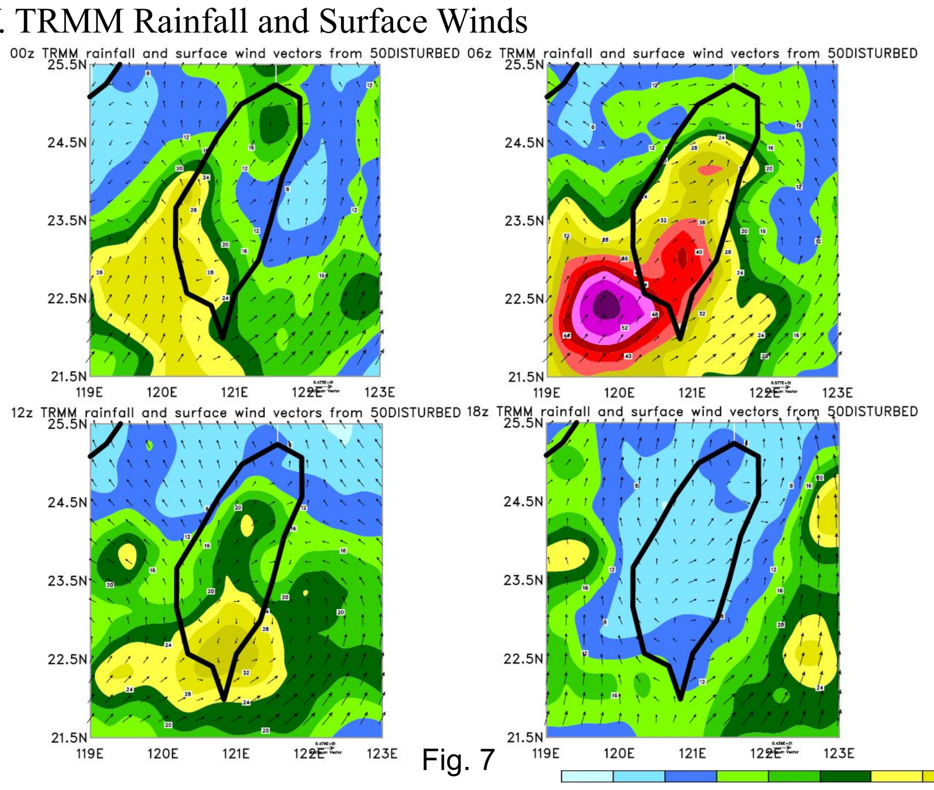


Fig. 7

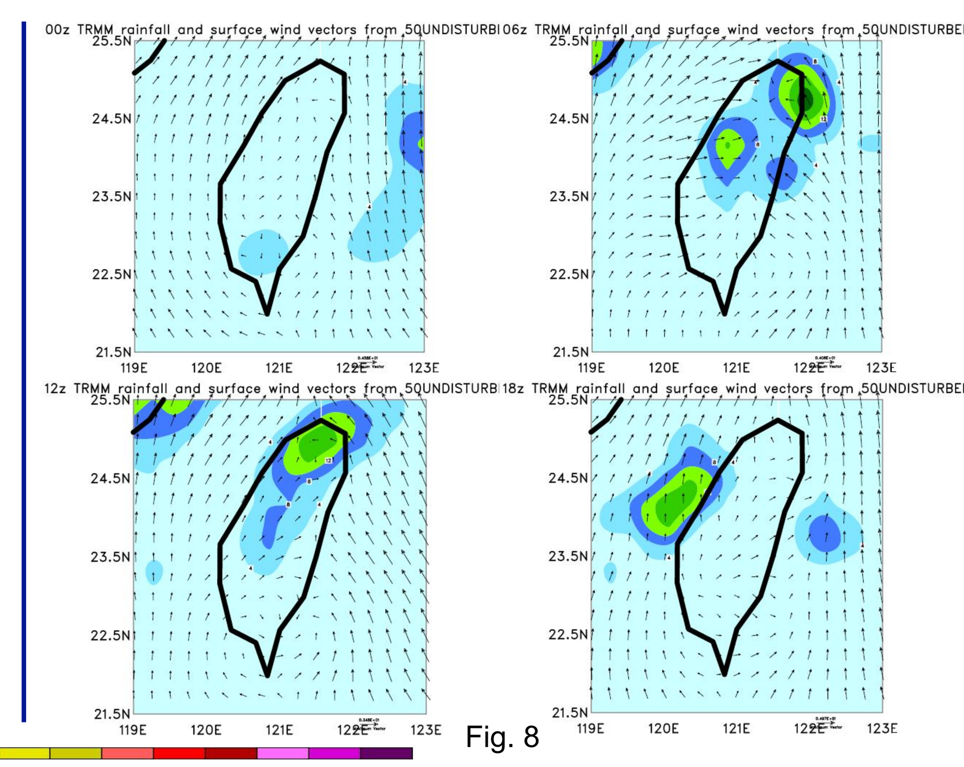


Fig. 8

The diurnal surface wind pattern and TRMM rainfall analysis from Fig. 7 and Fig. 8 show that land-sea breezes existed during both the disturbed and undisturbed periods. However, afternoon winds normal to the western coastline during the undisturbed period were 109% stronger than the disturbed period's. The disturbed period exhibited greater rainfall rates but concentrated mainly offshore.

V. Result Summary (Average Diurnal Differences)

	Disturbed	Undisturbed
18-00Z	1.32	1.92
00-06Z	1.27	2.12
06-12Z	-1.90	-2.90
12-18Z	-0.68	-1.13

6hr Potential Temperature Change (K)

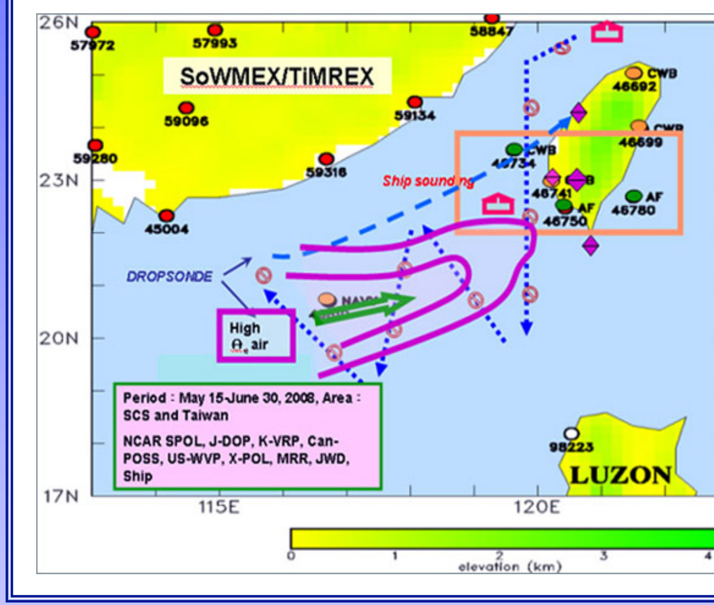
	Disturbed	Undisturbed
00Z	2.94	0.74
06Z	-9.31	-14.94
12Z	0.41	-4.97
18Z	2.90	-2.03

Surface Divergence (10^{-6} s^{-1})

	Disturbed	Undisturbed
00Z	0.55	-0.06
06Z	-1.43	-3.42
12Z	0.79	0.00
18Z	0.91	0.89

Near-Surface Vertical Motion (mb/hr)

EXPERIMENT SETUP



The 2008 Terrain-influenced Monsoon Rainfall EXperiment (TiMREX) was aimed to study the physical processes of orographical lifted precipitation and improve quantitative rainfall forecasting.

Appendix I. A diagram of dropsondes, rawindsondes, surface observation and radar sites deployed during the 2008 TiMREX.

DISCUSSION:

The 18 UTC winds normal to the western coastline during the undisturbed period were 24% weaker than the disturbed period's. This is somewhat unexpected because one would anticipate stronger land breezes on clear nights. However, since this project only considered the cloud cover from 00-06 UTC to identify the days with greater surface heating, the nighttime cloud cover was overlooked. If we had also considered the nighttime cloud cover, the results might have turned out differently at 18 UTC. In addition, there is probably not a large enough sample size (40 days) to obtain statistically meaningful results.[D1]

The differences between the two periods cannot be entirely attributed to the amount of cloud cover and surfacing heating. A major portion of the disturbed period was significantly influenced by synoptic features, such as the Mei-yu front over Taiwan from June 1st to June 8th. Future studies would have to take the effects of these features on surface flows, vertical motion, and rainfall rates into account.[D2]

The average diurnal vertical motion, divergence, and potential temperature changes were calculated using data retrieved from a smaller domain from 22.00N to 25.25N and from 120.25E to 122.00E to limit the effects of interpolated data over the ocean on the calculations. Thus, the calculated values were not completely representative of those just over land.[D3]

CONCLUSION:

While diurnal variations were present during both undisturbed and disturbed periods, their strength was enhanced during the undisturbed period, particularly daytime sea breezes, vertical motion and surface convergence. Data from SouthWest Monsoon EXperiment (SoWMEX) 09 and 10 will be used to validate the relationships observed in this research project. Future studies could also incorporate detailed cloud, surface heating, and land canopy data for quantitative modeling of diurnal surface flows and convection.

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1 Department of Meteorology, The Pennsylvania State University Email: cyw5059@psu.edu
2 Department of Atmospheric Sciences, Colorado State University

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