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Subtropical Oceanic Mesoscale Convective Vortex Observed during SoWMEX/TiMREX

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1. Introduction

The joint U.S.-Taiwan multi-agency field experiment SoWMEX (Southwest Monsoon Experiment)/ TiMREX (Terrain-influenced Monsoon Rainfall Experiment) was held during the period of May 15 to June 30, 2008. The southwest monsoon flow, which is located along the south side of the Meiyu front, usually transports high-θe environmental air northeastward and produces an environment of strong horizontal moisture contrast and horizontal wind shear (Chen and Yu 1988). The wind shear zone often extends from a wavy meso-scale disturbances and moves eastward or east-northeastward (Chang et al.1998; Ding 1992; Chang et al. 2000; Yamasaki 2005). In this sense, the Meiyu front is better characterized as a narrow strip of cyclonic vorticity than a true atmospheric front. The strong shear vorticity have been documented through ideal simulations (Kuo and Horng 1994; Du and Cho 1996), real case simulations (Zhang et al. 2003) and synoptic weather analyses (Chen et al. 2008). Furthermore, the intensive observations of SoWMEX/TiMREX provided scarce data to investigate the sub-synoptic environment and structure of the MCSs accompanying the strong cyclonic vorticity within the southwest monsoon flow upstream of Taiwan.

2. Subtropical oceanic mesoscale convective vortex

During the Intensive Observing Period (IOP) 6 of SoWMEX/TiMREX(04 Jun 1800UTC - 06 Jun 1200 UTC), a quasi-stationary Meiyu front stretched across the middle of Taiwan. A serial series of MCSs occurred south of the front and spaced approximately 400-500 km apart. A pronounced oceanic mesoscale convective vortex (MCV) developed within one of these MCSs. Visible satellite images captured the clear spiral cloud associated with cyclonic circulation (Fig1). Taiwan Cigu radar detected the condensed MCV characterized by dipolar radial velocity. The observed maximum radial velocity exceeded 30ms^{-1}, and the radius of maximum wind (RMW) of the MCV was less than 100km. The observed vorticity maxima close to the cyclonic circulation center reached 5x10^{-4} s^{-1}. The MCV motion vector was from 251° at 5.74 m s^{-1}, that is, directly toward Taiwan. The associated strong convection brought heavy rainfall inland.

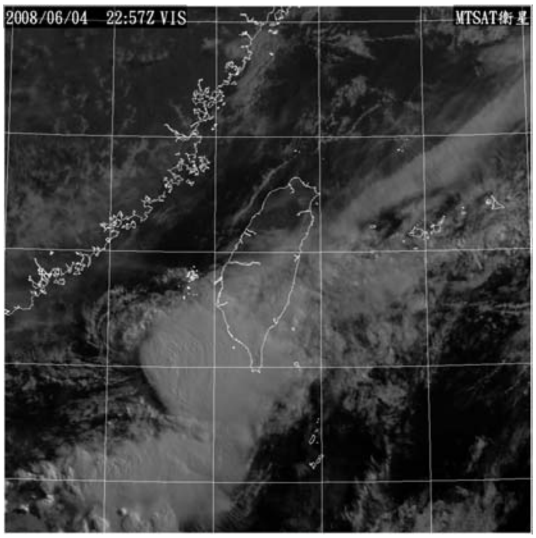

FIG 1 Visible satellite image at 2257 UTC 04 June 2008.

For the sake of exploring the kinematic and thermodynamic characteristics of the subtropical oceanic MCV, high density sounding network over land and two dropsonde flight missions over sea during IOP6 were launched to observe the exceptional MCV. Both plan perspectives and

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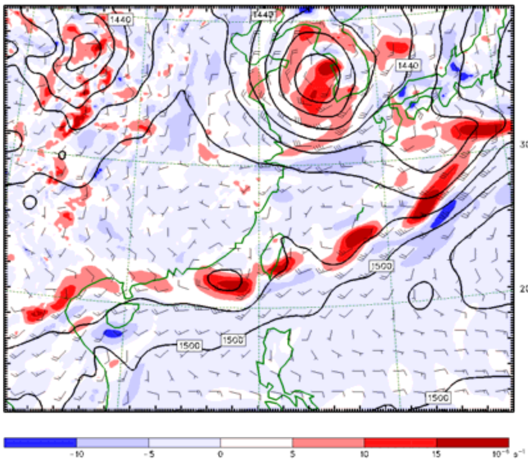
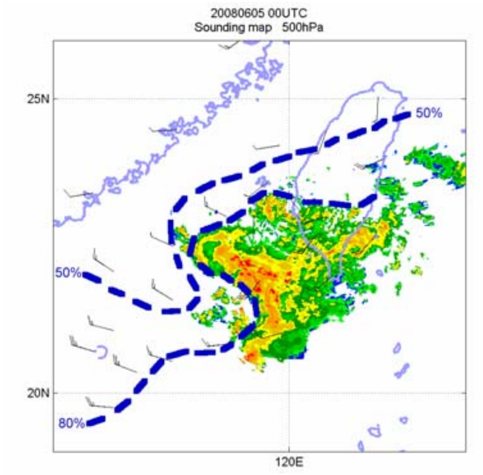


FIG 2 700-hPa geopotential hight (contour interval = 150m), relative vorticity (interval = 5 x 10^{-5} s^{-1}) and wind barbs at 1200 UTC 4 Jun 2008.

(a)



(b)

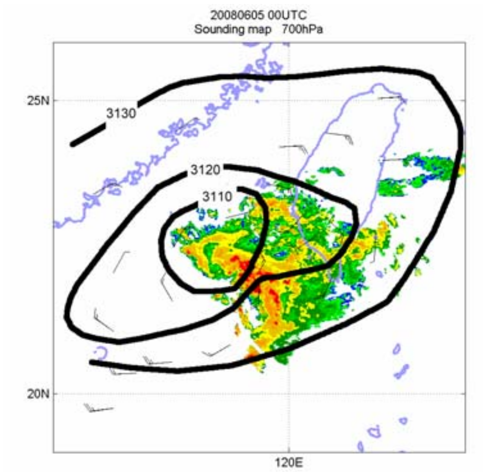


FIG3 Composite radar reflectivity images at 0000 UTC 5 Jun 2008 on (a) 5km and (b) 1.5km surface, respectively, superposed with (a) Relative humidity at 500hPa; (b) geopotential height at 850hPa.

vertical cross sections of these soundings were constructed to examine the MCV structure. Relevant wind derivatives via triangle approach also were employed (Bellamy 1949; Spencer and Doswell 2001; Davis and Trier 2007).

3. Synoptic environmental features

The narrow vorticity strip associated with the Meiyu front elongate almost 3000 km between 500hPa and lower troposphere (Fig2). The strong vorticity passing through the Taiwan Strait lasted about 48 hrs. The convection of the MCS was principally distributed in the eastern-southeastern periphery of the MCV center, and the northwestern area was clear. The cyclonic circulation and meso-low accompanying the MCS were apparent on the 700 hPa surface. The westerly low level jet (LLJ; Chen and Yu 1988) as the south part of the cyclonic circulation transported the moist air and created high CAPE environment, and increased convective instability. The adiabatic subsidence related to the deep trough, which was at higher troposphere in the midlatitude, and associated warm and dry air over the northern part of the MCV were revealed(Fig 3).

4. Kinematic and themodynamic structure

The east-west vertical section of meridional wind component exhibited distinct cyclonic circulation below 5 km with nearly upright structure (Fig 4). In general, the diameter of the MCV was about 250 km. The stronger tangential velocity couplet was revealed between 1.5 and 3 km. The average vertical wind shear between 500-900 hPa was less than 6 m s^{-1}. The strong convection occurred in the southerly wind region. No stratiform reflectivity was observed. The low tropospheric meso-low and the vorticity center fell 50km behind the main convection and temperature ridge. The convection enhanced in the vicinity of the coastline and southerly flow strengthened over the terrain. However, the mid layer of the convection became dryer.

5. Discussion and remarks

1. A narrow strip of horizontal shear, which is composed of westerly LLJ as the south part and easterly wind accompanying mid-high tropospheric deep trough subsidence as the north part, provided strong environmental vorticity. Both the strong convective updraft in the eastern-southeastern periphery of the MCV center and adiabatic subsidence in the northwestern area are contributed to

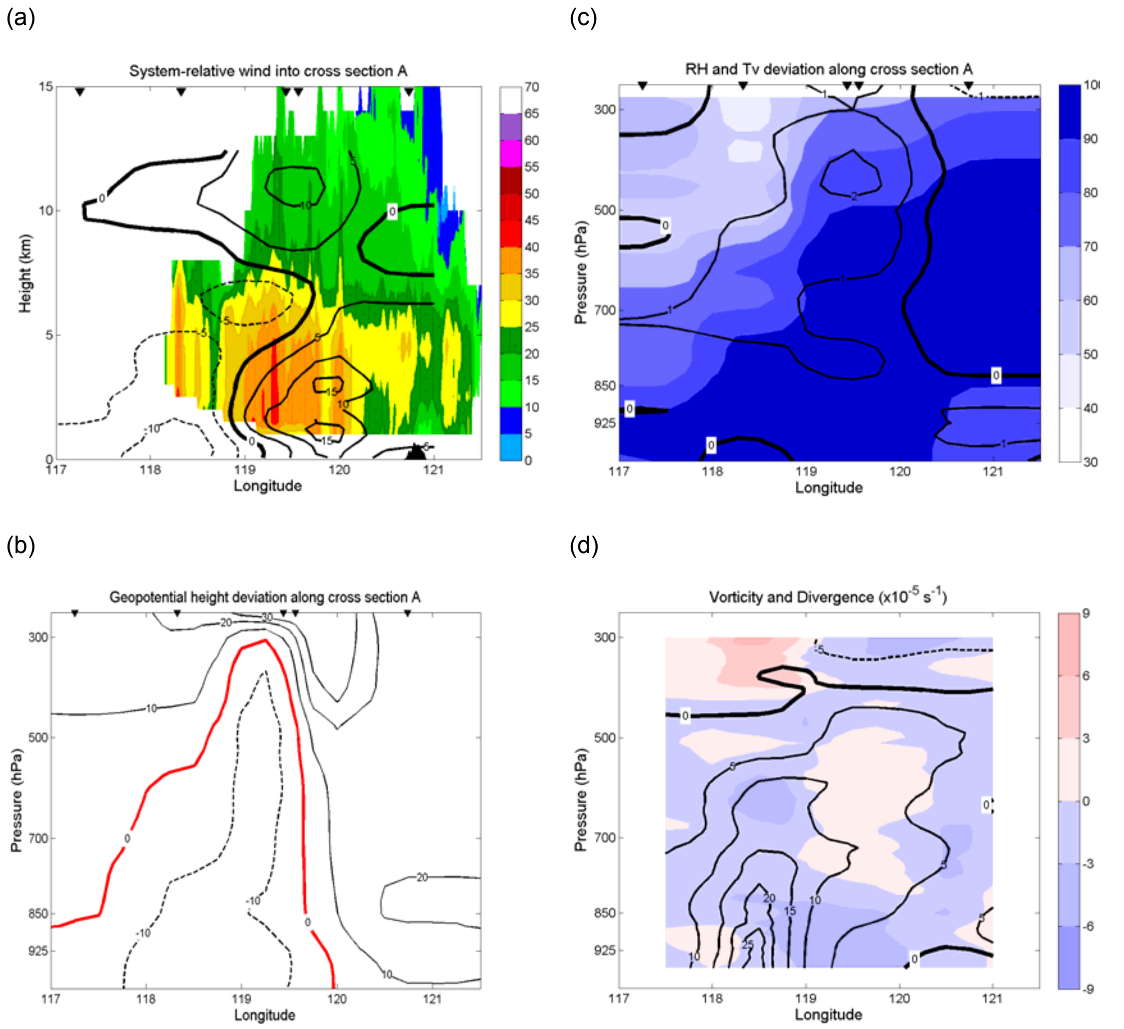


FIG4. East-west vertical cross sections through the center at 0000 UTC 5 Jun 2008. (a) reflectivity superpose meridional wind component contoured in intervals of 5 m s^{-1}. (b) geopotential height deviation with contour interval 10m; (c) relative humidity and virtual potential temperature deviation withcontour interval 1K; (d) divergence in color shading intervals of 3×10^{-5} s^{-1} and relative vorticity contoured in intervals of 5×10^{-5} s^{-1}.

cyclogenesis. However, the frontolysis resulting from adiabatic heating and relative weak vertical wind shear are unfavorable to the baroclinic disturbances building. The dry air entrainments also inhibit the deep convection and mature barotipic cyclones. Finally, the terrain effect destroyed the vortex.

2. The cyclonic circulation of the MCV condensed beneath 5km with diameter of 250 km. The maximum vorticity reached 5×10^{-4} s^{-1} within the inner core. The MCV lasted about 12 hrs and moved eastward. The strong convection occurred in the southerly and westerly wind region, yet the northwestern area was clear. The low tropospheric meso-low and the vorticity center roughly fell 50km behind the main convection and temperature ridge. The convection was fed with moist air delivered by the LLJ, enhanced from the terrain effect and split by the dry air entrainment.

6. *References*

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