# Triggering Mechanisms of Boundary Layer Convections over the Taiwan Area in Spring Season

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**ABSTRACT**

By using the Civil Aeronautics Administration (CAA) ground-based Doppler radar (25.08 deg N, 121.2 deg E) data, the kinemic and dynamic structures of boundary layer convections accompanying with the frontal system over the northern part of Taiwan were investigated. The three-dimensional conceptual models associated with this case were constructed in order to realize the possible mechanisms for triggering boundary layer convections.

The preliminary results show: (1) The Mei-yu frontal systems were quite shallow (less than 1.5 km in altitude) and possessed strong vertical wind shear (more than 14 $ms^{-1}km^{-1}$). The boundary layer convections associated with the shallow fronts could be triggered by the instability of the frontal system and the abundant supply of warm, moist air related to the southwesterly flow. (2) The southwesterly low level jet (LLJ) obviously occurred at altitude between 0.5 km and 1.5 km in intensity of more than 10 m/s in use of high spatial and temporal resolution radar data. The existence of LLJ couldn't be detected by the routine rawinsonde observations and was resulted from the strong pressure gradient force due to the high and low pressure distributions over the Taiwan Island which could be clearly delineated by the surface subjective analysis based on the hourly observation data. (3) The convective cells embedded in the frontal systems could be well organized into convective turbulences due to the following key factors. The first key factor was the confluent effect, which was resulted from the mergence of southwesterly, westerly and/or northwesterly flows and accumulated sufficient air mass and momentum at a specified region. The second one was the local cyclonic motion that made the convective cells well organized and triggered more precipitation over ground. The prevailing southwesterlies had a deceleration in the vicinity of the frontal edge and gave impulses to propagate the convective systems toward northeast within the frontal systems.

## 1. INTRODUCTION

The Mei-yu front in the vicinity of Taiwan in May and June is relatively shallow (cold air depth ~ 1 km) and satellite pictures usually show a long stratiform cloud band along the front with vigorous convection embedded within the band (Chen et al., 1989; Chen, 1993; Chen, 1978; Wang et al., 1990). The primary mesoscale meteorological phenomena related to the Mei-yu front include the mesoscale circulation associated with the Mei-yu front, a density current, a low-level jet (LLJ), pre-frontal squall lines, mountain convection, mesoscale convective systems (MCSs), frontal deformation due to topography, terrain-induced mesoscale circulation, and a land-sea breeze. Li et al. (1997) noted that the existence of an orographically induced barrier jet was located at about 1 km in altitude and suggested that the interactions among the barrier jet, synoptic southwesterly flow and the Mei-yu front determined the regions most favorable for the development of mesoscale convective systems (MCSs). Hor et al.(1998) found a well-define density current and MCSs accompanying with slight rising and sinking motions in a Mei-yu front leading edge and proposed that the intense horizontal pressure gradient force from rear to front in the cold core region and the moderate convective instability at the head of the system as well as the kinetic energy transport from the mean flow were the probable mechanisms for the propagation of the density current and the maintenance of the frontal system as well as the MCSs.

With good coverage obtained by the Civil Aeronautics Administration (CAA) Doppler Radar over the north part of Taiwan, the 18 May 1999 case offers a good opportunity to study the kinematic and dynamics structures of boundary layer convections accompanying with the Mei-yu front over ocean and land and examine the proper mechanisms of triggering and development of organized convections within the frontal system.

## 2. DATA SOURCES AND ANALYSIS PROCEDURES

### a. Data sources

The CAA C-band Doppler radar site is located at the northwest part of Taiwan island. The radar echoes observed by the CAA radar every 10-15 minutes were used to monitor the evolution of the boundary layer convections associated with the frontal system. Surface data (temperature, pressure, relative humidity, wind and precipitation) were used to delineate the surface signatures associated with the frontal systems. The sounding data from Pan-chiao (46692) and Ma-kung (46734) stations were applied to realize the environmental situations inside and outside the frontal system, respectively. The GMS-5 satellite imageries were good evidences to separate the MCSs that were directly related to the frontal system or propagated northward from the warm, moist ocean.

### b. Doppler radar data analysis procedures

Doppler data collected by the CAA radar from 2145 UTC 18 May to 0115 UTC 19 May 1999 were analyzed. The radar beamwidth is 0.86 deg. This means that the linear beamwidth at 20 km from the radar site (about the center of the MCS analyzed) would be about 300m. Thus, mesoscale perturbations with wavelengths of less than 1 km could not be resolved using the radar data. Ground clutter was removed, but no folded radial velocities were corrected due to that the unambiguous velocity is $\pm$ 48 m/s which is much higher than the observed wind speed. Only those data with a high signal-to-noise ratio (a radar reflectivity above 10 dBZ) were accepted for analysis.

## 3. RESULTS AND DISCUSSIONS

During this event from 2145 UTC 18 May to 0115 UTC 19 May, the Mei-yu front accompanying convective cells was approaching the northern part of Taiwan. The combinations of southwesterly, westerly and northwesterly flows initiated the confluent effect and triggered the existing convective cells become more intense. Fig. 1 shows the gradual change of wind direction in the vicinity of radar site estimated from the EVAD scheme from 2145 UTC on 18 May 1999 to 0115 UTC on 19 May 1999 while the frontal system was propagating southeastward. At the southeast side of the radar site, it occurred a strong convergence (>$10^{-3}s^{-1}$ in intensity) at the altitude of 0.75 km (see Fig.2). However, there were no intense convective cells along the frontal edge, probably due to the insufficiency of water vapor over the inland area. The vertical cross sections (shown in Fig. 3) demonstrated that the vertical instability did not play a role for the triggering of the convective cells in this area.

The preliminary results in this case study show two important findings:

(1) The southwesterly low level jets (LLJ) obviously occurred at altitudes between 0.5 km and 1.5 km in intensity of more than 10 m/s in use of high spatial and temporal resolution radar data. The existence of LLJ couldn’t be detected by the

routine rawinsonde observations and was resulted from the strong pressure gradient force due to the high and low pressure distributions over the Taiwan Island which could be clearly delineated by the surface subjective analysis based on the hourly observation data.

(2) The convective cells embedded in the frontal system could be developed into MCSs due to the following three key factors. The first key factor was the confluent effect, which was resulted from the mergence of southwesterly, westerly and/or northwesterly flows and accumulated sufficient air mass and momentum at a specified region. The second one was the local cyclonic motion that made the convective cells well organized and triggered more precipitation over ground. The prevailing southwesterlies had a deceleration in the vicinity of the frontal edge and gave impulses to propagate the MCSs toward northeast within the frontal system.

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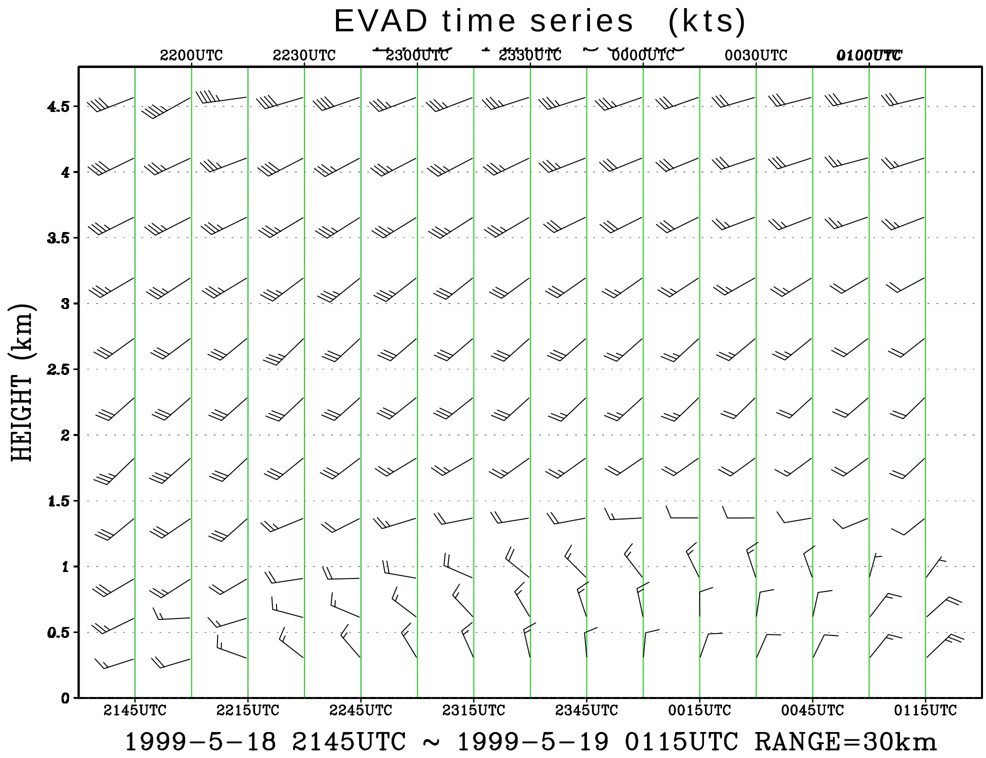


Fig 1. The EVAD time series from 2145 UTC on 18 May 1999 to 0115 UTC on 19 May 1999. The time interval is 15 min and the conducted radar range 30 km.

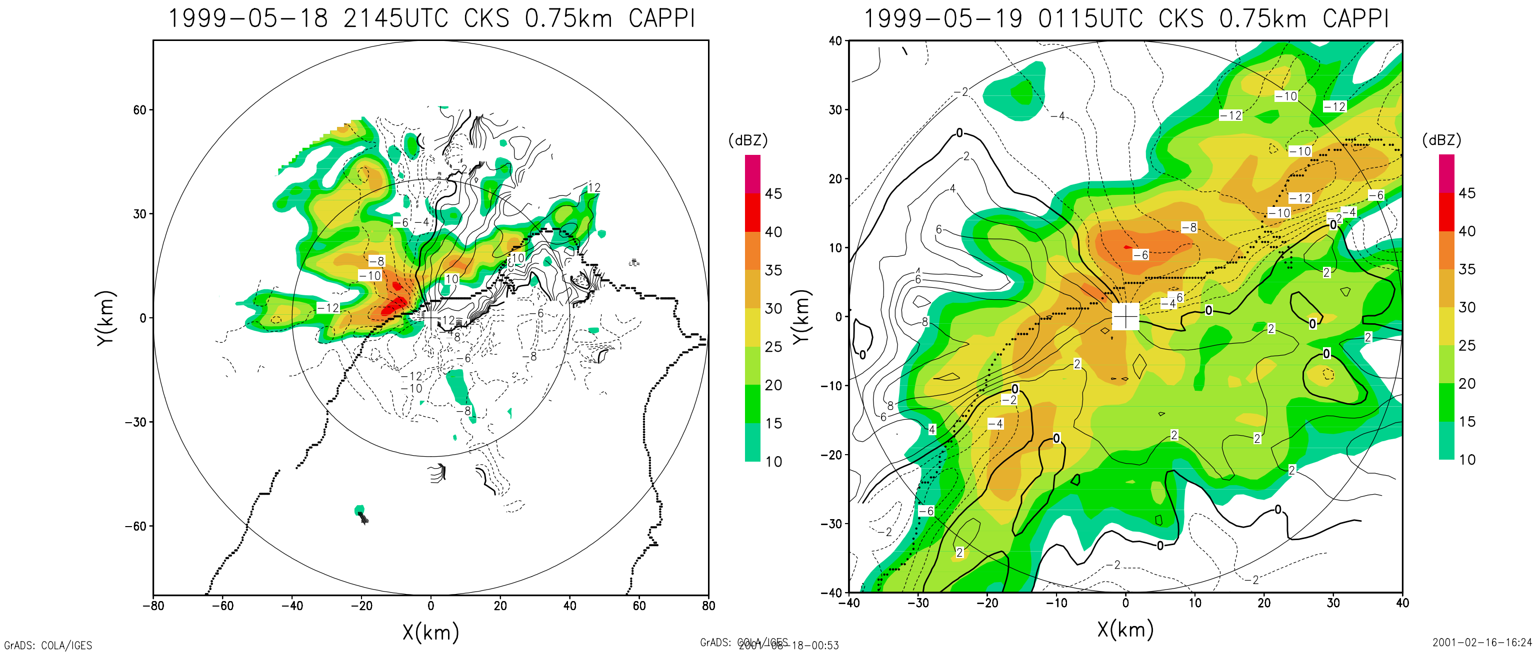


Fig.2 The composite constant altitude plan position indicator (CAPPI) at the 0.75 km altitude collected from reflectivity (dBZ) and radial wind (m/s) data of the CAA Doppler radar at (a) 2145 UTC on 18 May 1999. The domain size is 160 km x 160 km. (b) 0115 UTC on 19 May 1999. The domain size is 80 km x 80 km. The symbol "+" represents the CAA radar site of the Chiang Kai-Shek (CKS) International Airport.

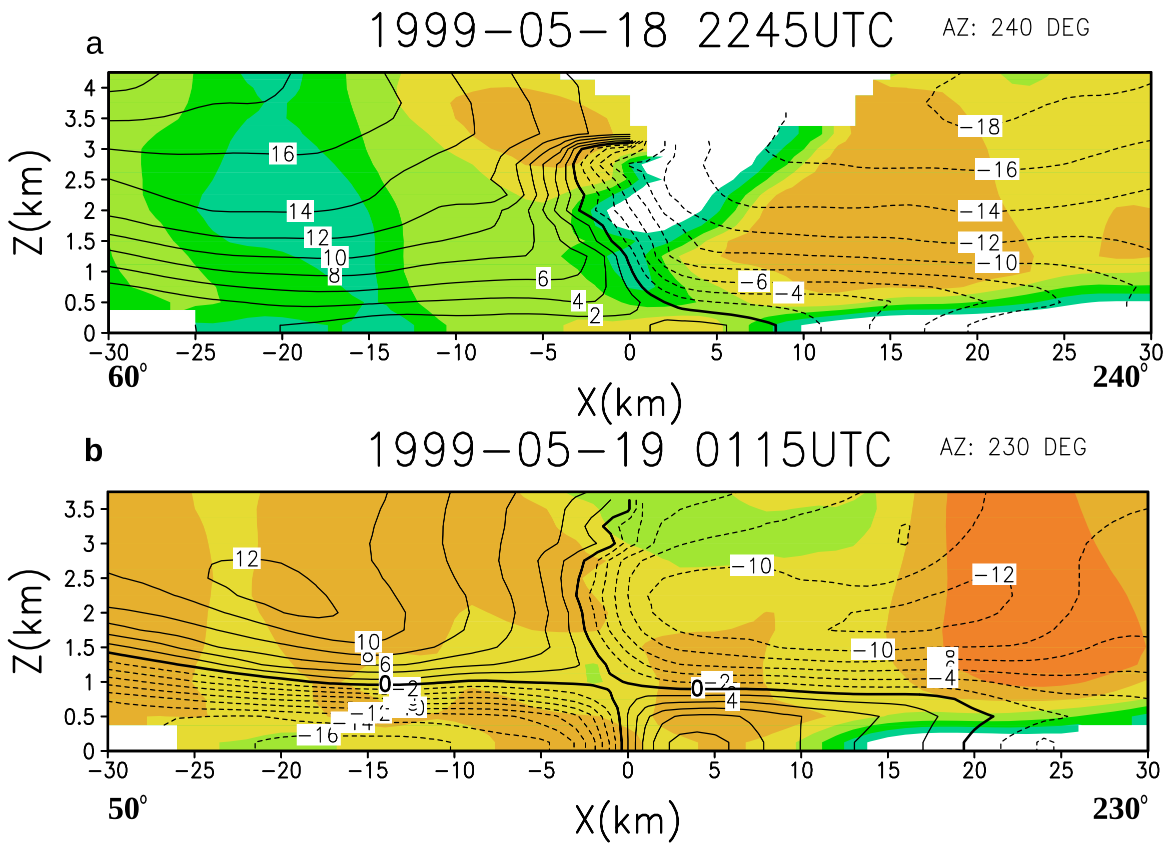


Fig.3 The composite vertical cross sections collected from reflectivity (dBZ) and radial wind (m/s) data of the CAA Doppler radar (a) along the azimuth angle of 240° at 2145 UTC on 18 May 1999 and (b) along the azimuth angle of 230° at 0115 UTC on 19 May 1999. The scale in the abscissa (X axis) represents the distance from the radar.