Analysis of Wind Fields in the Vicinity of Frontal Leading Edge by Using the Single Doppler Radar Data

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ABSTRACT

Currently, there are seven modernized Doppler radar sets deployed around the Taiwan Island. This radar arrangement seems over-intensive for weather surveillance and quite feasible for the dual Doppler analysis. But, due to the complexity and variety of topography in Taiwan, the single Doppler analysis is still the necessary approach for severe weather reconnaissance and warning. The purpose of this study tries to get more detailed and correct wind information from the radial wind fields based on the CAA single Doppler radar observations by using sounding data, selected peak values and making some subjective assumptions. First of all, the real wind field is analyzed in use of the radial wind on CAPPI diagrams calculated from single Doppler data. And then, the analyzed real wind field is executed to obtain the estimated radial wind field which will be compared with the observed radial wind field. The preliminary results show the approach can improve the understanding of the dynamic forcings of mesoscale convective systems in the vicinity of the Mei-yu frontal system over the coastal line area.

Key word: frontal leading, Doppler analysis

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1. INTRODUCTION

Heavy rainfall and high winds associated with synoptic- and meso-scale disturbances affecting the Taiwan posed significant hazards to society and people. Mesoscale structures of the Mei-yu frontal system and the accompanied convective systems over the Taiwan area as well as the effects of orography on the Mei-yu front and the MCSs (mesoscale convective systems) have had better understanding since the conduction of TAMEX (Taiwan Area Mesoscale Experiment, 1987). 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 MCSs. Hor et al. (1998) found a well-defined 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 TAMEX IOP 8 case (0210UTC to 1400UTC 8 June 1987) offers a good opportunity to study the kinematic and dynamic structures of mesoscale convective systems accompanying with the Mei-yu front over this area and examine the proper mechanisms of enhancement of MCSs within the frontal system. Since the multiple Doppler weather radar network operated during TAMEX IOP 8 so as to provide a good opportunity for dual Doppler radar synthesis, single-Doppler analysis is useful to the case of this study. There are two reasons with the following items.

(1) Most of the current radar networks still operate single-Doppler measurement, so it is necessary and useful that establishes a conceptual model which made from the single-Doppler analysis.

(2) The comparison and generalization of two cases analysis is the most important portion of this paper. Using single-Doppler technique can simplify radar data process and improve the cases investigation.

The scientific purpose of this paper wants to examine the flow patterns in the vicinity of frontal leading edge by single-Doppler signatures. In section 2, the data sources and analyzed methodologies are briefly descripted. The synoptic and mesoscale weather patterns discuss in section 3. The radar data description and Doppler velocity analysis present in section 4 and 5. The section 6 is conclision.

2. DATA AND ANALYSIS

2.1 Data sources

The radar echoes observed by the CAA radar every 10-15 minutes were used to monitor the evolution of the MCSs inside 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), Shui-nan (46751) 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 and propagated northeastward due to impulse of the prevailing southwesterly flow. Furthermore, based on the hourly surface observation over Taiwan area, the surface weather charts by subjective mesoscale analysis were drawn in order to show the scenario of the lowest atmosphere and make us realize weather patterns, which were strongly influenced by the variation of the topography.

2.2 Doppler radar data analysis

The CAA Doppler radar completed a volume scan every 10-15 minutes with 10 elevation angles from 0.5 ° to 15.0 ° in the Doppler mode. The composited constant altitude plan position indicators (CAPPI) including the radar reflectivity (dBZ) and radial wind (m/s) information were done based on the Doppler mode data. The radar beamwidth is 0.86 °. 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 ±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. SYNOPIC AND MESOSCALE WEATHER DESCRIPTIONS

The synoptic scale weather condition of TAMEX IOP#8 has discussed on the previous study of Trier et al. (1990). During the period of TAMEX IOP8 (0210 UTC to 1400 UTC 8 June 1987), the frontal system moved faster over the northern Taiwan area. The mesoscale surface subjective analysis (Fig. 1) presents that postfrontal cold air had wind speed more than 14 m /s near ground and the prefrontal warm moisture air had wind speed more than 12m/. The moisture zone of lower atmosphere processed all of the Taiwan area. The Pan-chiao station (46692) profiles showed that the energy supporting the parcel lifting in the atmosphere was not sufficient.

4. THE EVOLUTION OF RADAR OBSERVATIONS

The evolutions of the rainband along frontal leading edge were illustrated in Fig. 2. The whole period is about 3 hour from 0150 UTC to 0450 UTC, which is seemed to be the same period that the front is nearly stationary on the land. At 0150 UTC, The strong echo cores (>45 dBZ) existed at the southwest side of radar site. They can be separated into three parts. The largest part located at about 75 km far of radar site. It was an alignment, and oriented to northwest-southeast. The second one was at the west-southwest side of radar site and about 40 km far. The smaller part was positioned at the distance about 10-20 km far of radar site. The low level radial wind vector showed that the second and third echo cores were just within the frontal leading edge. After 0210 UTC, The third echo core was developed, and involved the second echo core to form a rainband of frontal leading edge. The largest echo core moved toward northeast and then merged into the rainband, so these three strong echo cores gathered to be a singular precipitating echo center. The echo center was stationary and developed well until 0300 UTC. Then it became little weaker and break up to two separated part: the sea part and land part. The land's part moved northwestward and its moving speed is faster than the sea's part. At 0320 UTC, the land's part was strengthened and its area was enlarged. Both strong echo cores maintained their structure until 0500 UTC and then all dissipated.

5. DOPPLER VELOCITY SIGNATURE

Based on the mesoscale surface subjective analysis and Doppler velocity signatures, it is apparent that the prevailing flows in the vicinity of frontal leading edge were dominated by the intense southwesterly in the prefrontal area and northeasterly in the postfrontal area. Evidently, the mean flow patterns assessed by the extend velocity azimuth display (EVAD) scheme (Fig. 3) exhibit that the northeast wind prevails in the low level (below 1.5 km) with wind speed of over 14 m/s, and the southwest wind prevails in the upper level (1.5 ~ 3.0 km) with wind speed of near 14 m/s. In order to get more detailed wind information from the radial wind fields based on the CAA single Doppler radar observations, some assumptions which decide the velocity of prevailing flows have to be made in advance. First, the prevailing wind fields were estimated by the EVAD scheme for postfrontal flow, and sounding data of Shui-nan (46751) for prefrontal flow. And then choosing the peak values of the Doppler velocity in the whole radial wind field for prefrontal and postfrontal flows. The comparison of wind speed of prevailing flows decided these two methods are shown in table 1.

In the beginning, the locations and patterns (linear or sinusoidal, Fig. 4) of the frontal zones are selected. And then, the uniform flow patterns are assumed at each side of the system based on upper air sounding data or selected peak values in the radial wind field. The real wind field is analyzed in use of the above arrangement. Choosing the peak values of the Doppler velocity as the wind speed of prefrontal and postfrontal flows, the assessed Doppler velocity patterns is overestimated that compare to the real radial wind field. Therefore, the wind speed of prefrontal and postfrontal flows were decided by the EVAD scheme and sounding data of Shui-nan. Furthermore, the analyzed real wind field is executed to obtain the estimated radial wind field which will be compared with the observed radial wind field (Fig. 5).

At 0320 UTC, The postfrontal cold air has wind speed more than 14 m/s near ground, and the prefrontal warn moisture air has wind speed more than 14m/s at the altitude of 1 km. Both of the flow interact and trigger the mesoscale convective system. Lately the MCSs propagated toward northeast and a local cyclonic motion and made the cnvective cells well organized at the altitude of 1.5 km (Fig. 6).

6. RESULTS AND CONCLUSIONS

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

(1) The approach is able to improve the understanding of the kinematic and dynamic forcings related to the MCSs triggering inside the Mei-yu frontal system near the coastal area. The land-sea difference and the variety of topography greatly affect the gradient of wind field and the intensity of convergence over land and ocean if the prevailing wind (southwesterly flow) in front of the frontal system as well as the northeasterly flow inside the system are homogeneous. Also, the pattern of sinusoidal zone seems better to describe the flow variations than the linear one in the vicinity of frontal system. Therefore, the flow variations and the different gradients of wind over land and over ocean will manage a suitable environment to trigger a locally cyclonic motion over there which make the isolated and weak convections integrated and become MSCs gradually.

(2) The convective cells embedded in the frontal system could be developed into MCSs due to the following two key factors. The first key factor was the convergent effect which was resulted from southwesterly and northeasterly flows and accumulated sufficient air mass and momentum at a specified region. The second one was the local cyclonic motion that was triggered by the strong horizontal wind shear due to the land-sea contrast over ground. This factor made the convective cells well organized inside the frontal system. 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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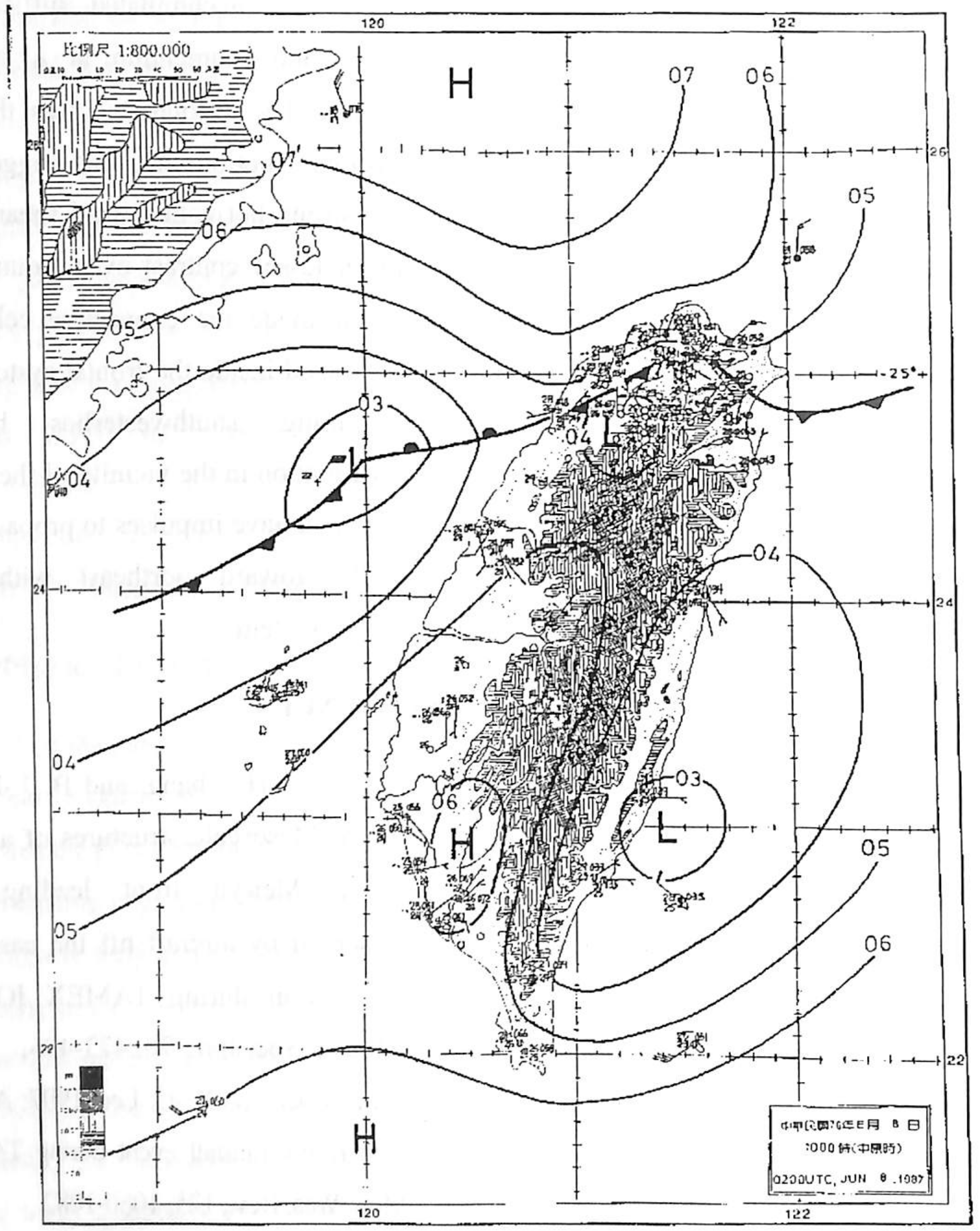


Fig.1 The surface weather chart by subjective mesoscale analysis at 0200 UTC on 8 June 1987.

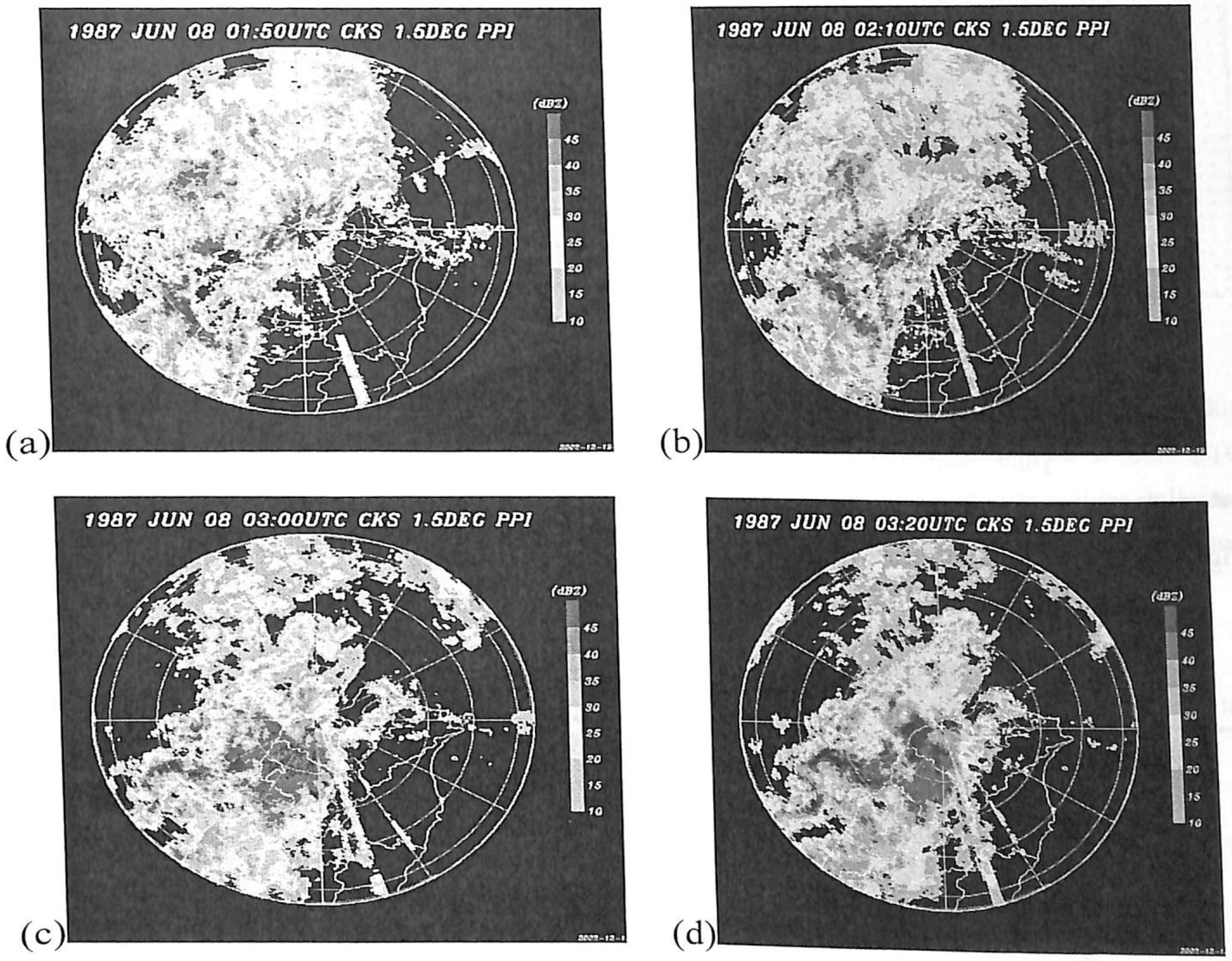
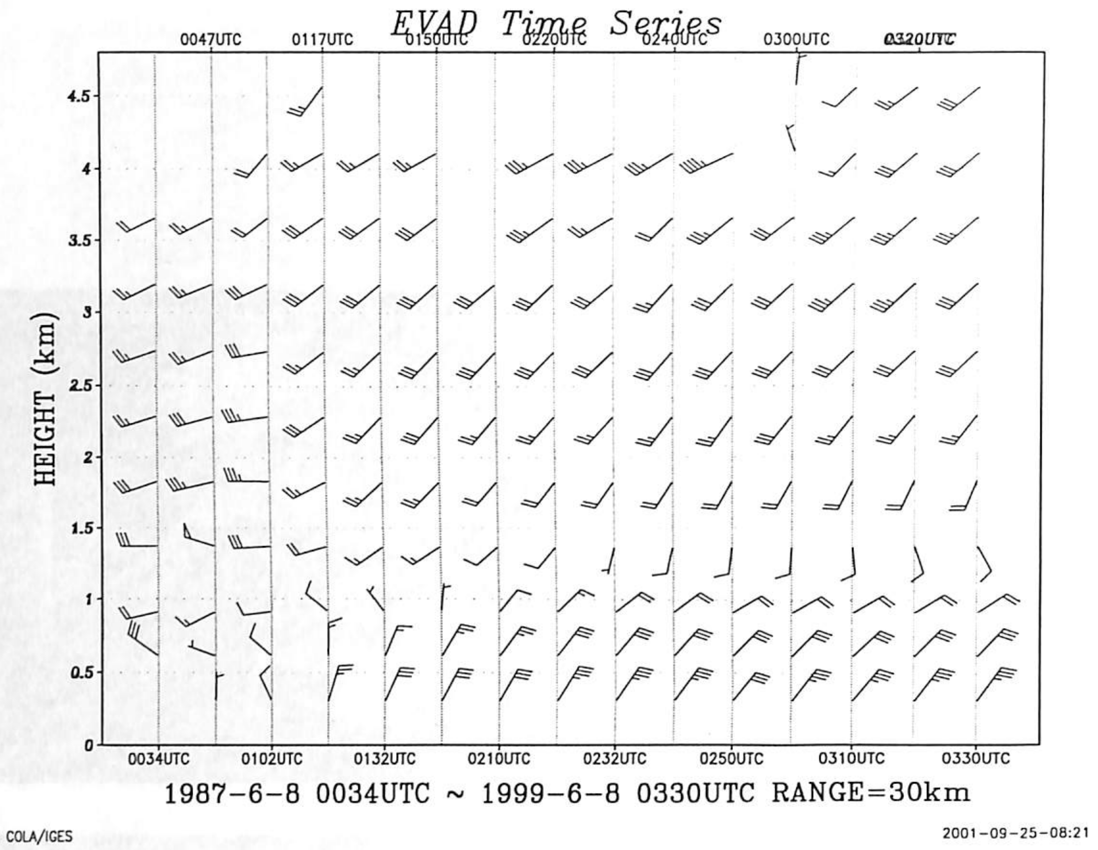


Fig. 2 The plan position indicator (PPI) at the elevation of 1.5 degree collected from the CAA Doppler radar at (a) 0150 UTC on 8 June, (b) 0210 UTC on 8 June, (c) 0300 UTC on 8 June, (d) 0320 UTC on 8 June 1987. The symbol "+" represents the CAA radar site. The domain size in the figure is 120 km x 120 km.


EVAD Time Series

1987-6-8 0034UTC ~ 1999-6-8 0330UTC RANGE=30km

GrADS: COLA/IGES 2001-09-25-08:21

Fig. 3 The EVAD time series from 0034 UTC on 8 June to 0330 UTC on 8 June, 1987. The averaging range is 30 km.

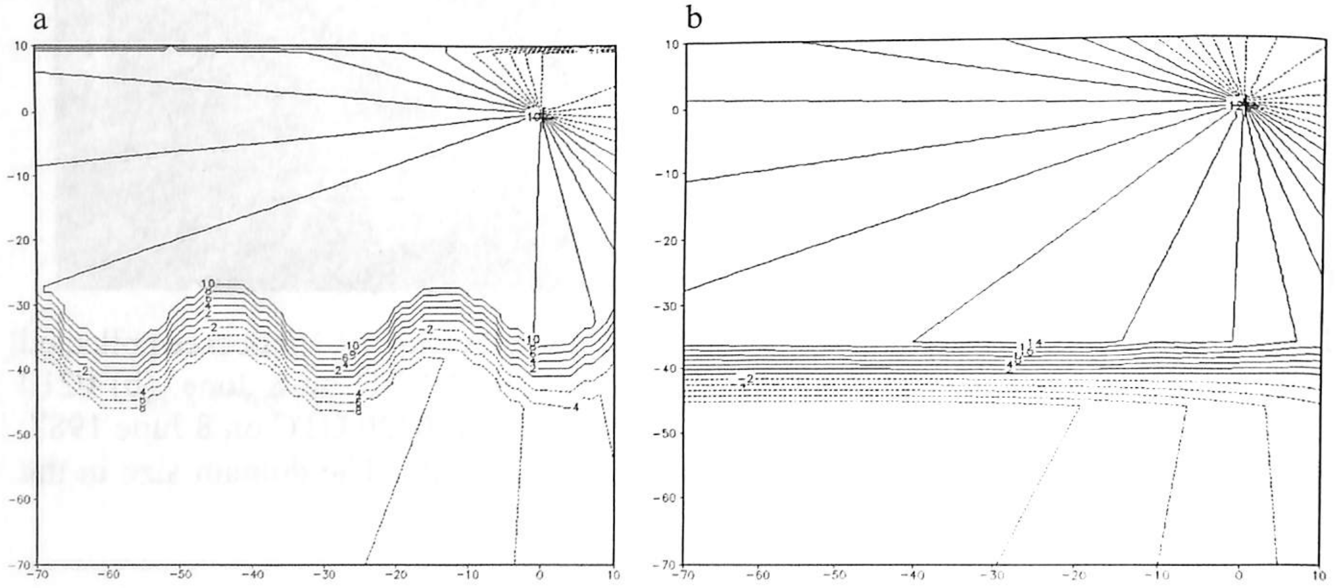


Fig.4 (a) The estimated radial wind field for the sinusoidal frontal pattern. (b) The estimated radial wind field for the linear frontal pattern. The symbol "+" represents the CAA radar site. The domain size in the figure is 80 km x 80 km

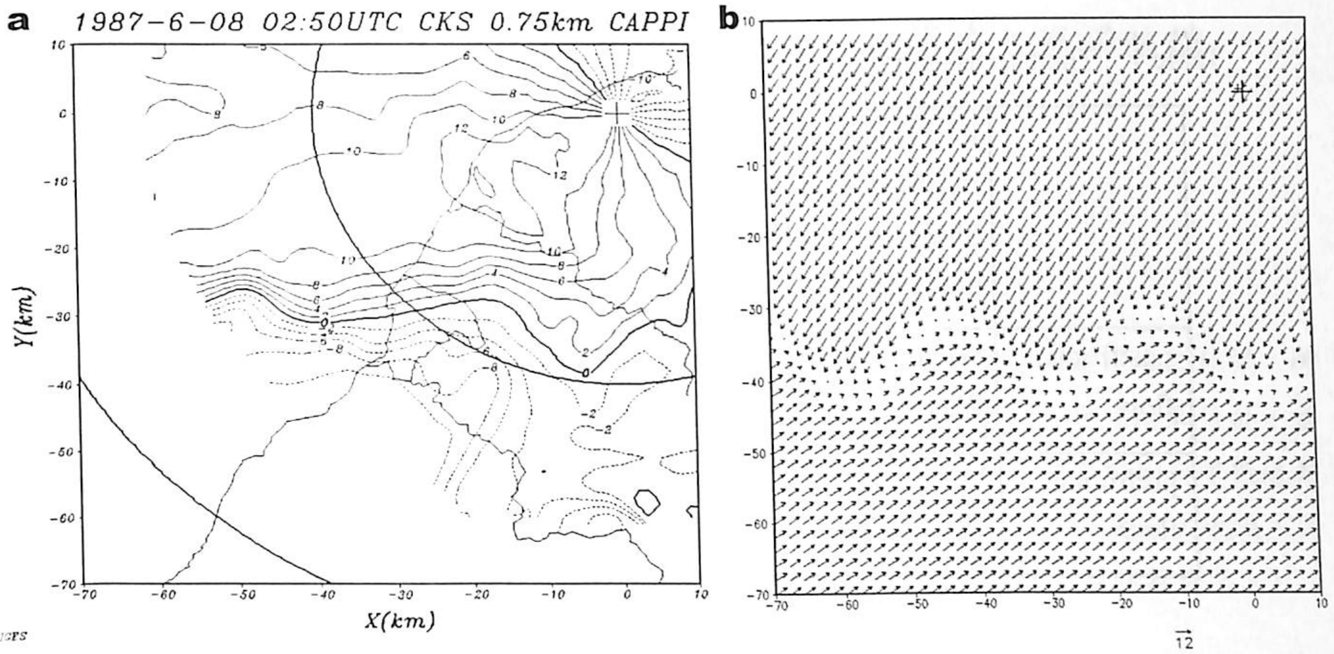
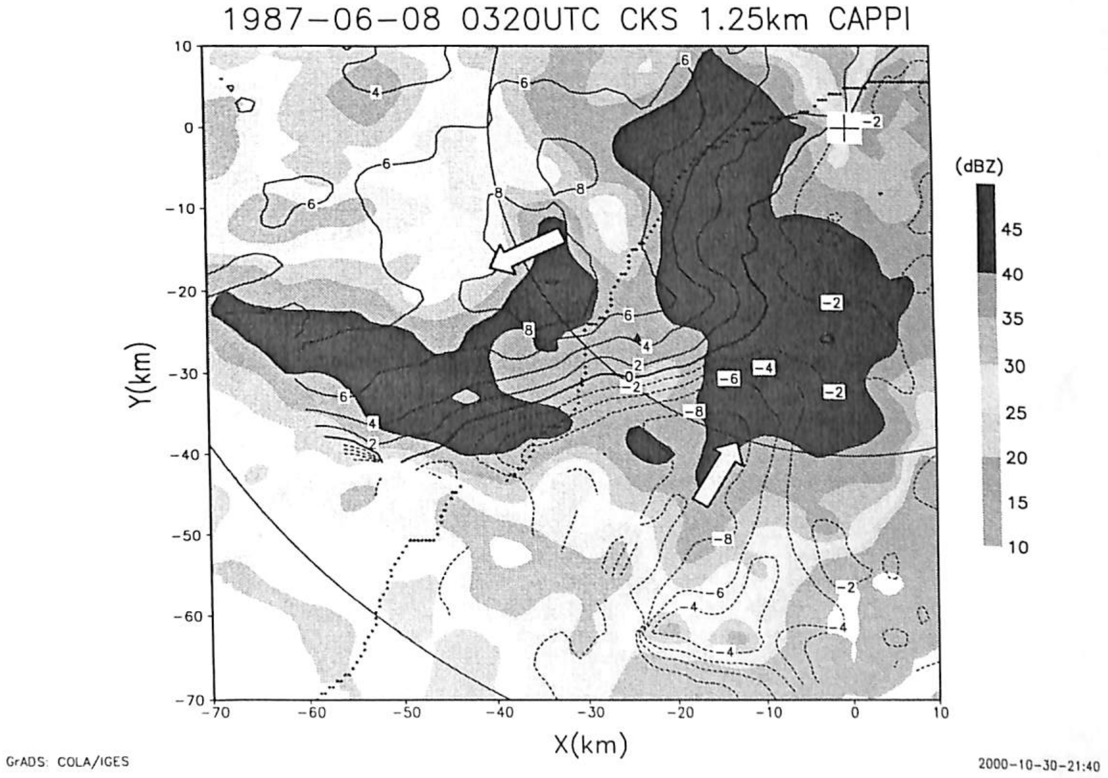


Fig. 5 (a) The composite constant altitude plan position indicator (CAPPI) at the 0.75 km altitude collected from radial wind (m/s) data of the CAA Doppler radar at 0250 UTC on 8 June 1987. (b) The estimated real wind field based on the peak values collected from (a). The symbol "+" represents the CAA radar site. The domain size in the figure is 80 km x 80 km.


1987-06-08 0320UTC CKS 1.25km CAPPI

GrADS: COLA/IGES 2000-10-30-21:40

Fig. 6 The composite constant altitude plan position indicator (CAPPI) at the 1.25 km altitude collected from radial wind (m/s) data of the CAA Doppler radar at 0320 UTC on 8 June 1987. The symbol "+" represents the CAA radar site. The domain size in the figure is 80 km x 80 km. The arrows denote the vector of Doppler velocity.

Table 1 The two assumptions for deciding the wind speed of prevailing flows.

	EVAD scheme for postfrontal flow and Shui-nan sounding for prefrontal flow	Peak values of the radial wind fields for prefrontal and postfrontal flows
postfrontal flow	Wind direction: 50° Wind speed: 12 m/s	Wind direction: 55° Wind speed: 14 m/s
prefrontal flow	Wind direction: 200° Wind speed: 9 m/s	Wind direction: 215° Wind speed: 12 m/s

利用單一都卜勒雷達資料分析鋒面前導線之風場結構

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摘　要

本研究利用單一都卜勒雷達資料，分析梅雨鋒面之鋒面前導線附近風場之結構，所研究之個案為 TAMEX IOP 8 之中正機場都卜勒氣象雷達觀測資料。研究結果指出，當鋒面前導線反映在雷達都卜勒速度為零的等值線時，前導線的走向與形勢均與零值線相同。此外在本個案中，鋒面前導線後緣約 1.25 至 1.5 公里高度上存在一氣旋式環流，此環流乃由於強盛的西南與東北氣流所造成之風切而形成，促使對流系統持續發展。

關鍵詞：鋒面前導線、都卜勒分析