The Characteristic of the Squall—An Analysis of Meteorological Factors by Using High Temporal Observations

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Abstract

The present study analyses the high temporal observation collected by the 6 Automated Weather Observing Systems which are deployed around the Taoyuan International Airport to investigate the surface variation of wind filed, temperature and surface pressure for a squall line. The dataset is useful for estimating vertical velocity near the surface and, by analyzing the continuity equation, for justifying the dynamic and mass budget of the vertical velocity.

The primary findings are: (1) The pressure rises to the highest value and the temperature decreases to the lowest point as the outflow associated with the squall line is remarkable. The variation of the temperature is smoother than that of the pressure. (2)The contribution of the local change of density for assessing vertical velocity is two magnitude of order less than the divergent term. The dynamic effect dominates the development of vertical velocity near surface. (4) As the squall line approaches Taiwan's northern coastline, the upward motion becomes significance. The maximum vertical velocity reaches 10cm/s. During the pass of the squall line, the upward vertical velocity prevailed. The convective downdraft hardly appeared before and after the squall line pass by.

keyword: squall line, Automated Weather Observing Systems

1. Introduction

The severe wind usually accompanies with a squall line. The front-to-rear flow, which brings high equivalent potential temperature air, penetrates the leading edge from the low level. It is lifted by the updraft and tilts toward to the rear of the leading edge. And the rear-to-front flow associated with low equivalent potential temperature air exists at the middle level. After the passage of the squall line, the air becomes cold and dense with abrupt temperature drops. The wind direction also changes dramatically. In the past, variations of meteorological factors, such as surface wind speed, temperature and pressure, associated with a squall line while propagating inland from sea, are not well been aware due to poor temporal and spatial resolution. The limitation confines the capability for predicting these parameters quantitatively so to improve aviation safety. In fact, some of the observational sites have been build a brand new observing system by the technological progress for providing very high spatial and temporal resolution measurements (Straka et al. 1996, Pietrycha and Rasmussen 2004). In Taiwan area, there are six Automated Weather Observing Systems (AWOS) deployed at the Taoyuan International Airport (TIA) in addition to advanced Doppler weather. These systems can offer measurements in very high temporal resolution. During May 1-2, 2006, a severe linear rainband passed through the TIA, which provided a good opportunity to analyze the variation of surface meteorological factors. The study focuses on the analysis of the variation of surface meteorological factors during the passage of squall line. The useful high temporal observation is valid for attempting the estimation of vertical velocity at low level.

2. Data Sources

As previous mentioned, measurements collected from the AWOS are the principal data for the study. The six AWOSs are installed along the runway, designated as station 05, 0523, 23, 06 0624 and 24 (Fig. 1.) Each station can collects wind field in 1-second interval. Only the 05, 0523, 06 and 0624 measure the pressure field. And only 0523 and 0624 provide temperature and dew point measurements. The temporal interval for pressure and temperature observation is 1-minute. Besides, the reflectivity and Doppler velocity collected from TIA Doppler weather radar is useful for determining the propagation of the squall line.

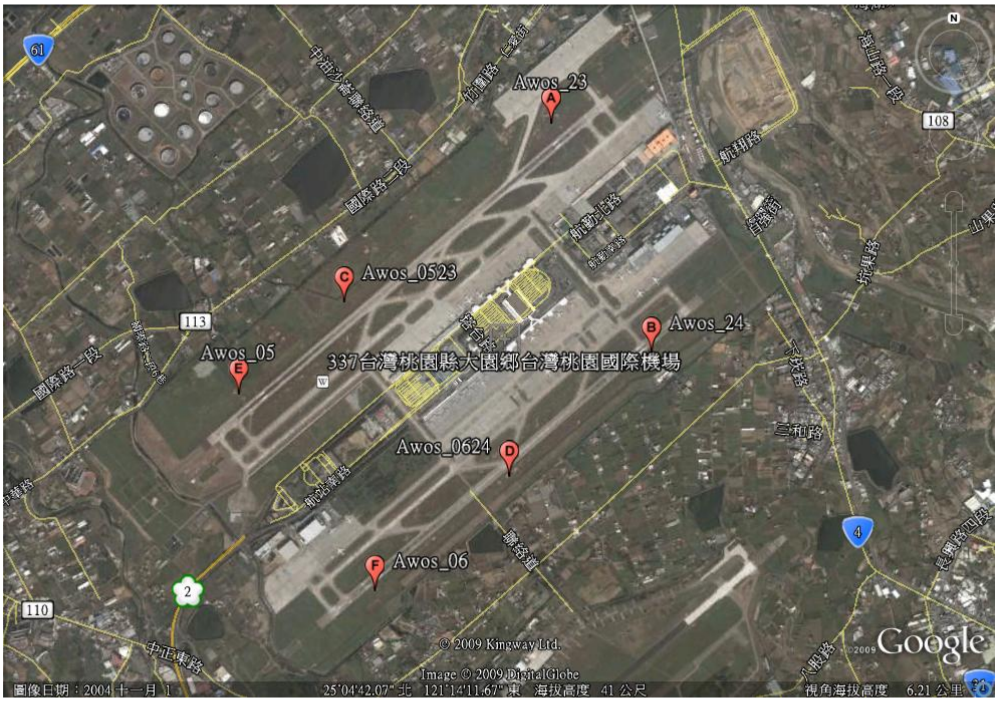

Fig 1. Locations of 6 AWOSs around TIA (captured from google earth)

a. **b.**

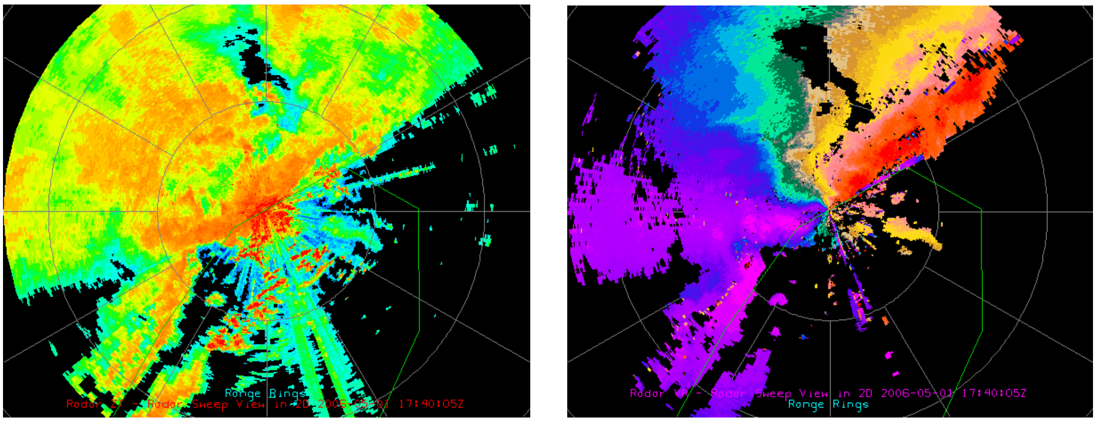

Fig 2. (a) Reflectivity and (b) Doppler velocity observed by the TIA Doppler weather radar at 0.5 elevation angle at 1740 UTC, May 1st 2006.

3. Descriptions for Mesoscale condition and radar observation

The surcafe chart at 1500 UTC, May 1st 2006, showed that a cold front was located at the north of Taiwan Strait. The plan position indicator (PPI) at 0.5 elevation angle at 1740 UTC (Fig. 2.) depicted that an intense linear echo was approaching the TIA, which was just located in front of the cold front. The linear rainband, which might regard as a squall line, aligned with the orientation of TIA's runway. The Doppler velocity implied that the southwesterly was prevailing at the leading edge at low levels. The maximum speed of the flow exceeded 15 ms^{-1}. Behind the squall line, the westerly and northwesterly flow dominated. The analysis reveals that flows associated with the squall line changed abruptly.

4. Analysis for surface observation

The surface wind observed by AWOS is divided into two components. The u component represents the wind along the direction of runway. The v component stands for direction across squall line. The u and v wind deduced from station 0523 changed drastically between 1730 and 1810 UTC (Fig. 3.). The maximum across wind could reach 35 knots (17.5 ms^{-1}) directed inland, indicating a obvious outflow existed at the leading edge. The station 0624 also observed the same feature except existed a bit of time lag.

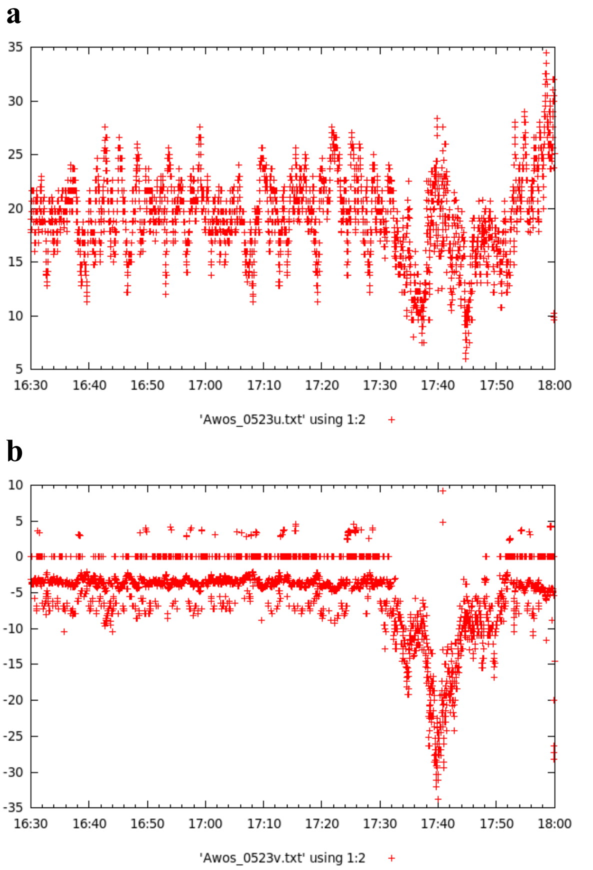

Fig 3. The time sequence of surface wind observation at station 0523 berween 1600 and 1930 UTC May 1st 2006. (a) u component and (b) v component.

During the pass of the squall line, the temperature dropped from 29 to 22℃ between 1730 and 1810 UTC. (Fig. 4.) The extreme fluctuation appeared between 1736 to 1745 UTC with dropping 5.6℃. The sequences revealed an intense temperature gradient associated within the squall line. The variation of temperature for the air located in front and rear of the squall line confined to 0.5 – 1℃, suggesting the characteristic of both flows are quite different.

The pressure jump was also significant (Fig. 5.). It started around 1700 UTC and reached maximum at 1750 UTC. The total raise of pressure was 3.3 hPa. Comparing with the sequence of temperature, the response of pressure is prior to that of temperature for almost 30 minutes.

5. The estimation of vertical velocity

The vertical velocity is estimated by applying mass continuity equation. Since the measuring tower is 10 m in height, the estimation stands for the vertical velocity in the boundary layer.

$$\frac{1}{\rho}\left(\frac{\partial \rho}{\partial t} + U\cdot\nabla\rho\right) + \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = -\frac{\partial w}{\partial z}$$

The result showed that the prominent upward motion dominated between 1738 and 1745 UTC. The maximum position vertical velocity reached 0.1 ms^{-1} (Fig. 6.). However, the downdraft was hard to define during the same period, implying the non-existence of convective downward motion. The third term of the equation contributes the most triggering mechanism of positive vertical velocity, suggesting that the speed convergence of cross wind component is intense.

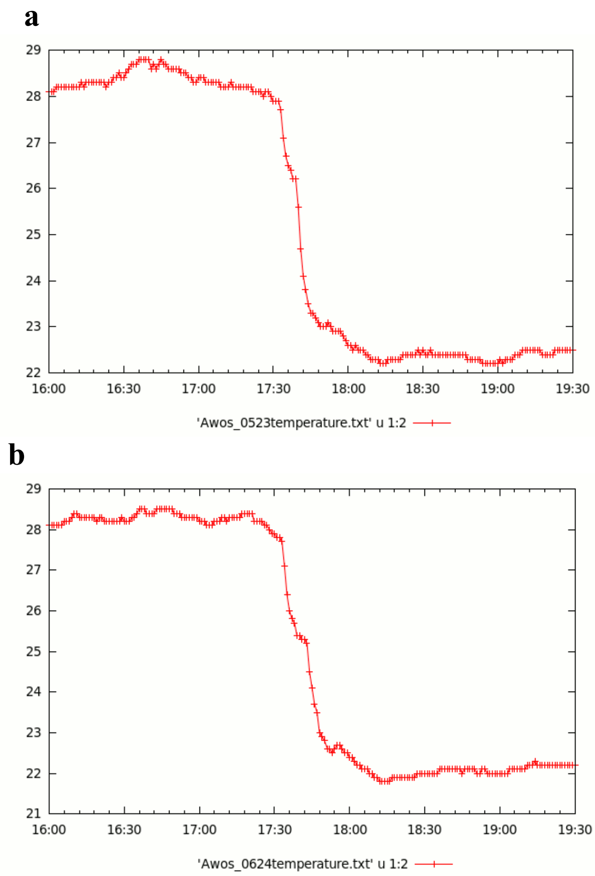

Fig 4. The time sequence of surface temperature field observed at (a) station 0523 and (b) station 0624.

6. Summary

The analysis of surface observations showed that the characteristic of such an oceanic squall line is different from that of a midlatitude squall line. The variation of temperature only reveals the differences of characteristic between the air ahead and behind the squall line. The convective disturbance, such as downdraft, does not appear during the passage of squall line. Therefore, the positive vertical velocity dominates during the same period due to the speed convergence of cross wind component.

Reference

Leary, C. A. and R. A. Houze Jr., 1979: **Melting and Evaporation of Hydrometeors in Precipitation from the Anvil Clouds of Deep Tropical**

Convection. *J. Atmos. Sci.,* **36** 669–679.

Pietrycha, A. E. and E. N. Rasmussen **Finescale Surface Observations of the Dryline: A Mobile Mesonet Perspective.** *Wea. Forecasting,* **19**, 1075–1088.

Straka, J. M., E. N. Rasmussen and S. E. Fredrickson, 1996: **A Mobile Mesonet for Finescale Meteorological Observations.** *J. Atmos. Oceanic Tech.,* **13**, 921–936.

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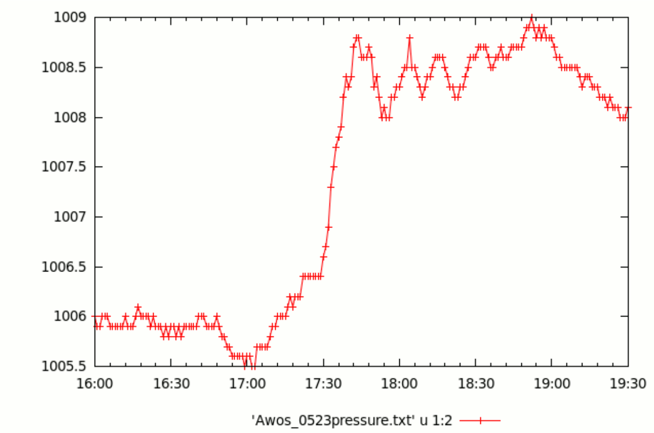

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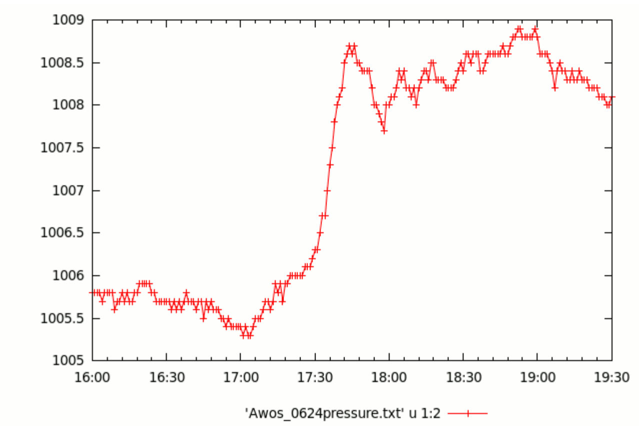

Fig 5. The time sequence of surface temperature field observed at (a) station 0523 and (b) station 0624.

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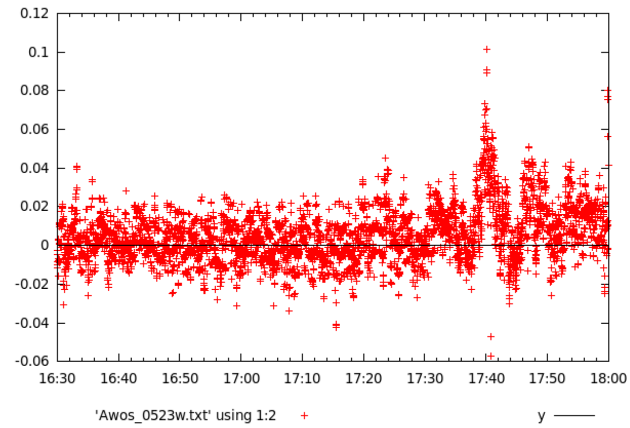

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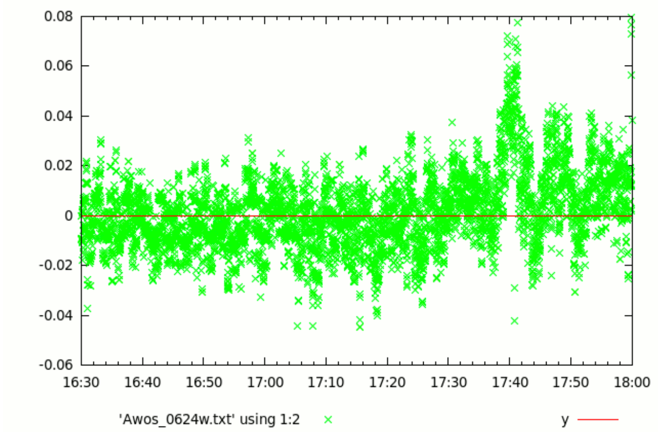

Fig 6. The time sequence of vertical velocity deduced from (a) station 0523 and (b) station 0624.