Mesoscale Analysis on the Asymmetric Rainband of Typhoon Matmo (2014) and the Related Weather Situations for the GE 222 Aircraft Crash Case

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ABSTRACT

The study focuses on the mesoscale analysis of convective cells embedded within the rainbands accompanied by Typhoon Matmo (2014) which was in moderate intensity (38 m/s in maximum wind speed and 960 hPa in minimum pressure) and penetrated the Taiwan area in the north-northwestward propagation. After it passed the Central Mountain Range, the organized convective cells inside the outer rainbands became several line echo wave patterns (LEWP) in the northeast-southwest orientation. The wave-like echoes gradually moved northeastward, and featured a key factor on the development of rainbands in use of mesonet surface data analysis and dual-Doppler radar analysis. Also, it is feasible to investigate the possible situations for the GE 222 aircraft crash case from the perspective of abrupt mesoscale weather variations.

Based upon the prilinary findings, we learned that the wave-like echoes were quite similar to the bow echo pattern while the typhoon system kept moving northwestward. The mesonet surface data analysis told that each echo in the LEWP consisted of several convective cells bringing heavy rainfall and the resulting temperature drops on the ground along the west coast of Taiwan. The radar analysis delineated that the inflow, the vertical convection and the secondary circulation at the rear flank of LEWP became more obvious and well organized. The wave-like echoes in maximum intensity were accompanied with intense horizontal and vertical wind shears which will threat the aviation safety greatly.

Keywords: LEWP, rainband, mesonet surface data analysis, dual-Doppler radar analysis, turbulence.

1. Introduction

In sub-tropical ocean area, the weather systems are different with those in mid-latitudes. For instance, the rainband embedded within a tropical cyclone is an important phenomenon owing to its significant effect on quantitative and qualitative rainfall. While Typhoon Otto (1998) was over the open ocean, it appeared inner and outer rainbands, and the vertical cross sections along the radial showed that the outer rainband tilted outward and were more intense than the inner one (Hor, et al., 2005). The vertical kinematic characteristics of the rainband in Typhoon Morakot (2009) revealed two types of downdrafts, namely inner-edge and low-level downdrafts (Wei, et al., 2014). The outer areas of tropical cyclones usually possessed larger convective available potential energy and lower humidity than the inner-core environment, and rainbands in the tropical cyclones could develop squall-line-like airflow structures and a low-level cold-pool signature (Yu and Tsai, 2013). Furthermore, most of outer rainbands (more than 50 %) were characterized by convective precipitation, an convergence zone between the band-relative rear-to-front flow and front-to-rear flow at low levels, and a surface cold pool signature (Yu et al., 2018).

On July 23, 2014, TransAsia Airways passenger flight GE 222, an ATR-72 airplane, took off from Kaohsiung International Airport for Makung Airport in Penghu County. There were 58 people on board, including 2 flight crewmembers, 2 cabin crewmembers and 54 passengers. The aircraft crashed in Xixi Village near Makung Airport at 19:06 LST (UTC+8) when conducting the RWY 20 VOR approach, caused 48 fatalities and 10 serious injuries. 5 residents on ground suffered minor injuries. (The ASC Aviation Occurrence Report, 2016)

The FDR (flight data recorder) flight path versus wreckage map during the last 34 seconds for TransAsia Airways GE222 Occurrence is shown in Fig. 1. It tells that the plane seriously deviated from its regular route due to some reasons.

The goals of this study will cover:

a. Describe the characteristics of the line echo wave pattern embedded within the rainbands of Typhoon Matmo.

b. Investigate the possible causes of airplane crash from the perspective of mesoscale weather analysis.

2. Mesonet Analysis

Typhoon Matmo (2014) which was in moderate intensity (38 m/s in maximum wind speed and 960 hPa in minimum pressure) penetrated the Taiwan area in the north-northwestward propagation and moved into the mainland China at 1500LST on 23 July 2014. Fig. 2 describes the best track observed by the Central Weather Bureau of ROC. After it passed the Central Mountain Range of Taiwan, the organized convective cells inside the outer rainbands became several line echo wave patterns (LEWP) in the northeast-southwest orientation moving northeastward. Fig.3 delineates the composite radar reflectivity images in dBZ that three waves embedded within the typhoon rainband were going to pass through Makung Airport at 1500LST on 23 July 2014, about 4 hours before the occurrence. The study will focuses on the mesoscale analysis of convective cells embedded within the rainbands in use of mesonet surface data analysis and dual-Doppler radar analysis.

Based upon the preliminary findings, we learned that the wave-like echoes were quite similar to the bow echo pattern while the typhoon system kept moving northwestward. The mesonet surface data analysis told that each echo in the LEWP consisted of several convective cells bringing heavy rainfall and the resulting temperature drops on the ground along the west coast of

Taiwan. According to Makung airport weather observations (Fig. 4), the abrupt wind change led the peak of rainfall in about 40~60 minutes, and the temperature drop and the pressure rise delayed the peak of rainfall about 80~120 minutes. The first LEWP touched the Makung airport at about 1600 LST with abrupt variation in wind direction and wind speed and brought the rainfall peak at about 40 minutes later as well as the quick temperature drop and pressure rise at about 100 minutes later. Afterward, the second LEWP reached the Makung airport at about 1740 LST and brought the rainfall peak at about 60 minutes later as well as the quick temperature drop and pressure rise at about 80 minutes later. Furthermore, the third LEWP arrived the airport at about 1840 LST and brought the rainfall peak at about 60 minutes later as well as the quick temperature drop and pressure rise at about 120 minutes later. The following immediate procedures for the QNH (an aeronautical code Q code) adjustment and the change of flight rolling statue will be necessary for flight crewmembers. Furthermore, the two pilots would face the difficulty to find out the exact runway due to getting worse visibility. Finally, the runway visual range (RVR) measured by AWOS (Automatic Weather Observing System) at Makung airport (Table 1) delivers the last 7 minutes' RVR data before the occurrence. The RVR varied significantly from larger than 2000m (1857LST) to 500m (1906LST) in 7 minutes due the short duration heavy rainfall with maximum rainfall rate in 14mm per 10 minutes. It was below the required landing minima for the runway 20 VOR approach.

3. Radar Analysis

The Dual-Doppler synthesis of Chiku and Makung weather radars at 2 km level at 0809UTC (1609LST) on 23 July 2014 is shown in Fig.5. The algorism applied in the estimation includes the downward integration, the boundary condition with wt = wb = 0, and variational adjustment. The radar analysis delineated that the prevailing wind on the normal flight route nearby the airport was northwesterly. The inflow, the vertical convection and the secondary circulation at the rear flank of LEWP became more obvious and well organized. Usually, the updrafts occurred at the front edge of LEWP and the downdrafts occurred at the rear of it. Also, the wave-like echoes in maximum intensity were accompanied with great variation of wind direction and wind speed, and resulted in the harmful turbulence to airplanes.

Also, the northwesterly prevailing wind on the normal flight route might bring influential crosswind to the airplane when it was conducting the RWY 20 VOR approach.

4. Conclusions

After Typhoon Matmo (2014) moved into the mainland China at 1500LST on 23 July 2014, the associated rainband became well-organized over the Taiwan Strait area. At least three LEWP embedded within the rainband affected the Makung airport while the typhoon system kept moving northwestward. The mesonet surface data analysis told that each echo in the LEWP consisted of several convective cells bringing heavy rainfall and the resulting temperature drops on the ground along the west coast of Taiwan. The radar analysis delineated that the inflow, the vertical convection and the secondary circulation at the rear flank of LEWP became more obvious and good shaped.

According to the Aviation Occurrence Report prepared by Aviation Safety Council in 2016, it described that the Makung airport was affected by the outer rainband of Typhoon Matom at the time of the occurrence. At the final approaching stage the weather conditions were not consistent with the encounter of wind shear and downburst. During 1906:00LST and 1906:12LST, the head wind decayed from 19mi/h (knots) to15mi/h (knots), and the right crosswind increased from 27mi/h (knots) to 30mi/h (knots). Furthermore, at the last 2 minutes interval, the airplane might encounter turbulence classified as light to moderate level. Conclusively speaking, the meteorological conditions included thunderstorm activities of heavy rain, significant changes in visibility, and changes in wind direction and speed. (The ASC Aviation Occurrence Report, 2016)

Generally, the preliminary findings are quite similar to those in the ASC report. These three LEWPs caused significant change in wind direction and wind speed accompanied with lagged heavy rainfall, pressure rise and temperature drop. However, the Dual-Doppler synthesis of Chiku and Makung weather radars at 2 km level tells that the vertical velocity (m/s) at the rear of the core echo region reached -2 m/s in maximum speed about 25km away from the Makung weather radar site (Fig.5a). Also, the right crosswind kept 27~30mi/h (knots) at the last approach stage. It means the plane faced a multiplex and severe weather situation, including the intense crosswind, obvious downdraft and quite low visibility. Therefore, it might result in the large amount of pitch and yaw angle changes in the final approaching stage while the plane was flying in low attitude and slow speed.

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The Aviation Occurrence Report for TransAsia

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Table 1. The time series of one-minute average RAR measured by AWOS N at Makung Airport on 23 July 2014. LST represents the Taipei Standard Time (UTC+8), and RVR is the Runway Visual Range in unit of meter.

TIME (LST)	**07/23 1859**	**07/23 1900**	**07/23 1901**	**07/23 1902**	**07/23 1903**	**07/23 1904**	**07/23 1905**	**07/23 1906**	**07/23 1907**	**07/23 1908**
RVR (m)	**>2000**	**1800**	**800**	**650**	**600**	**650**	**600**	**500**	**450**	**550**

Fig.1 The FDR (ATR's flight data recorder) flight path versus wreckage map during the last 34 seconds for TransAsia Airways GE222 Occurrence at Makung Airport in Penghu Island on 23 July 2014 based on the Aviation Occurrence Report prepared by Aviation Safety Council in 2016.

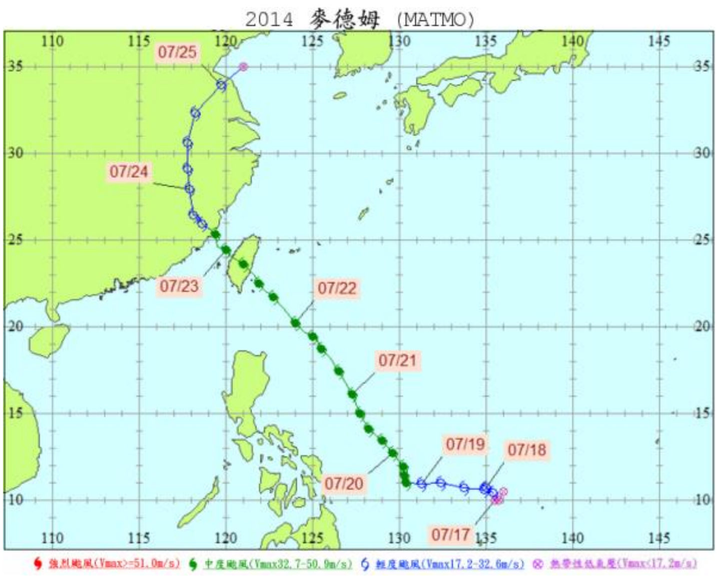

Fig. 2 The best track observed by the Central Weather Bureau of ROC.

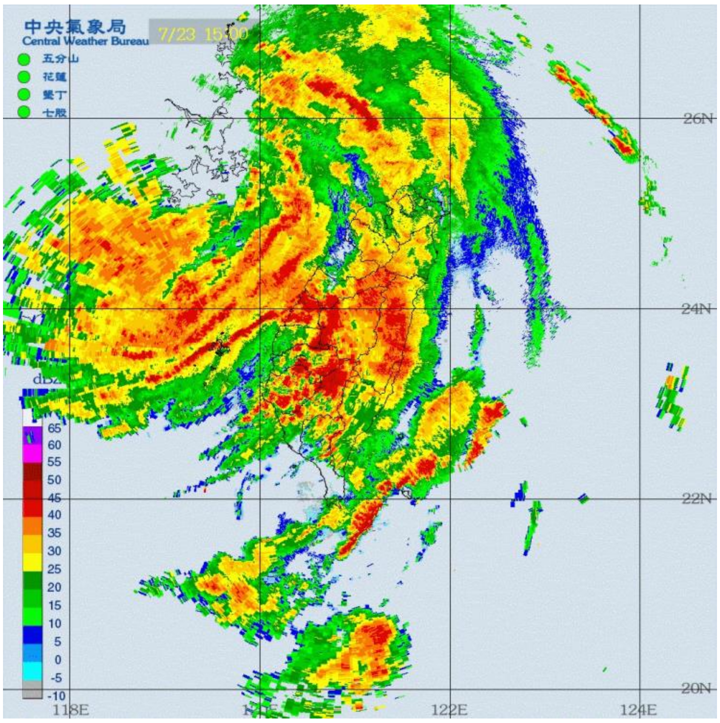

Fig. 3 The composite radar reflectivity images in dBZ indicated that three waves embedded within typhoon rainband passed through Makung Airport at 1500LST on 23 July 2014, about 4 hours before the occurrence. (Referred from the Central Weather Bureau of ROC)

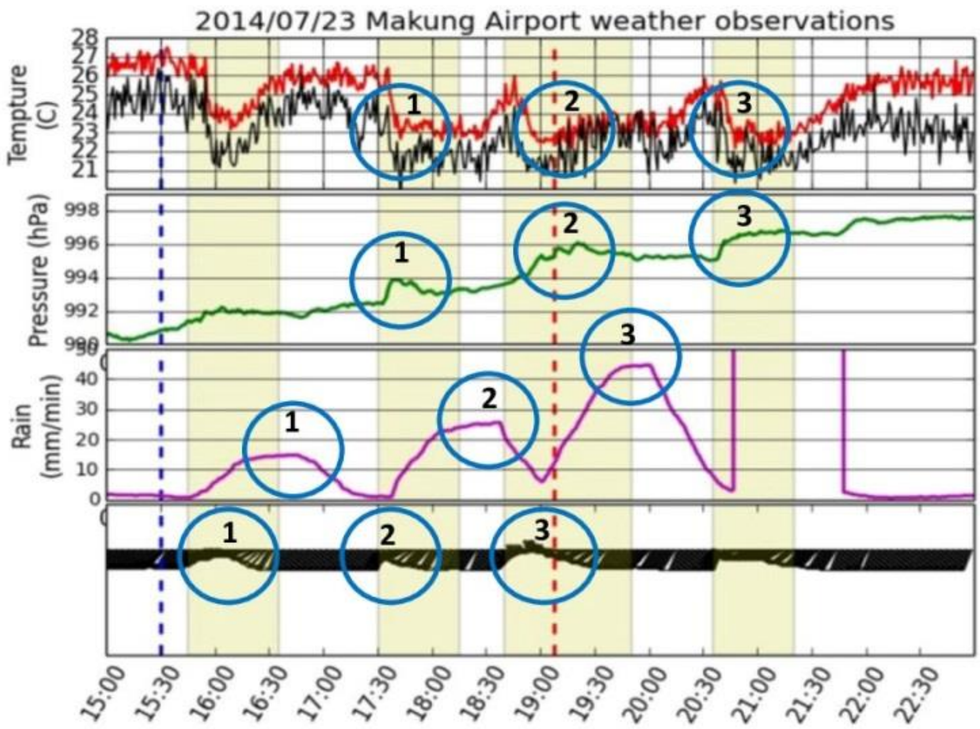

Fig. 4 The surface observations measured at the Makung Airport from 1500LST to 2300LST on 23 July 2014, including temperature (C), dew point (C), pressure (hPa), and rainfall rate (mm/min).

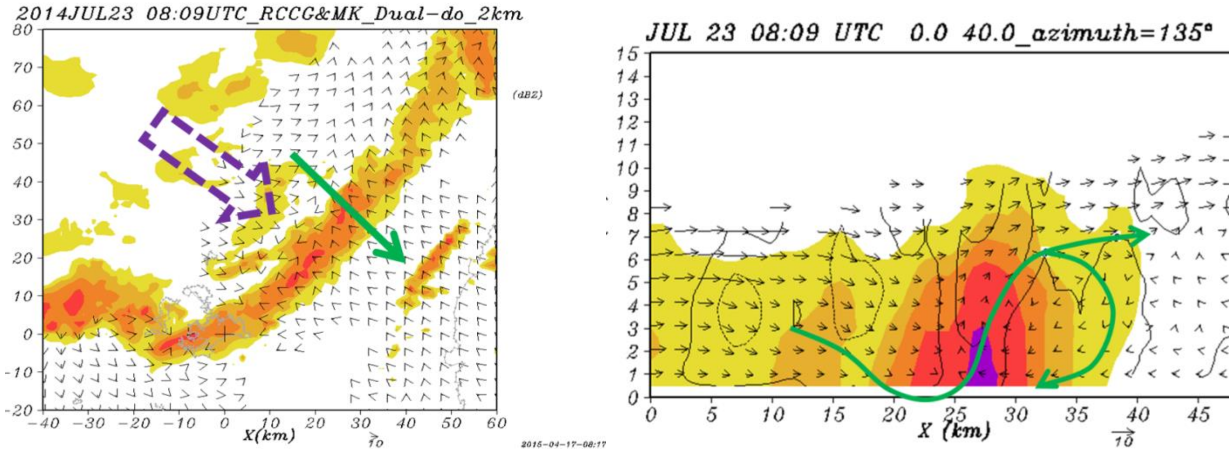

Fig. 5 (a) The Dual-Doppler systhesis of Chiku & Makung weather radars at 2 km level at 0809UTC(1609LST) on 23 July 2014. The algorism applied in the estimation includes the downward integration, the boundary condition with wt=wb=0, and variational adjustment. The vertical axis is the y-distance (km) and horizontal one represents the x-distance (km) with respective to the Makung radar site. (b)The vertical cross section along the green line on the panel (a) shows the echo intensity (dBz) and the vertical velocity (m/s) with maximum speed of -2 m/s.