High resolution X-band Doppler radar observation of misocyclones along the convergence line.

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I. INTRODUCTION

Tornado occurrence on the Japan Sea side in Japan is characterized by the winter-monsoon tornadoes associated with cold air outbreaks over the warm sea surface. Since winter monsoon tornadoes can cause considerable damage in the Japan Sea coastal region, where the population is concentrated, it is important to reveal their detailed structure and their mechanisms of generation and evolutions in order to prevent and mitigate wind disasters in this region. As part of a research project for the development of an automatic strong gust detection system for railroads, the Shonai Area Railroad Weather Project, field observation is being conducted in the Shonai area, Japan, to study the fine-scale structure and time evolution of strong gusts in the Japan Sea coastal region in winter. The initial survey showed that most of the surface gusts observed in 2007 winter was associated with the upper vortex signatures in the Doppler radar observations (Kusunoki et al., 2009). Among these events, this paper presents the gusty event associated with the misocyclones along the convergence line on 31 December, 2007, under winter monsoon situation, and focused on the characteristics and temporal evolution of the misocyclones.

II. DATA, OBSERVATIONAL AREA AND INSTRUMENTS

The major facilities for the observation are two X-band Doppler radars and automated surface weather transmitters. X-band Doppler radar of East Japan Railway Company (hereafter JR-EAST radar) was installed at Amarume Station, Yamagata Prefecture, Japan, in order to assess the utility of Doppler radar for the use in operational railroad warning systems (Kato, 2007). Since JR-EAST radar is needed to observe wind gusts successively, it is operated in a single PPI mode of 2rpm at the lowest elevation angle of 3.0 degree so as to provide the reflectivity and Doppler velocity fields as close to the ground as possible. A series of PPI scans taken every 30 seconds provides unique datasets to document temporal and spatial variations of low-level circulation. X-band Doppler radar of Meteorological Research Institute (MRI) (hereafter MRI radar) was also installed at the roof top of Shonai airport during 2007 winter. MRI radar was operated in a multi PPI and RHI mode to observe the three dimensional structure of the storms.

We also used the surface observational data at 26 automated weather stations, which were installed at 4-km interval for the Shonai Area Railroad Weather Project.

III. SYNOPTIC SITUATION

On December 31, 2007, an upper-cold vortex was over the north of the Japan Sea and the surface pressure pattern showed east-west pressure gradient, which is typical of winter monsoon situation around Japan. A cold-air outbreak from the Eurasian continent over the warm sea surface continued and the SW-NE oriented transverse mode snowbands, which extended perpendicular to the mean wind direction and nearly parallel to the coastline, were observed around the Shonai area.

Associated with the passage of low-level trough, a well-developed transversal snowband passed over the observational area around 04 LST (LST = UTC + 9 hours), which corresponded to the time of the surface gust observation.

Wind profiler observation of Sakata Weather Station of JMA showed that while northwesterly to westerly prevailed below 2km MSL during the cold-air outbreak, southwesterly was observed before the passage of the intense snowbands (not shown).

IV. OBSERVED SURFACE WIND GUST AND THE MISOCYCLONES

Strong surface gust of 25.0 m s^{-1} was observed around 0405 LST at one of the automated weather station near the coast (B1, Fig. 1). Associated with the increase of wind speed, sudden change of wind direction (from SW to NW) and the pressure dip was also observed, whereas the temperature showed little variation. It is indicated that the observed gust occurred at the wind shear line between southwesterly and northwesterly.

The Doppler radar observation also showed that this intense transversal snowband was formed between the southwesterly and the following northwesterly, indicating distinct horizontal shear ($\sim 10^{-3}$ s^{-1}) and convergence ($\sim 10^{-2}$ s^{-1}) across it.

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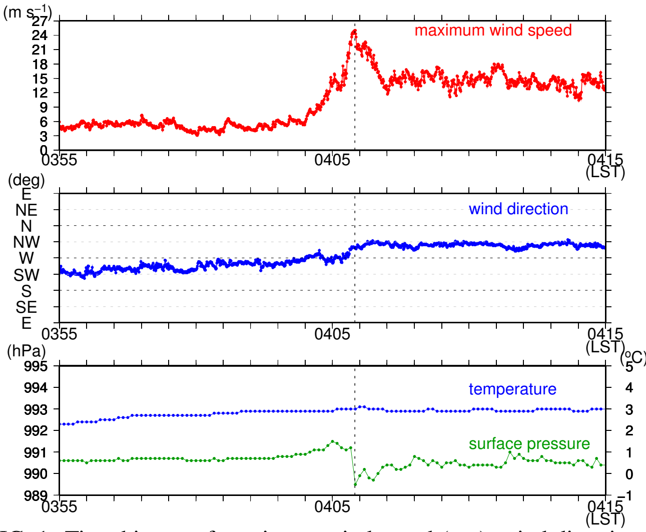

FIG. 1: Time history of maximum wind speed (top), wind direction (bottom), temperature and relative humidity (bottom) at B1 station between 0355 to 0415 LST.

TABLE I: Characteristics of misocyclones 1-5 derived from JR-EAST radar data. Lifetime (T), averaged eastward and northward translational velocity (V_x,V_y) for each misocyclone are listed together with minimum - maximum of diameter (D), tangential velocity (V_t) and vertical vorticity (Vor).

	1	2	3	4	5
T (seconds)	350	903	670	1048	146
V_x (ms^{-1})	14.0	13.9	12.7	12.3	17.4
V_y (ms^{-1})	0.5	-1.0	-0.3	-0.6	2.3
D (m)	300-2100	300-2900	600-2100	200-1800	400-1500
V_t (ms^{-1})	4.7-8.7	6.3-8.5	7.1-9.5	7.0-10.9	6.7-8.5
Vor (s^{-1})	0.01-0.09	0.01-0.12	0.01-0.06	0.02-0.16	0.02-0.07

Within the transversal snowband along this convergence line, at least five cyclonic vortex signatures, which were referred to as misocyclones for their smaller horizontal scales, were observed by the JR-EAST radar with the separation of 4 $\sim$ 9 km. Low-level reflectivity field showed a staircase pattern, likely due to the distortion of the snowband near individual misocyclones.

Detection of the misocyclones for each PPI scan of JR-EAST radar at every 30 seconds was performed manually by identifying Doppler velocity couplet of maximum and minimum and tracking the size and location of each misocyclone. Each misocyclone was labeled 1 to 5. The lifetime of each misocyclone was 17 minutes at the longest. The diameter ranged from about 200 to 2900 m, the tangential velocity was 5 to 11 m s^{-1}, and the estimated vertical vorticity was about the orders of 10^{-2} to 10^{-1} s^{-1} (Table I).

The misocyclones extended to the height of about 2.5 km at the maximum and their diameters and tangential velocities did not show much vertical variation with height. It is likely that the misocyclones associated with deeper convection extended to the higher altitude.

The time of misocyclone 4 passage over B1 station was consistent with that of surface gust observation (Fig. 2). Although the tangential velocity of misocyclone 4 at that time was estimated to be 8.6 m s^{-1}, maximum wind speed of about 22.1 m s^{-1} was estimated by adding the relatively large translational speed of 13.5 m s^{-1} associated with the passage of misocyclone 4 over B1 station. The estimated maximum wind speed was comparable to the observed surface gust. Since the translational speed of the convective cloud during the cold-air outbreaks is generally large, it is suggested that vortices of relatively weak tangential velocities can cause wind gusts due to their large translational velocity.

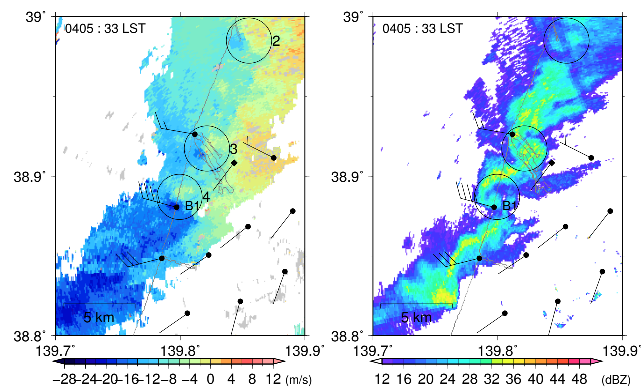

FIG. 2: Doppler velocity (left) and radar reflectivity (right) of JR-EAST radar at 0405:33 LST. The detected misocyclones are shown by the circles. Wind barbs measured at automated weather stations are also depicted (one barb denotes 5 m s^{-1}).

V. SUMMARY

During the cold air outbreak, gusty wind was observed at one of the surface automated weather stations on 31 Dec, 2007 in the Shonai area, Japan. The observed gust corresponded to the passage of one of the misocyclones within the transversal snowbands, which was associated with the distinct convergence line. The temporal evolution of the misocyclones along the convergence line are discussed in the presentation.

VI. ACKNOWLEDGMENTS

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VII. REFERENCES

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