THE VERTICAL STRUCTURES WITHIN A WINTER TORNADIC STORM DURING LANDFALL OVER THE JAPAN SEA AREA

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I. INTRODUCTION

On Japan railroads, wind conditions affect operating efficiency, infrastructure, and safe passage of people and freight. For instance, strong and gusty winds cause regional delays or shutdowns, and especially hazardous crosswinds may lead to overturn of railcars. Since propeller-vane/cup anemometers densely cover on the railroads for operations through some wind speed thresholds (e.g., winds in excess of 25 ms^{-1}), small-scale but strong gusty winds are difficult to detect with the present system. The Shonai area railroad weather project will investigate fine-scale structure of wind gust dynamics and kinetics such as tornadoes, downbursts, and gust fronts. The ultimate goal of the project is to develop an automatic strong gust detection system for railroads, which the decision to warn is generally based upon information from a single-Doppler radar at low elevation angles. The volume scan radar data were obtained at very close range (<1km) in one tornado on 25 January 2008. In this presentation, the detailed vertical structures of the high-resolution reflectivity and velocity fields of this tornado during landfall are described.

II. INSTRUMENTATION

Figure 1 shows the study area where the high-resolution observations of strong gust phenomena have been performed over the Shonai area (Yamagata Pref., Japan). Primarily, over the Sea of Japan side, severe storms such as tornadoes and gust-generating cold fronts occur frequency in winter season. The study area would provide an ideal setting for studying these phenomena (Kusunoki et al. 2007). Major observing instrumentation for this project included the two X-band Doppler radars and the network of automated weather station sites.Some of these facilities, highlighted below, provided the data used in this presentation.

1) MRI portable X-band Doppler radar

MRI portable X-band Doppler radar (X-POD: X-band, POrtable Doppler radar) has been developed as a ground-based radar observation platform to make fine-scale observations of various phenomena. An important aspect of X-POD is its portability. In addition to its small-size and low power consumption, X-POD can be easily dismounted from the truck and deployed on top of a building. The X-POD have been installed on the roof of Shonai Airport building in Sakata City since late December 2007 (Kusunoki and Ichiyama, 2007).The radar, in combination with other devices such as the JR EAST X-band Doppler radar, has been used to obtain detailed meteorological data in the Shonai area. The X-POD has a 60-km observation range, a 2.0 azimuth resolution, and a pulse length of 1.0/0.5/0.2 micro-sec providing independent data points every 150/75/30 m in range. In the Shonai area, the X-POD had a 2.5 minute-volume scan update rate with 4-6 constant elevation angles.

2) JR EAST X-band Doppler radar

JR EAST X-band Doppler radar was installed at the Amarume station in Shonai Town since March 2007. Since it is needed to observe wind gusts successfully, the radar is operated in a single PPI mode at the lowest elevation angle possible to provide the reflectivity and Doppler velocities as close to the ground. The single elevation angle is 3.0 degree and the scans are taken every 30sec (Kato et al. 2007).

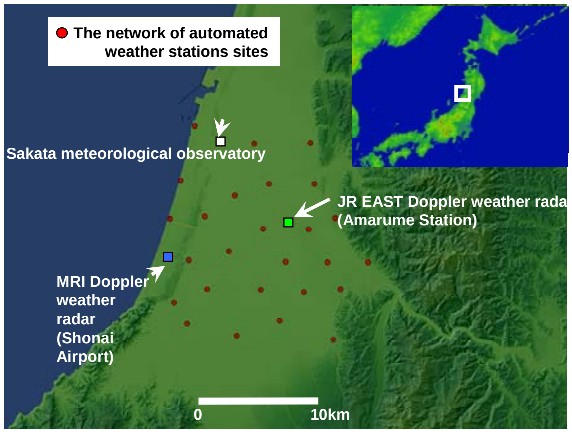

FIG. 1 Map of the Shonai area. Closed circles are the network of automated weather station sites. The inset shows the locations of the Sea of Japan and the study area (in the square).

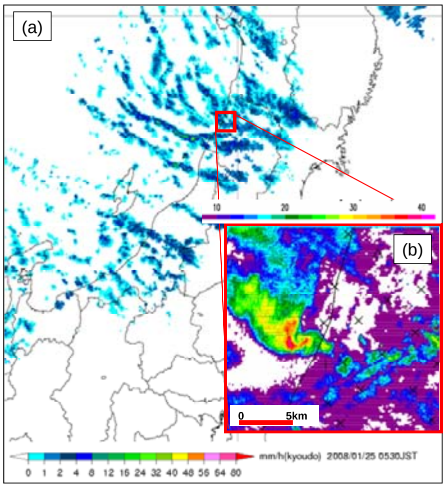

FIG. 2 (a) JMA (Japan Meteorological Agency) radar image of the snowbands at 05:20 LST on January 25, 2008. (b) PPI scan of reflectivity (dBZ) from the JR-E radar at the Amarume station at 05:24:12 LST on January 25, 2008.

III. RESULTS

On 25 January 2008, many snowbands, which is the typical pattern which the winter monsoon prevails around Japan, was observed around the Shonai Coast in the direction nearly normal to the monsoon. Fig. 2 represents a

JMA (Japan Meteorological Agency) radar image of the snowbands and a PPI scan of reflectivity from the JR-E radar at the Amarume station. The reflectivity reveals a pronounced hook echo, which was resolvable by JMA radar, embedded within the snowband. The hook echo is associated with a relatively intense cyclonic circulation (i.e., tornadic vortex) in the Doppler velocity field, as will be mentioned later. The tornadic vortex moved into radar range at 05:04 LST, landed over southwestern portion of the study area, and decayed at the western edge of the Shonai Plain at 05:50 LST.

At about 5 minutes after the landfall, the Shonai airport was close to the area over which passage of the vortex was identified with the JR-EAST radar (FIG. 3). Associated with the passage of the vortex, surface observations at the Shonai Airport confirmed wind gusts (28.8ms^{-1}; FIG. 4). A surface pressure drop also confirmed with the passage of the vortex.

The volume scan radar data of the tornadic vortex were obtained at very close range with the XPOD at the Shonai airport. The vertical structures of reflectivity fields during landfall are shown in FIG. 5. Before landfall, the reflectivity field revealed a characteristic hook shape that the center of the tornado had a weak-echo eye partially surrounded by an eyewall (FIG. 5(a)). The hook echo embedded within the vortex extended vertically through the volume-scan data. The diameter of the hook echo was approximately 2700-3300m. After landfall, the eyewall was transformed to spiral structures spiralling outward from the eye (FIG. 5(b)). The diameter of the reflectivity spiral was approximately 1700-2700m.

Figure 6 shows vertical structures of core diameters (distance from peak inbound to peak outbound Doppler wind speeds) before and after landfall. The tornado vortex before landfall had a core diameter from 320-490m with very little tilt with height. After landfall, a core diameter contracted from 320m to 160m at the height near 300m. This indicates that the tornadic vortex was tilted downstream. Figure 7 shows the vertical profiles of the vorticities estimated from observed Doppler velocities. After the vortex arrived over the Shonai Plain, the vorticities at lower altitudes rapidly intensified reaching a maximum vorticiticity of over 3.1x10^{-1}sec at 125m height. This intensification was accompanied by shrinking of the vortex diameter. It is suggested that during the landfall the vortex tube tilted downstream and shrinked at lower altitudes since the near surface vortex modified and decelerated by the changes in the roughness.

IV. ACKNOWLEDGMENTS

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V. REFERENCES

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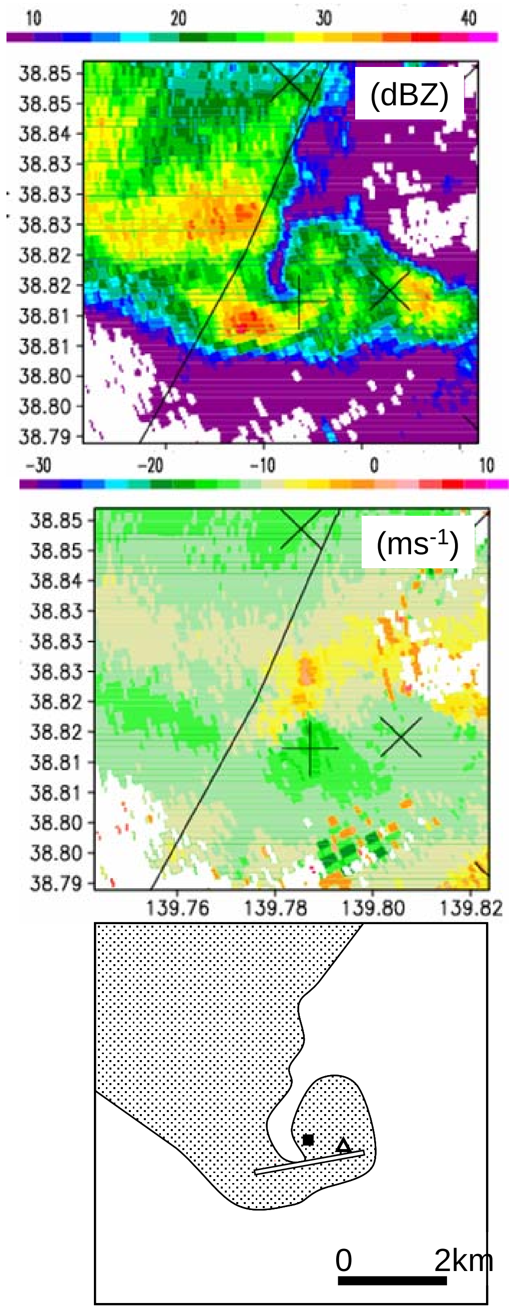

F FIG. 3. PPI scans of reflectivity (top) and Doppler velocity (center) from the JR-E radar located at the Amarume station at elevation angle of 3.0 at 05:27:07. The right panel shows the CR profile along the cloud. The shaded region (bottom) represent reflectivities greater than approximately 30 dBZ. The open rectangle line is the runway of the Shonai Airport. Square is the location of the aerotonometer and triangle is the location of the anemometer.

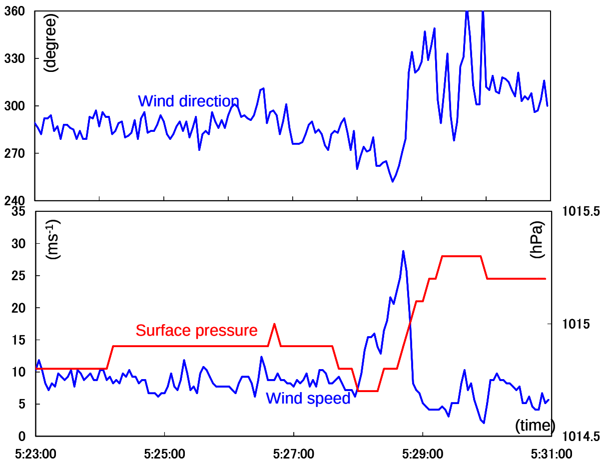

FIG. 4 Time series of surface wind speed, direction, and surface pressure from the Shonai Airport.

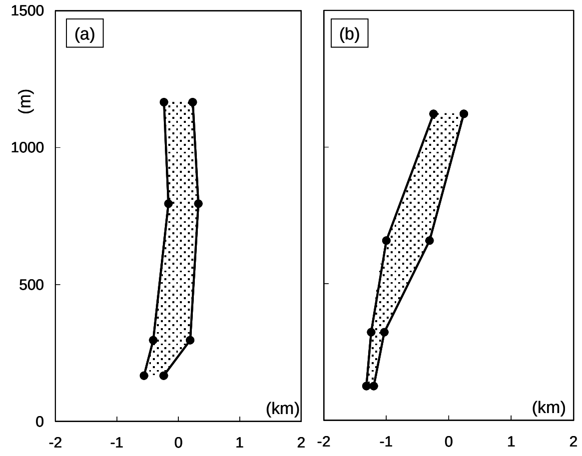

FIG. 6 Vertical structures of core diameters.(a) Before landfall. 5:20:35-5:23:55 LST. (b) After landfall. 5:30:35-5:32:14 LST.

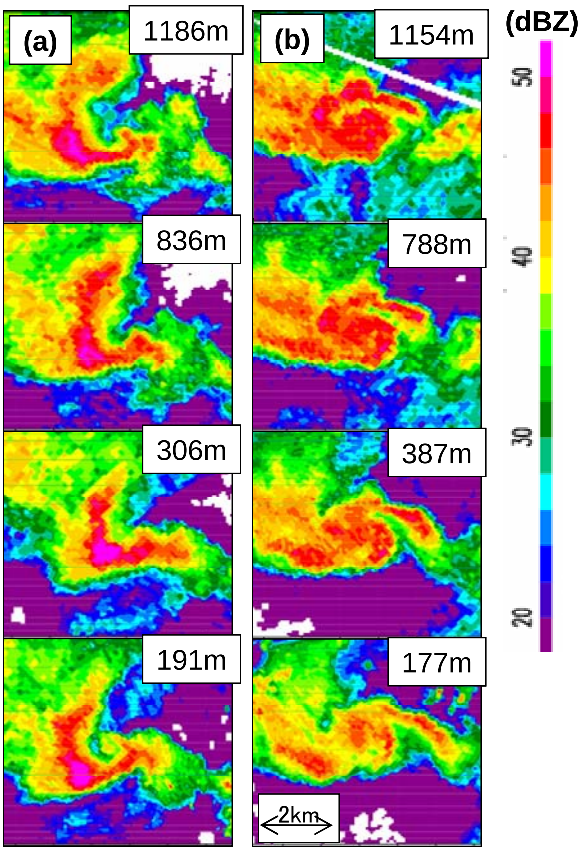

FIG. 5 PPI scans of radar reflectivity from the XPOD.
(a) Before landfall. 5:20:35-5:23:55 LST. (b) After landfall. 5:30:35-5:32:14 LST
Numbers in boxes denote heights of the center in meters AGL.

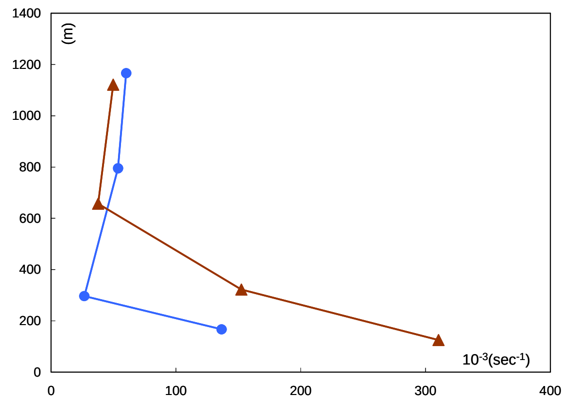

FIG. 7 Vertical profiles of the vorticities estimated from observed Doppler velocities. Line with circles shows profiles before landfall(5:20:35-5:23:55 LST). Line with triangles shows after landfall(5:30:35-5:32:14 LST).