Damaging wind fields associated with Typhoon Jebi in the Kansai region in Japan on the 4th September 2018 derived from multiple-Doppler wind synthesis over complex terrain

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The strongest Typhoon Jebi making landfall in the Japan’s mainland in 25 years brought about record-breaking strong winds in Kansai region, causing extensive damages. Indeed, the maximum surface gust speed exceeding 58.1 m s^{-1} at 1340 JST (Japan Standard Time: JST = UTC + 9 hours) was observed at Kansai International Airport (KIX), and the wind speed larger than 20 m s^{-1} prevailed at many surface stations during its passage over this region. VAD-derived wind profiles showed the existence of strong wind exceeding 50 m s^{-1} at heights between 2.5 km and 5 km above sea level at this airport. The maximum tidal levels were also higher than ever at several observation points. These strong winds and high tides forced to close this airport.

In order to analyzed the strong wind fields associated with the typhoon, three-dimensional wind fields are recovered at several-minute intervals from multiple-Doppler wind synthesis, wherein at most five operational Doppler radars are involved; two of which are at C-band, and others are at X-band. These two X-band radars are located at altitudes of about 0.9 km in mountainous regions, and other three radars are deployed over the Osaka Plain. These radars collect data in observation mode of multiple conical scanning, and are equipped with the dual-PRF processing to extend their respective Nyquist velocity up to about 45 - 50 m s^{-1}. The strong wind resulted in measured Doppler velocities that cannot be correctly handled with the dual-PRF technique. The correction of these velocity data is carried out by a combination of the following three methods. First is a technique proposed by Yamada and Chong (1999), which is enhanced to correct even dual-PRF velocity data, the second is a method based on the continuity of velocity data in the vertical direction, and the last is a method relying on the detection and correction of unnatural gaps in the velocity fields by a local continuity.

Wind recovery was made by MUSCAT over complex terrain (Chong and Cosma 2000), the data fit formulation by Yamada (2013) being employed. The additional constraint imposed on the cross-baseline wind component (e.g., Chong and Bousquet 2001; Bousquet et al. 2008) is applied to the grid points, where the wind measurements were made by two radars. The data set of orography was prepared from the 10-meter resolution digital topographical map provided by the Geospatial Information Authority of Japan. Since the highest elevation angles of radars involved in the wind synthesis are mostly lower than 20 degrees, the wind fields were available at heights below about 5 km above sea level.

Three-dimensional wind fields were restituted using two or more radars in Cartesian coordinates in a fixed frame of reference, by changing the spatial resolutions. The origin of the coordinates is collocated with the KIX radar site, whose height is 41 meters above sea level. The x- and y-axes go toward the east and the north, respectively. Figure 1 shows a ground-relative horizontal wind field derived from quintuple-Doppler analysis at 1343 JST, around which the surface wind speed was most intense at KIX. The use of data from the five radars ensemble allowed to analyze wind fields in wider domains with higher spatial resolutions. The horizontal and vertical resolutions are, respectively, 0.5 km and 0.4 km with the lowest analysis height of 0.4 km above the radar at KIX. This wind field shows a cyclonic circulation associated the typhoon, whose center is located far southwest to KIX at this time. Strong winds exceeding 60 m s^{-1} are found in the southern part of the Osaka Plain and the coastal area of the Osaka Bay. This spatial distribution of strong horizontal wind over land is consistent to the surface wind observations operated by the Japan Meteorological Agency. Vertical profiles of mean horizontal wind derived at different analysis times showed maximum at height of about 3.5 km, consistent to VAD wind profiles at KIX. Vertical structures of radar-derived wind fields suggested that the very strong wind in the southern portion of the Osaka Plain would have been caused by the transport of horizontal momentum at upper heights by downdrafts in the leeside of the Izumi Mts. In addition, the wind structure associated with the typhoon may be modified by the interaction with the orography.

Derived vertical air motions were not so intense such that most of their magnitudes were less than 5 m s^{-1}, except for the upwind side of Mount Rokko. In fact, updrafts in convective clouds exceeding 20 m s^{-1} were found, accounting for a localized intense rainfall in 10 minutes at Kobe between 1340 and 1350 JST, reaching 24.5 mm. These intense convective clouds appear to be induced by the interaction of the low-level strong wind and the orography around the Kobe city. The hourly rainfall amount at Kobe was 59 mm from 1300 to 1400 JST, whereas those at other stations in the Kansai region were mostly less than 20 mm for this period of time.

The wind fields at different spatial resolutions as well as the echo structures will be also demonstrated.

Fig. 1. Horizontal cross-section of ground-relative horizontal wind (arrows) and topography (shaded) at a height of 0.4 km above the KIX radar. Contours (in black) indicate the horizontal wind speed, and the region, where the horizontal wind speed are larger than 50 m s^{-1}, is shown by dots. The locations of Doppler radars involved in the wind synthesis are also shown by red (C-band radar) and blue (X-band radar) circles.

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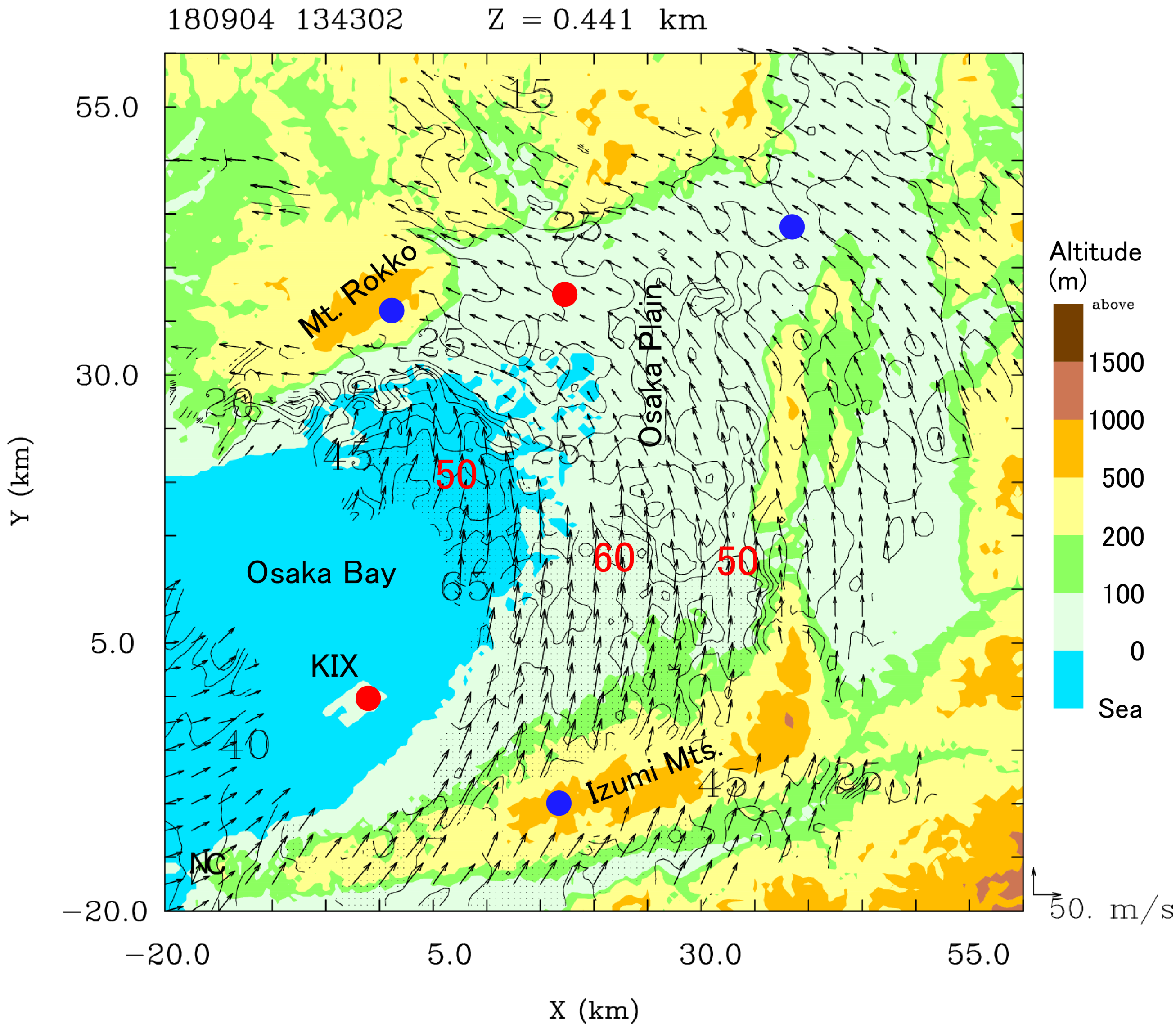
Keywords: Multiple-Doppler wind synthesis, complex terrain, typhoon


180904 134302 Z = 0.441 km
Mt. Rokko
Osaka Plain
Osaka Bay
KIX
Izumi Mts.
NC
50
60
50
Altitude (m)
above
1500
1000
500
200
100
0
Sea
50. m/s
Y (km)
X (km)
55.0
30.0
5.0
−20.0
−20.0
5.0
30.0
55.0