

Fine-scale Structures of Meso- β -scale Vortices that Cause Tornado-like Vortices

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Sudden gusty winds caused by meso- β -scale vortices (MBVs) of 30-50 km diameter occurred at the southwestern part of the Sea of Japan between 0300 and 0400 JST (Japan Standard Time; UTC+9 hour) on 1 September 2015, and between 0630 and 0730 UTC 21 August 2011. A similar MBV was also observed near southern coast of Kii Peninsula on 17 October 2016, although there is no report of damaging gusty winds around the region. C-band Doppler radars of Japan Meteorological Agency (JMA) detected spiral-shaped reflectivity patterns associated with the MBVs. Couplets of positive and negative Doppler velocities exceeding 50 m s^{-1} were observed near the center of the spiral-shaped reflectivity pattern.

To clarify the fine-scale structures of the MBVs that caused the damaging gusty winds, triply-nested numerical simulations using JMA non-hydrostatic model were performed. The simulations with the finest horizontal grid spacing of 50m and 100 vertical levels successfully reproduced the MBVs with spiral-shaped precipitation systems and associated tornado-like vortices within the MBVs. Unlike mesocyclones in supercell storms that spawn tornadoes, the simulated MBVs had the maximum vertical vorticity near the surface.

In the simulations, tornado-like strong vortices developed within the MBVs. The formation positions of tornado-like vortices relative to the cyclone center vary from case to case: In the simulation for the MBV on 1 September 2015, multiple tornado-like vortices with maximum vorticity exceeding 1 s^{-1} grew and decayed repeatedly near the surface in the west of the MBV, where strong horizontal shear exists. It is suggested that these vortices were strengthened by the shear instability. On the other hand, a tornado-like vortex formed in the southeastern part of the center of the MBV that occurred on 21 August 2011. For the MBV on 17 October 2016, multiple tornado-like vortices develop near the MBV center, eastern part of the MBV center, and southeastern part of the MBV center. In all simulations, tornado-like vortices have maximum wind velocity of $45\text{-}60 \text{ m s}^{-1}$.

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