Fine-scale Structure of Mesoscale-beta-scale vortices that caused tornado-like vortices

Eigo Tochimoto[1], Sho Yokota[2], Hiroshi Niino[1], Wataru Yanase[2]
1. Atmosphere and Ocean Research Institute, the University of Tokyo, Japan
2. Meteorological Resaerch Institute, Japan Meteorological Agency
Email: tochimoto@aori.u-tokyo.ac.jp

Abstract

A sudden gusty winds caused by meso-β-scale vortex (MBV) 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. The MBV formed in the northeastern part of the center of extratropical cyclones. A C-band Doppler radar of Japan Meteorological Agency (JMA) detected spiral-shaped reflectivity patterns associated with the MBV. Couplet of positive and negative Doppler velocities exceeding 50 m s-1was observed near the center of the spiral-shaped reflectivity pattern. The observed convective system is not associated with a quasi-linear convective system nor pre-existing mesoscale convective complexes. Thus, to our knowledge, this kind of MBV and the associated strong gusty winds due to embedded tornado-like vortices over the oceans have not been reported previously, yet they can be a serious threat to marine traffic.

A triply-nested numerical simulation using JMA non-hydrostatic model was performed to clarify the fine structure and evolution of the MBVs that caused the damaging gusty winds. The simulations with the finest horizontal resolution of 50m and 100 vertical levels successfully reproduced the MBV with spiral-shaped precipitation systems and associated tornado-like vortices (TLVs) within the MBV. The simulated MBV had the maximum vertical vorticity near the surface. A vorticity budget analysis and a circulation analysis show that the near-surface vorticity of the MBV is strengthened by stretching of vertical vorticity associated with horizontal shear between northeasterly and southeasterly winds in the EC. TLVs with maximum vorticity exceeding 1 s-1grew and decayed repeatedly near the surface in the region of the horizontal shear. It is suggested that TLVs were generated and strengthened by the shear instability. The simulated maximum wind speed near the surface were about 50 m s-1, which is

comparable to Japanese Enhanced Fujita scale of 1~2.

Similar MBVs have been detected with radar observations over the oceans around Japan on 21 August 2011, and 16 October 2016. The MBV in 2011 also caused a gusty wind, resulting in a shipwreck. Unlike the MBV in 2015, these MBVs are seem to be associated with liner-shaped convective systems. Similar triply-nested simulations succeeded in reproducing fine structures of MBVs and associated strong TLVs. The locations of TLVs with respect to the MBV center, however, varies from case to case: a TLV in August 2011 formed in the southeast of the MBV, and TLVs in October 2016 formed in west and east of the MBV. Thus, TLVs in MBVs seem to occur in various regions with respect to the MBV center. The circulation analysis show that the source of near-surface strong vorticity for both MBVs in 2011 and 2016 is due to environmental circulation.