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A case study on the meso-scale disturbances causing the severe snowstorm in Niigata Prefecture on 13 January 2010

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Previous studies have revealed that mesoscale vortical disturbances are formed over the Japan Sea in winter and that they cause heavy snowfall and severe wind hazards in the coastal region of the Hokuriku District. The vortical disturbances often develop into meso-alpha or meso-beta scale disturbances (MASDs and MBSDs, respectively). It's important to know the generation and development processes and internal structures of these disturbances in order to prevent and mitigate disasters.

In this study, we investigate the development processes and the 3-dimensional structure of MBSDs that approached the Hokuriku District on 13th January 2010. By the passage of the MBSDs, the JMA surface observation at Aikawa recorded a maximum wind speed of 40.0 m/s at 0745JST, and the snowstorm caused several power failures and traffic accidents in the Niigata prefecture. The JMA operational radar displayed five MBSDs between 00JST and 12JST on 13. Two of them moved ahead toward east-northeast. Thereafter, the other three moved toward southeast, two of which are considered the cause of the heavy snowfall and severe winds. The surface observation showed that the temperature within the eastern part of the MBSDs were higher than that in other areas. We suppose that the positive temperature deviation represented the warm core (hereafter WC) of the MBSDs.

In order to examine the internal structure of the MBSDs, we performed numerical simulations using a JMA-nonhydrostatic model (Saito et al. 2006) with a horizontal resolution of 2km. Three telescoping one-way nested grids (horizontal grid spacing of 20km; 20km-NHM, 5km; 5km-NHM, and 2km; 2km-NHM) were used. The initial and boundary conditions of the 20km-NHM were produced from the GANAL. The settings of each proccess in the 5km/2km-NHM are the same as that of Saito et al.(2007).

The 2km-NHM reproduces MBSDs moving toward either east-northeast or southeast. As for the MBSDs causing the snowstorm, the horizontal scale of the distribution of the simulated snow particles was larger than that by JMA radar observation. However the simulated MBSD moved a little southly and made landfall in Niigata prefecture 2-hour earlier than the observation, features (wind, decreased pressure, and WC) of the observed MBSD were well simulated.

Previous studies suggest that MBSDs have a WC (Ninomiya et al. 1990) and the WC is produced by the advection of airmass with high equivalent potential temperature from the major cyclone passing over Japan, diabatic heating due to condensation, and adiabatic heating due to downdraught (Murakami et al. 2005). In order to investigate the genesis of WC, we analysed the backward trajectories of particles around the center of MBSD. The result of the analysis shows that there were no airmass advection from the major cyclone. In the vicinity of the simulated MBSD, there existed convective clouds with heavy snowfall accompanied by updraghts instead of downdraughts. In order to investigate the effect of diabatic heating due to condensation on the development of the MBSDs, we performed a sensitivity experiment using a dry model without the condensation process. The MBSDs moving toward southeast were well simulated, but they had no WC or severe winds. In addition, the MBSDs moving toward east-northeast stalled off the coast of Niigata prefecture maintaining the WC structure which was given initially. As the MBSDs moving toward southeast were approaching the WC of the stalling MBSDs, severe winds appeared around the center of the MBSDs. The result implies that the WC of MBSDs causing a severe snowstorm was mainly produced by diabatic heating due to condensation in this case, and further suggests the possibility that it plays a major role in the development of MBSDs with severe winds. The MBSD was also collocated underneath the upper vortex with high potential vorticity dipping down into low levels. This suggests the possibility that the upper vortex contribute the development of MBSDs.

Keywords: vortical disturbances, NHM