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Relation of Dec.2005 heavy snowfall and cloud-top heights estimated from objective analyses and forecasts of cloud-resolving model

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Cloud-top heights of cumulonimbi are almost estimated from the level of neutral buoyancy (LNB). A low-level humid air is lifted adiabatically from the originating level to the lifting condensation level along the dry adiabat, and it is lifted further along the moist adiabat. The upper point at which the moist adiabat crosses the profile of Temperature is the LNB. The higher equivalent potential temperature makes the LNB higher. Over the Sea of Japan in winter, a near-surface air gets the sensible and latent heat from relatively warm sea surface. This air-mass transformation becomes large when the fetch becomes longer and the temperature distance between sea surface and cold air-mass becomes larger. Therefore, the low-level equivalent potential temperature becomes higher around the Japan-Sea side of the Japan Islands, and consequently cloud-top heights become higher there.

The LNB around the Japan-Sea side of the Japan Islands is statistically examined using 6-hourly Regional Objective Analysis Data (RANAL, horizontal resolution: 20 km) of the Japan Meteorological Agency (JMA). The statistical period is December and January in 2001-2005 winter seasons. The relation between Dec. 2005 heavy snowfall and cloud-top heights is comparatively examined from the horizontal distributions of averaged LNB in Dec. 2005 and the other years. The averaged LNB in 2005 is higher than 700 hPa, and it becomes exceeding 50 hPa higher than that in the other years. The appearance rate of LNB in 2005 is also 20-30 % higher. Therefore, heavy rainfall in Dec. 2005 was caused by the environmental condition under which cumulonimbi not only easily form, but also develop higher.

The consistency between cloud-top heights and LNB is examined using the predicted results of a cloud-resolving model (JMA nonhydrostatic model with the horizontal resolution of 1 km, CRM). The initial and boundary conditions of CRM are produced from the 12-hour forecasts of JMA nonhydrostatic model with the horizontal resolution of 5 km (its initial and boundary conditions are produced from the RANAL). The precipitation is calculated using a bulk-type microphysics scheme in which the mixing ratios of cloud and ice cloud, rain, snow and graupel are predicted. 9-hour forecasts are performed 4 times a day by the CRM, and 3-9 hour predicted data are used in this study. The precipitation distribution predicted by the CRM well reproduced that of JMA Radar-Raingauge analyzed precipitation (R-A), although the precipitation amount is overestimated. This overestimation could be brought from the underestimation of R-A.

Averaged cloud-top heights in Dec. 2005 predicted by the CRM are higher over plain areas (about 680 hPa). Meanwhile, they are relatively lower over mountainous areas, because clouds formed by updrafts on the slope are included. The vertical profiles of appearance rate of predicted cloud-top heights show that the LNB in Dec. 2005 appears exceeding two times over a 600-hPa level more frequently than in Jan. 2006, and the vertical level with the maximum frequency is exceeding 50 hPa higher. In other words, the higher development of snow clouds caused the heavy snow fall in Dec. 2005.

The vertical profiles of appearance rate of LNB, estimated from the results of CRM, well correspond with those from the RANAL. In the profile of Dec. 2005 over the sea, the appearance rate of LNB over a 600-hPa level is remarkably higher than that of Jan. 2006. The comparison of heights between cloud tops and LNB shows that cloud-top heights appears with about an half frequency of LNB, and the vertical profiles of appearance rates of LNB over the sea are very similar to those of cloud-top heights on the land. This indicates that snow clouds forming over the sea develop on the land.

For our future works, the relation of predicted cloud-top heights by the CRM to those observed by meteorological radars should be examined.