Importance of vertical water vapor analysis
- A problem in assimilating TPW with 4DVar -

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1. Introduction

During the "Observation of Baiu front over East China Sea and Kyushu in 2001" (X-BAIU-01), the nonhydrostatic model (NHM, Saito et al, 2001) with a horizontal grid size of 5 km (5km-NHM) was operated twice a day to support the observations. 5km-NHM usually predicted rainfall successfully, while failing to do in a few cases. In the morning on 23 June, a band-shaped Mesoscale convective system (MCS) with strong precipitation intensity was observed over southern Kyushu (Fig. 1a), while 5km-NHM hardly predicted rainfall there (Fig. 1b). This MCS suddenly formed at 03 JST (= UTC + 9 hours) to the southwest of Kyushu Island, and rapidly developed. After 08 JST, the MCS stagnated over southern Kyushu until noon.

The purpose of the present study is to improve the prediction of heavy rainfall. The improvement of prediction is investigated when the initial fields are modified using the special observation data. Also the prediction is compared with the results in case of the Tropical Rainfall Measuring Mission Microwave Imager (TMI) data being assimilated to the mesoscale analysis of the JMA.

2. Numerical models

The NHM used in the present study is the full compressible version, in which the density is calculated directly from the state equation without any approximation. The sound waves are treated implicitly both in horizontal and vertical directions. The full scope of microphysics is used to explicitly predict the mixing ratios of cloud water, rainwater, cloud ice, snow, and graupel. For other specifications, see Table 1 in Kato and Goda (2001). The initial and boundary conditions are produced by interpolating the forecasts of Regional Spectral Model (RSM) with a 20-km resolution. The 6-hour forecast of RSM (starting at 00 JST and 12 JST, 22 June 2001) is used as the initial conditions.

3. Improvement of prediction

By comparing the observations with the simulations, the failure of heavy rainfall prediction could be resulted from the lower atmosphere being drier than it is in reality. Therefore, the initial lower atmosphere

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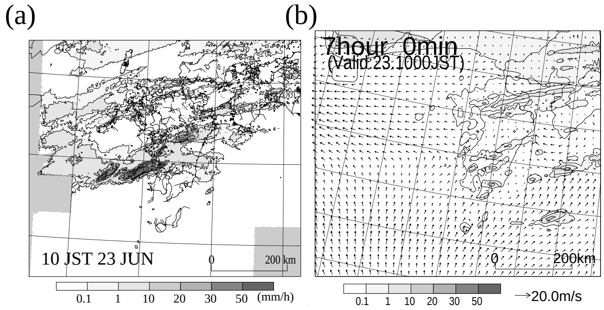

Fig.1 (a) Hourly accumulated rainfall at 10 JST on 23. (b) Same as (a), but for simulation by 5km-NHM.

of 5km-NHM over ocean southwest of Kyushu Island has to be humidified to reproduce the heavy rainfall. In the present study, two methods are used. One is called MOD that the relative humidity *rh* below a height of 1.5 km is increased to over 95 % for the TPW to be close to the TMI-derived TPW. The four-dimensional variational data assimilation technique (4DV) was used for another method. The initial field of 5km-NHM was produced by interpolating the mesoscale analysis with 4DV. In the present study, the TMI-derived TPW data was added to the mesoscale analysis (Sato et al, 2002).

Figure 2 shows the vertical cross section of *rh* in a south-north direction in the initial of 5km-NHM. The lower atmosphere in the control simulation (Fig. 2a) was considerably dry to the south of the area where the band-shaped MCS formed. This dry air made a small value of TPW in the control simulation. In the sensitive experiment with MOD (Fig. 2b), the lower atmosphere below a height of 1.5 km was nearly saturated, and a humid air was supplied into the area where the band-shaped MCS formed.

Figure 3 show the rainfall distributions simulated with MOD and 4DV. For MOD (Fig. 3a), the band-shaped rainfall with the precipitation intensity over 50 mm h^{-1} was reproduced successfully. But, it was simulated southward by 50 km in comparison with the observation (Fig. 1a).

For 4DV (Fig. 3b), rainfall areas were simulated over southern Kyushu. The location of the simulated band-shaped MCS was closer to the observation than that for (Fig. 3a). However, the structure of the simulated band-shaped MCS was not reproduced well, and the simulated precipitation intensity was not strong enough to forecast a heavy rainfall. Noted that the atmosphere below a height of 3.5 km was nearly

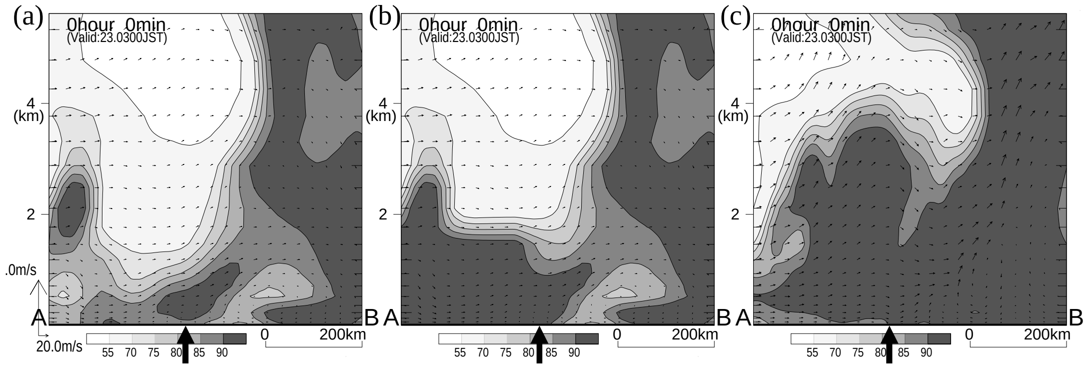

Fig. 2 The vertical cross section of *rh* in a south-north direction in (a) the control simulation, and sensitive experiments with (b) MOD and (c) 4DV. Bold arrows denote the location of the band-shaped MCS forming.

saturated to the upstream of the area where the band-shaped MCS formed at 04 JST (Fig. 2c). Such a weak convectively unstable layer cannot induce a heavy rainfall. The 4DV cannot well retrieve the vertical profile of water vapor only using the TPW data. This result indicates that the vertical water vapor analysis is significant to simulate a heavy rainfall.

4. Conclusion

Good accuracy in the analysis of a vertical water vapor profile is necessary for the NHM to forecast heavy rainfalls during the Baiu season. Especially, the accuracy over the East China Sea, i.e., the upstream of the Baiu frontal zone, is significant. However, few upper-air soundings are operated there. Therefore, the 4DV analysis using the TPW retrieved from satellite data such as TMI data is expected to improve the water vapor field. However, it is difficult to reproduce the vertical profile of water vapor from TPW data. This is.because, when the TPW is assimilated by 4DV, the water vapor at all vertical grids is increased or decreased at the same rate in proportion to the amount of TPW, i.e., it is impossible to humidify only the lower atmosphere (Fig. 4b). Although the lower atmosphere can be mainly modified by setting a weight function in 4DV to reproduce the present heavy rainfall (Fig. 4a), this modification cannot be applied to whole areas and all seasons

Spatially and temporally dense upper-air soundings are necessary in order to use TPW data effectively. This is because the estimation of a water vapor field among upper-air sounding points is difficult due to its being a passive tracer, while dynamical fields such as temperature and wind can be reasonably interpolated by 4DV. These dense soundings may be replaced in the near future by remote-sensing observations from the ground and satellites. Furthermore, spatial observations of low-level water vapor, such as those made by aerosondes, are significant because the water vapor over the sea south of the Baiu frontal zone concentrates in the lower atmosphere and few upper-air soundings are conducted there.

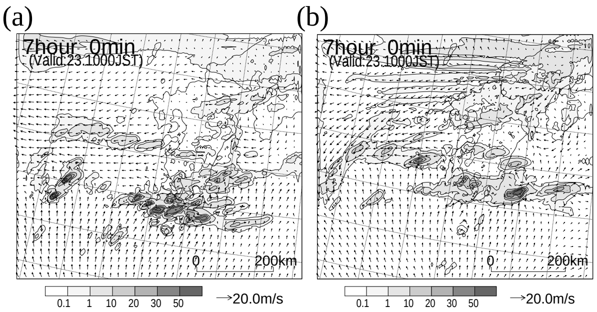

Fig. 3 Same as Fig. 1, but for sensitive experiments with (a) MOD, and (b) 4DV.

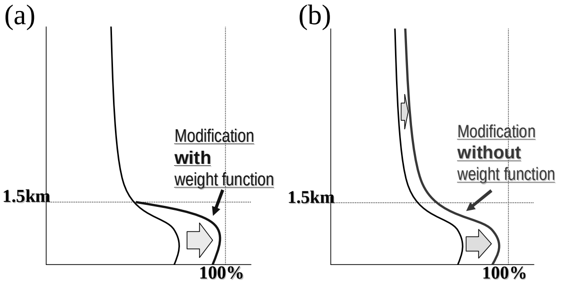

Fig. 4 Modification of water vapor profile by assimilating TPW using 4DV (a) with and (b) without weight function in areas without rain.

Refferences

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