A CASE STUDY OF HOURLY AMV ASSIMILATION WITH JMA-MSM

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ABSTRACT

The Meteorological Satellite Center (MSC) has been producing high density atmospheric motion vector (HD-AMV) data since May 2003, operationally. The HD-AMV is produced four times a day with a grid interval of 0.5 degrees. And it could be obtained hourly, although it was not produced hourly in the operation. Such a high density data are expected to improve meso scale model. Therefore, observation system experiments (OSEs) with JMA Meso-Scale Model (MSM) were performed for six-hourly HD-AMV (OSE1) and for hourly HD-AMV (OSE2) in this study.

Rainfall forecast over the Japan Island was considerably improved in the OSEs, and OSE2 showed much better rain forecast than OSE1. The analyses and the forecasts on the cold low were also much improved in the OSEs. However the typhoon forecasts were not so much improved. The HD-AMV could make the typhoon more intense and sustainable but it was too much. Besides the HD-AMV, the OSEs used the bogus wind and sea surface pressure data around the typhoon. It is thought that the combinational use of the HD-AMV and the bogus data made the typhoon too intense. It needs to improve the way to use the HD-AMV and the bogus data together.

The experiments showed feasibility that hourly HD-AMV improves the MSM performance operationally, but it needs further investigation of optimum use of HD-AMV in the MSM operation, especially for the relation to the other assimilated data.

1. INTRODUCTION

The JMA has been operating a Meso-Scale Model (MSM) with 4D-VAR data assimilation system (Meso 4D-VAR). The MSM is operated four times a day and provides 18-hour forecasts. The results are utilized for very short range rainfall forecast to mitigate natural disasters.

The Meso 4D-VAR was implemented on March 2002, which conducts 3-hour cycle analyses to prepare initial conditions for MSM. Although the implementation of the Meso 4D-VAR brought considerable improvement in the precipitation forecasts of MSM, it still needs to have higher accuracy to predict heavy rainfall quantitatively. It needs not only to improve MSM and Meso 4D-Var but also to introduce new observation data into the system.

The Meteorological Satellite Center (MSC) has been producing high density atmospheric motion vector (HD-AMV) data since May 2003 using GOES-9 half-hourly images, operationally. The HD-AMV with its quality indicator (QI) is calculated four times a day with a grid interval of 0.5 degrees, while the normal density AMV was produced with a grid interval of 1 degree (Kumabe, 2004). Ahead of the operation, it was tested to produce HD-AMV using GMS-5 half-hourly images. Moreover, it was also confirmed in the test that the HD-AMV could be obtained using hourly sequential images instead of using the half-hourly ones, though the number of derived AMV became much less. The GMS-5 took the image hourly for normal observations and half-hourly for AMV observations. By using hourly GMS-5 normal observation data, it is possible to obtain hourly HD-AMV. Such a high density data are expected to improve meso scale model.

The Meso 4D-VAR enables to assimilate hourly observation data considering its observation time. With the Meso 4D-VAR, the observation system experiments (OSEs) were performed for six-hourly HD-AMV (OSE1) and hourly HD-AMV (OSE2) in this study.

2. OSE SYSTEM AND STUDY CASE

The MSM is a hydrostatic spectral model with a horizontal resolution of 10km and 40 vertical levels up to 10hPa. It covers Japan and its surrounding region with the extent of 3600km by 2880km. The domain is shown in Fig. 1. It runs four times a day and produces 18 hour forecasts routinely.

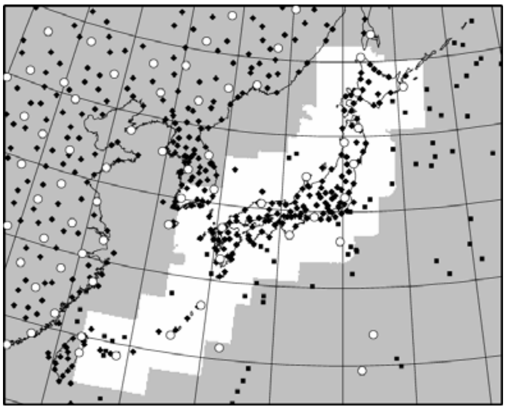

Fig. 1 Domain of MSM. Open circle shows upper air soundings, closed symbol shows surface observations, and unshaded area shows the coverage of Radar-AMeDAS rainfall observation

To prepare the initial condition of MSM, Meso 4D-VAR with three-hour assimilation window has been used. The Meso 4D-VAR employs an incremental method to reduce the computational cost. The horizontal resolution of the inner-loop model is 20km. The forward model in the Meso 4D-VAR is the same as MSM except for the horizontal resolution. In the adjoint model, several physical processes are omitted.

The observation data assimilated operationally are upper air soundings, surface observations, aircraft observations, hourly wind profiler data, and hourly Radar-AMeDAS precipitation data (RA). RA is one hour precipitation data estimated from radars and calibrated with rain gauge data. The normal density AMV data is also used in the present operation. The both total column precipitable water and rain rate data retrieved from space-borne microwave imager data and typhoon bogus data were introduced in 2003. They were also used in this study.

In the operation, 6-hour continuous data assimilation, which is realized by two sequential Meso 4D-VAR data assimilations with three-hour window, and 18 hours MSM forecasts are performed every 6 hours. The process flow of the operations is shown in Fig. 2.

In this study, three experiments were performed. They are:

CNTL) without HD-AMV
OSE1) with 6 hourly HD-AMV (QI>70)
OSE2) with hourly HD-AMV (QI>70)

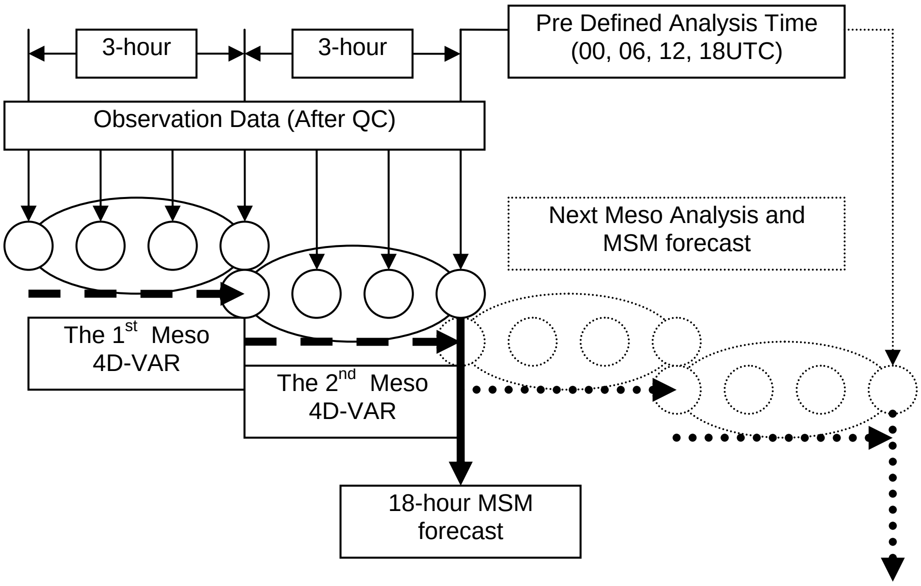

Fig.2 Process flow of JMA operational Meso Analysis and MSM forecast

The target date is 10 July 2002, when the heavy rainfall was observed in eastern Japan. Fig. 3 shows the GMS-5 water vapour channel (WV) images on (a) 06 UTC 9 July 2002 and (b) 00 UTC 10 July 2002. In Fig.3 (a), the typhoon Chataan (T0206) was to the south of Japan and moved toward the direction of north east. At the same time, there was a cold low (CL) around North Korea, and moved to the vicinity of Vladivostok after 18 hours.

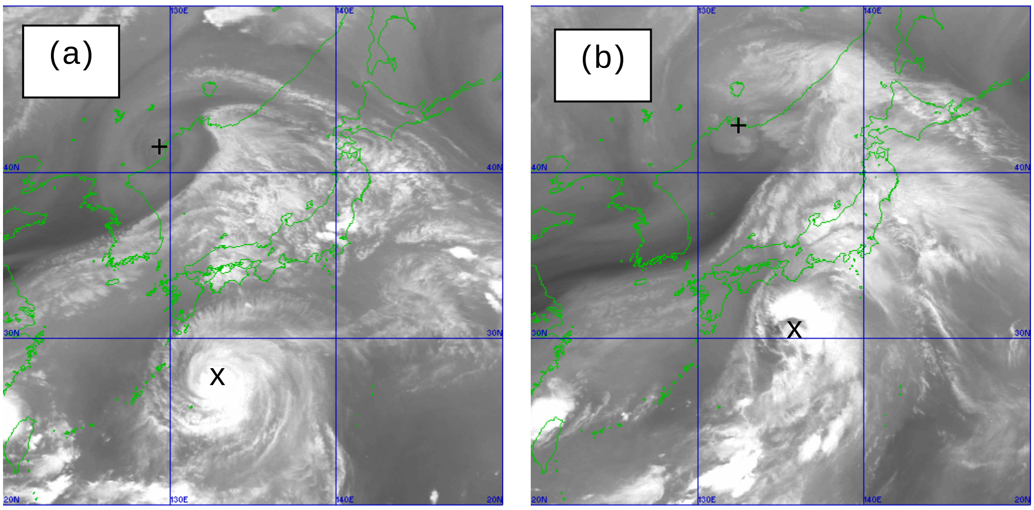

Fig. 3 GMS-5 water vapour channel images on (a) 06 UTC 9 July 2002 and (b) 00 UTC 10 July 2002. The symbol (x) shows the center of the typhoon Chataan, and the symbol (+) shows the center of the cold low.

Fig. 4 shows the distribution of the HD-AMV with QI > 70 at (a) 06 UTC 9 July 2002, and (b) 00 UTC 10 July 2002. The HD-AMV was produced very densely over the cloudy area. The circulation of the CL can be identified clearly, although there was no cloud. The HD-AMV illustrates the upper level divergence from Chataan at the peripheral region at 06 UTC 9 July 2002.

Fig. 5 shows the distribution of the HD-AMV made from the imageries with one hour interval at 21 UTC 9 July 2002. The data were very sparse in contrast to the Fig. 4. However the circulation of the CL is able to be identified at different position from one in Fig. 3(b), which shows the data at three hours after. It means that the data enables to show the movement of the CL in the three-hour assimilation window.

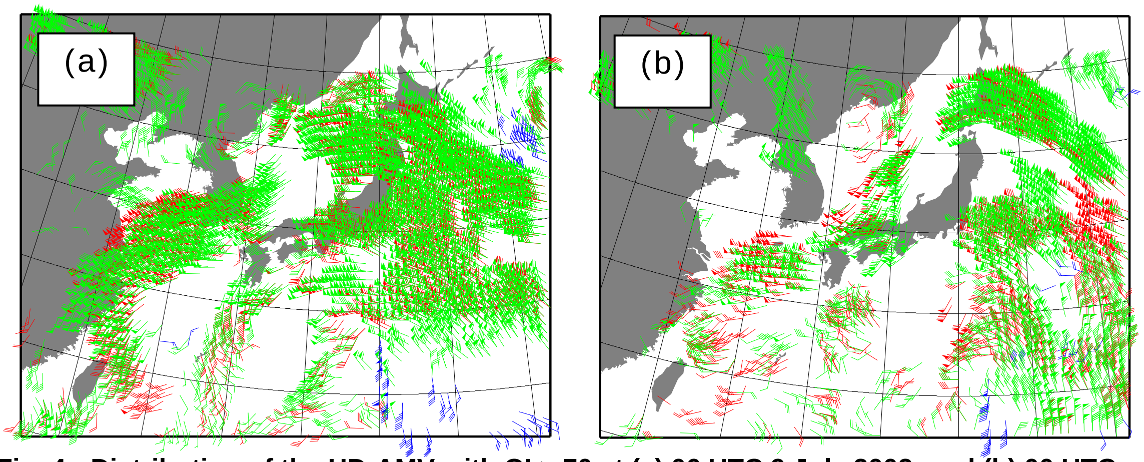

Fig. 4 Distribution of the HD-AMV with QI > 70 at (a) 06 UTC 9 July 2002, and (b) 00 UTC 10 July 2002. The barb colour shows the used channel for the HD-AMV derivation. Red is from infrared, blue is from visible and green is from water vapour.

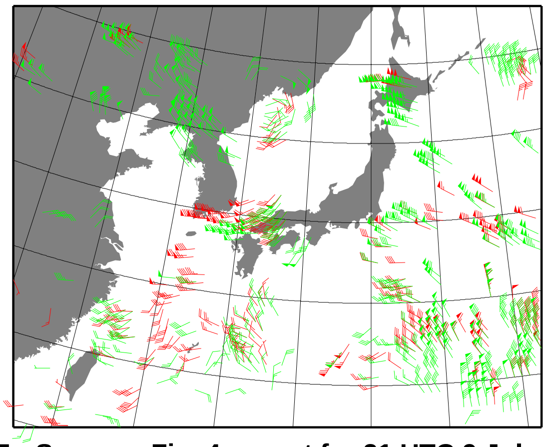

Fig. 5 Same as Fig. 4 except for 21 UTC 9 July 2002.

The HD-AMV data is assimilated after quality control process and thinning process. The processes are same as the processes for normal AMV data. In this study, the data was thinned only spatially, but not thinned temporally. The assimilation was performed for one day starting from 12 UTC 8 July 2002. While there are four forecasts performed with six hour interval, the forecast from 06 UTC 9 July 2002 is shown mainly.

3. RESULTS AND DISCUSSION

Fig. 6 shows the geopotential height field at 500 hPa (Z500) at the initial time (FT00) and 18 hours forecast (FT18) from 06 UTC 9 July 2002. In the OSEs, the positions of the CL at FT00 are almost same as the one in CNTL. However, the positions at FT18 are much different from the one in CNTL. In CNTL, the CL moved toward the east and located northern part of the Japan Sea at FT18. In the OSEs, they moved toward the north-east and located near Vladivostok at FT18. The forecasts in the OSEs show good correspondence with the GMS-5 observation (Fig. 3(b)). That means the HD-AMV assimilation improved the CL forecast. Comparing the OSE1 and OSE2, the CL was more intense in OSE2 than that in OSE1. The predicted value of Z500 over Vladivostok at FT18 was 5721m in CNTL, 5712m in OSE1 and 5709m in OSE2, while the corresponding upper air sounding showed Z500 was 5670m.

In case of the typhoon Chataan, the both analyzed and predicted positions are almost same in the three experiments. However, the intensity forecasts are quite different. Fig. 7 shows the time sequence of the central pressure of Chataan. The pressure at FT00 is 960 hPa for CNTL, while 958 hPa for the both OSE1 and OSE2. In CNTL, the pressure was predicted to become increase monotonically. In OSE1, it was predicted that it was not changed till FT06 and became increase after that. In OSE2, it was predicted that it decreased till FT06 and increased after that. Since HD-AMV observed the upper level divergence wind from

Chataan, it is thought that the assimilation strengthened its vertical circulation and the intensity of Chataan was reinforced. As a result, the analyzed pressure at FT00 and the predicted pressure at FT06 became closer to the best track data. However, since the best track shows the monotonic increase of the pressure, it is thought the assimilation intensified Chataan too much.

Considering the other data, the both bogus wind profiles and bogus sea surface pressure data were assimilated about the typhoon region. Since the bogus data was prepared to correct the typhoon intensity and position over the data scarce region, it was not so considered to use with the other data. Moreover, the HD-AMV was thinned only spatial but temporal, while the temporal error correlation must not be ignored. It needs to investigate the temporal error correlation structure of the HD-AMV, and the optimum way to use with typhoon bogus data.

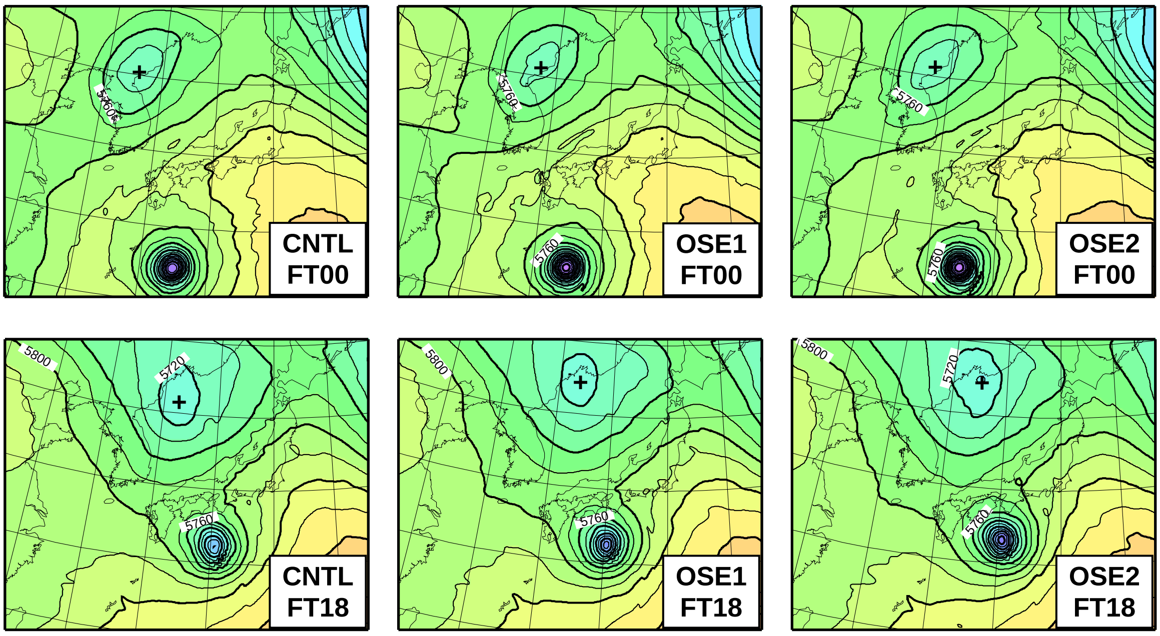

Fig. 6 Z500 at initial time (upper panels) and 18-hour forecast (lower panels) in the forecast from 06 UTC 9 July 2002. The left panels show CNTL, the center OSE1, and the right OSE2. The contour interval is 20m. The symbol (+) shows the center of the cold low.

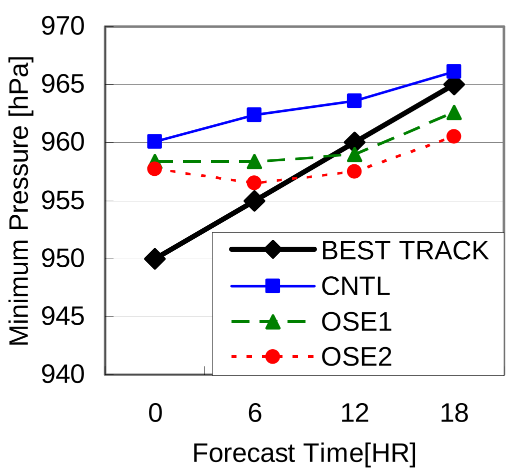

Fig. 7 Time sequence of minimum surface pressure.

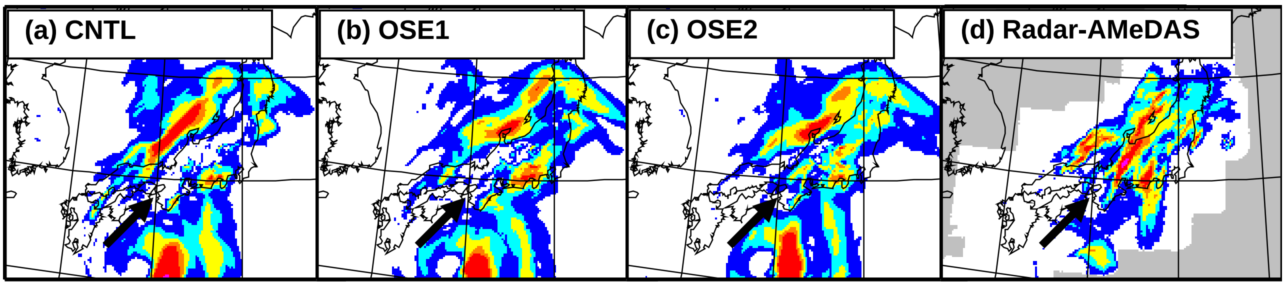

Fig. 8 Three-hour rainfall forecasts at FT18 in the forecast from 06 UTC 09 July 2002 and corresponding Radar-AMeDAS three hour rainfall observation data.

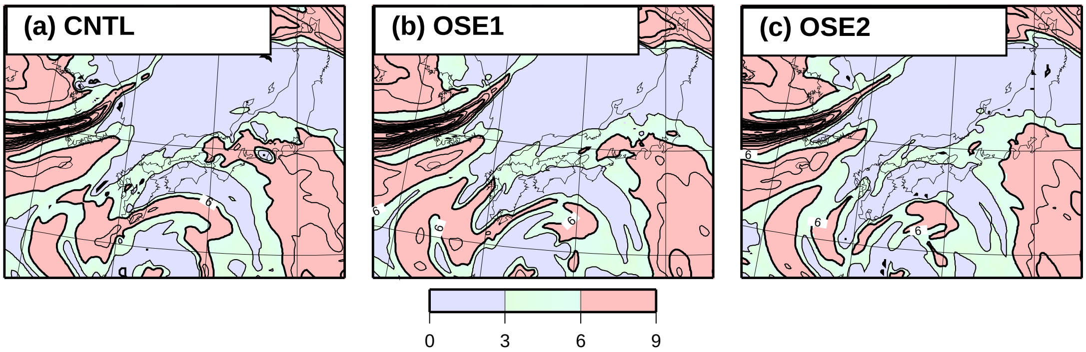

Fig. 9 T-Td field on 700hPa at FT06 in the forecast from 06 UTC 09 July 2002. The contour interval is 3K.

Fig. 8 shows the three-hour rainfall forecasts at FT18 and the corresponding RA three-hour rainfall observation data. In CNTL, there is rain free area along the Japan Island. The cause is that the typhoon entrained the dry air over the Japan Island and it stagnated over there. Fig. 9 shows T-Td fields on 700hPa at FT06. Fig. 9(a) shows the intrusion of dry air with T-Td>6K very clearly. Although the rain area broadened in OSE1, there are rain-free area and dry air intrusion, too. The rain area broadened much more in OSE2, and it shows better correspondence with the observation data. It is thought that the HD-AMV intensified the CL to the north of Japan, and it made developed the disturbance over the Japan Sea. It enforced the southerly wind over the Japan Island and the flow toward the typhoon became weaker, relatively. Consequently the dry air intrusion became smaller and humid air could be remained over the Japan Island.

Fig. 10 shows the threat scores calculated from the four forecasts in the three experiments for weak (1mm/3hr) and moderate (10mm/3hr) rainfall. Those were validated by RA rainfall observations. OSEs show the better score than CNTL. Moreover, the OSE2 is much better than OSE1 in this case. Therefore, it is thought that the hourly HD-AMV assimilation brought the better rainfall forecast than six-hourly HD-AMV one.

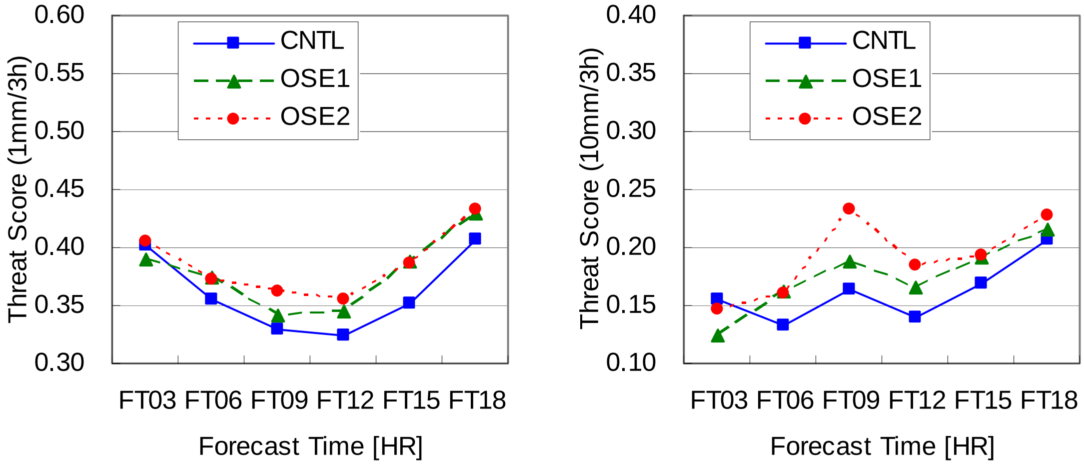

Fig. 10 Threat scores calculated from the four forecasts for weak (1mm/3h) and moderate (10mm/3h) rainfall.

4. SUMMARY

The OSEs for six-hourly HD-AMV and hourly HD-AMV were performed using JMA Meso-Scale Model and its data assimilation system. With the data, the analysis and the forecasts of cold low became much better and it made the better rainfall forecast over the Japan Island. However, the typhoon forecasts were not improved. It was thought the dense data and combination with the bogus data made the typhoon intensified too much. It needs to confirm the error correlation structure in the data and the bogus data.

The experiments showed feasibility that HD-AMV improves the MSM performance operationally, but it needs further investigation of optimum use of HD-AMV in the MSM operation, especially for the relation to the other assimilated data.

5. REFERENCES

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