Assimilation of Hourly MTSAT-1R AMV into JMA-MSM

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Abstract

The operation of the MTSAT-1R satellite began in June 2005 at the Japan Meteorological Agency (JMA). JMA has been using SATOB atmospheric motion vector data from MTSAT-1R in a meso-scale 4-dimensional variational assimilation system (Meso 4D-VAR) for Meso-Scale Model (JMA-MSM: 10km resolution) since July 2005. High density atmospheric motion vector (HD-AMV) data from MTSAT-1R are generated every hour at intervals of 0.5 degrees along with QI (Quality Indicator) by the Japan Meteorological Satellite Center (MSC). JMA is conducting a preliminary study to make use of HD-AMV data in Meso 4D-VAR.

The HD-AMV data need thinning to avoid the spatial correlation of observation errors in the assimilation system. The distance dependency of covariance of the observation-guess departure for JMA-MSM is investigated to estimate a thinning interval and observation errors.The statistics are calculated using the HD-AMV data with QI higher than 60-90. The thinning interval is defined as a distance where the correlation falls to 0.5, and a value of 150 km is obtained. Observation errors are set to a little larger than the values obtained from the statistics in consideration of the correlation left after the thinning.

In a case study using the HD-AMV data in Meso 4D-VAR, a trough in eastern China strengthened and predicted precipitation became closer to radar observations in the vicinity of Japan than that without using the HD-AMV data.

1. INTRODUCTION

The JMA-MSM is a non-hydrostatic spectral model with a horizontal resolution of 10km and 40 vertical levels up to about 22060 meters[*1]. It covers the Japan islands 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. The results are utilized for very short-range rainfall forecasts meteorological warnings to mitigate natural disasters.

Figure 1: Domain of JMA-MSM

[*1] The JMA-MSM was updated on March 1, 2006 : a horizontal resolution of 5km and 50 vertical levels up to about 21800 meters. It is operated eight times a day.

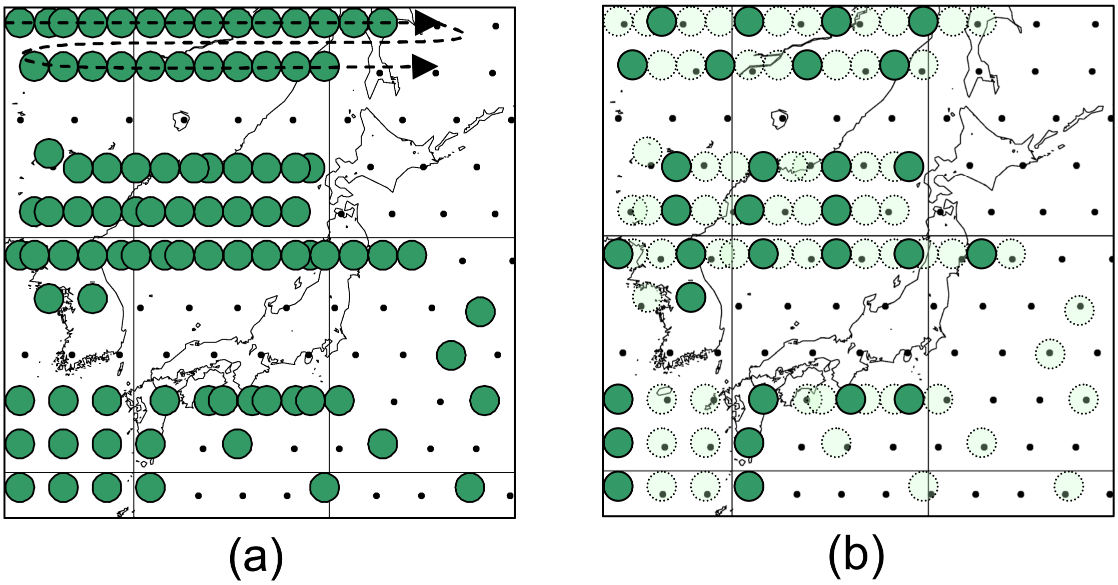


Figure 2 : AMV data distributions by the one-third thinning of reported-order thinning method
(a) : AMV data distributions before thinning. The reported-order is indicated by arrows
(b) : AMV data distributions after the one-third thinning of reported-order thinning method
Dark green circles indicate surviving AMV data. Light green dash circles are removed. Black dots are the centers of grid boxes.

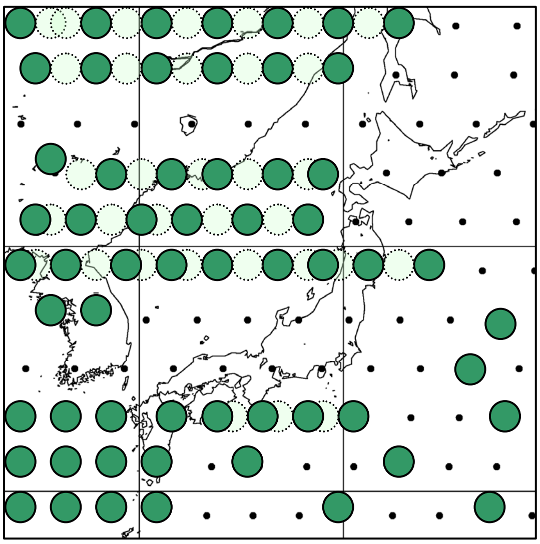


Figure 3 : AMV data distributions after thinning by the equal-distance thinning method

The Meso 4D-VAR was implemented on March 2002, which conducts 6-hour cycle analyses with consecutive two 3-hour assimilation windows to prepare initial conditions for JMA-MSM[*2]. The observational data assimilated operationally are radiosonde observations, surface observations, ship observations, buoy observations, aircraft observations, hourly wind profiler data, QuikScat wind data, Doppler radar radial wind data, hourly Radar-AMeDAS precipitation data (RA)[*3], temperature data from NOAA/ATOVS, total precipitable water data and rain rate data from DMSP/SSMI,TRMM/TMI

[*2] The Meso 4D-VAR was upgraded on March 1, 2006 to conduct 3-hour cycle analyses with 6-hour assimilation windows.
[*3] RA is 1-hour accumulated precipitation data estimated from radar data through calibration with rain gauge data.

QI threshold	Extra-tropical (x>=20° or x<=-20°)	Tropical (-20° <x<20°)
IR : high level < 400hPa	60	85
IR : middle level (400hPa < x <= 700hPa)	60	60
IR : low level > 700hPa	75	70
VIS : only low level	60	60
WV : only high level	90	70

Table 1: QI threshold for METEOSAT-5 and METEOSAT-7 in the operation.

and Aqua/AMSR-E. The SATOB AMV data are also used in the present operation. Typhoon bogus data are assimilated when a typhoon exists in the domain of JMA-MSM.

JMA has been assimilating SATOB AMV from MTSAT-1R in JMA-MSM since July 15, 2005. The quality of AMV generated from MTSAT-1R is shown by Imai (2006). In contrast, High-density AMV (HD-AMV) data from MTSAT-1R are currently not used. The data are produced every hour at intervals of 0.5 degrees with QI by MSC. The HD-AMV data are expected to improve smaller scale analysis. To use the HD-AMV data in operation, we develop more appropriate assimilation preprocessing techniques, such as thinning, and assess their impacts with an observation system experiment (OSE).

2. REVISION OF THINNING METHOD AND ESTIMATE OF OBSERVATION ERROR

The AMV data thinning procedure is important for removing redundant AMV data and for reducing computer burden. Currently, JMA uses a reported-order thinning method in the operation. An example of one-third thinning in reported-order method is shown in Fig. 2. If the AMV data are reported in the order as shown in Fig. 2(a), the method selects AMV data as in Fig. 2(b). This method is simple, but causes a highly inhomogeneous distribution, which is unfavorable for the data assimilation system.

In order to obtain a more homogeneous distribution (Fig.3), we developed a new thinning method called the equal-distance thinning method. In the equal-distance thinning method, the first step is to set a grid box at every observation time. The second step is to select an AMV with a high QI value and closest to the center of the grid box in each grid box. The vertical size of the box is set to 100 hPa.

To determine the horizontal size of the thinning box, we investigated the distance dependency of covariance of departure between the HD-AMV observations and the first-guess (O-B) by Meso-Scale Model, by using Hollingworth-Lonnberg method (F.Bouttier and Courtier, P. 2002). This study period was from July 15, 2005 to August 15, 2005. The statistics are calculated using the HD-AMV data with QI higher than 60-90. The QI threshold used in this investigation is shown in Table 1, which comes from the operational setting for METEOSAT-5 and METEOSAT-7. The thinning interval was defined as a distance where the correlation falls to 0.5 as a trial basis, because the AMV data generated over a wide region from an identical sensor may have the observation error correlations. In this result, the thinning interval was approximately 150km for all sensor types (Fig. 4). The correlation of difference observation point also remains.

The Hollingworth-Lonnberg method was also used to estimate observation error. We assumed that there was no correlation between observation and background errors, assumed that there was no correlation between different observation points. So, the O-B variance is equal to the sum of the observation and the background error variances, and background error covariance is represented by a gaussian distribution. Then, the background error variance is estimated from the value where separation of background error covariance is set to zero. Observation error was estimated from the remaining of the background error variance. Table 2 shows the result of the statistical investigations. Table 3 is the setting used in the operational system, which is larger than observation errors obtained by the statistical investigations. Observation error was set a little larger value than those obtained by the statistical investigations to avoid unreasonable impacts from correlation left after thinning. So, we use the same value as the operation in Table 3.

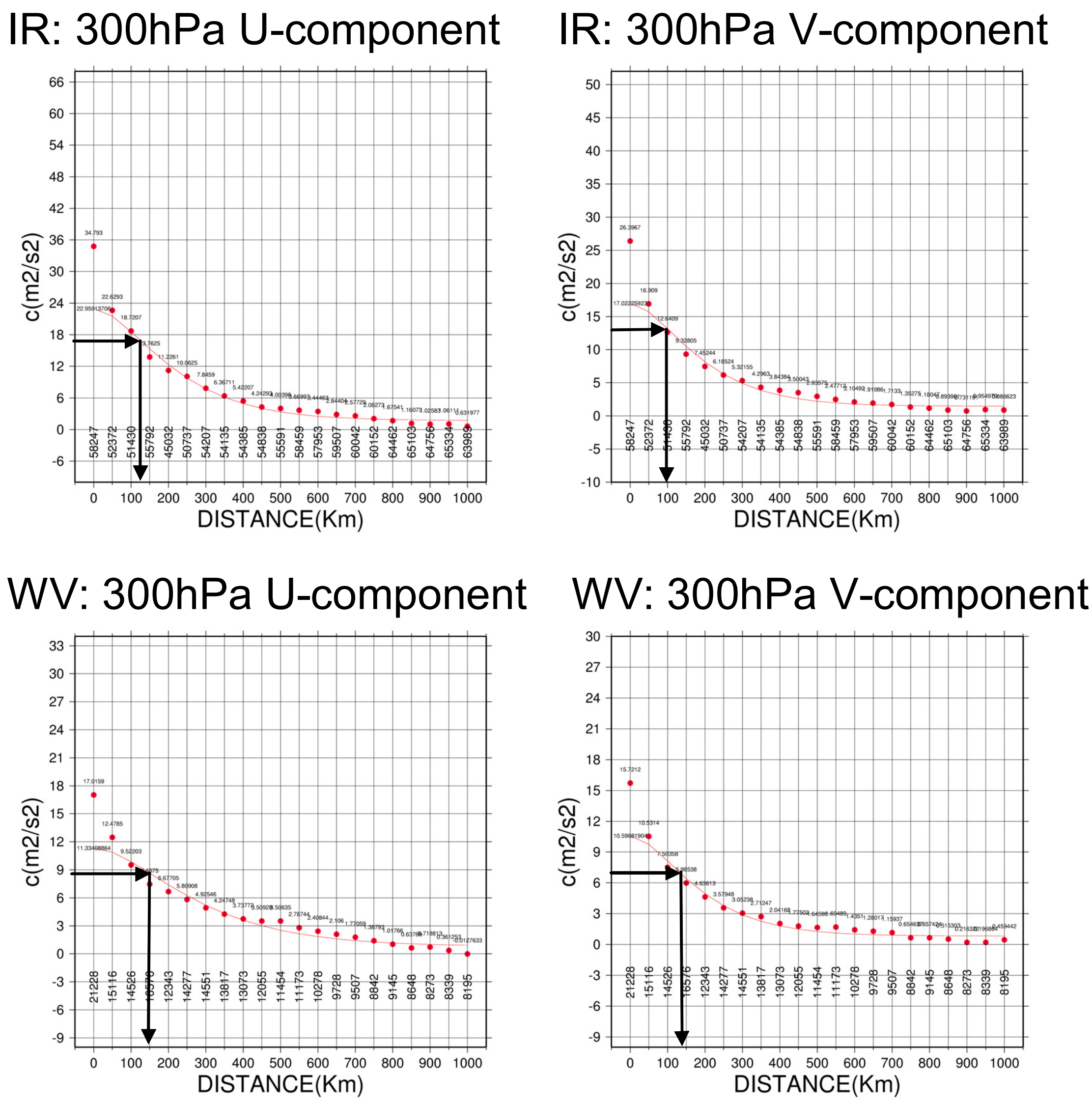


Figure 4 : The distance dependency of covariance of departure between the HD-AMV observation and the first-guess by Meso-Scale Model for IR winds and water vapor winds(WV).
The thinning interval is defined as a distance where the correlation falls to 0.5 (correspond to half of variance（y-axis）) as a trial basis. The estimate method of the thinning interval are indicated by arrows. As this result, the thinning interval was approximately 150km.

Level	U(m/s)	V(m/s)
200hPa	3.4	3.2
300hPa	3.5	3.2
850hPa	2.3	2.4

Table 2 : Observation errors obtained by the statistical investigation.

Level	U(m/s)	V(m/s)
200hPa	5.8	5.8
300hPa	5.3	5.3
850hPa	4.5	4.5

Table 3 : Observation errors in the operation.

3. OVERVIEW OF EXPERIMENTS

To evaluate the impacts of HD-AMV data using the equal-distance thinning method, JMA carried out HD-AMV experiments as follows. The data assimilation system is Meso 4D-VAR. The forecast model is JMA-MSM. Meso 4D-VAR data assimilation cycles were run every six hours from 00UTC September 10, 2005 to 00UTC September 11, 2005.18-hour forecasts were executed from 00UTC September 11, 2005. In this study, two experiments were performed.

CNTL) with MTSAT-1R SATOB winds (identical to the operational data)
OSE) with HD-AMV which pass the following quality control procedures :

① QI>=60
② no winds above 200 hPa and below 950hPa
③ use all sensor winds : between 200-950hPa (under such conditions)
priority winds : WV : between 350-250hPa
VIS : below 850hPa
only use IR winds : IR : between 400-500hPa

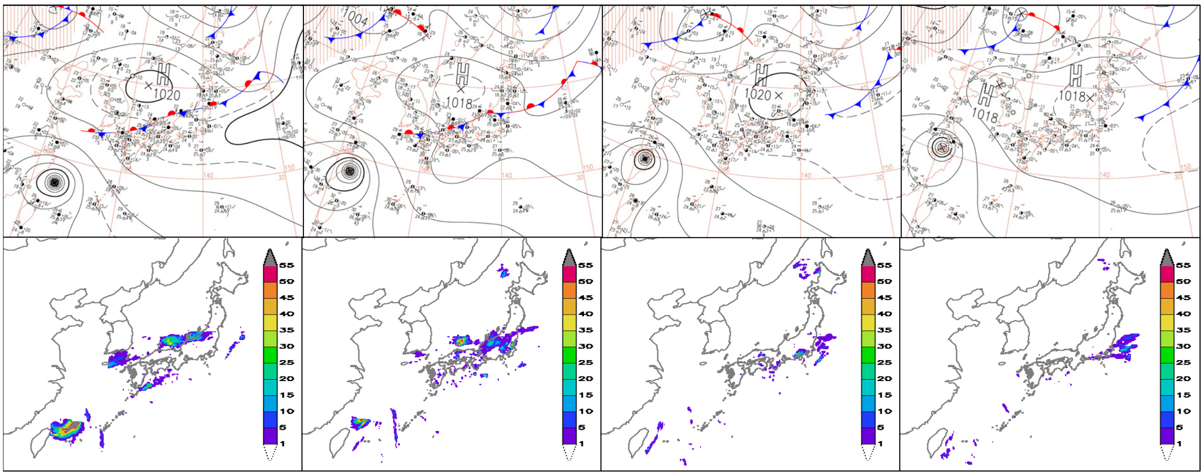
4. RESULTS

Figure 5 shows weather charts and RA on September 11, 2005. At 00UTC , in the vicinity of Japan, a stationary front extending from east to west brought rain. From 06UTC to 18 UTC, this front moved southward and dissipated. In the operational forecast at 18 UTC, rain prediction of the eastern part (kanto and toukai area) of Japan did not well agree with RA (shown in Fig. 6).

Figure 7 compares AMV data distributions in CNTL and OSE. The OSE uses more AMV data than the CNTL.

Figure 8 shows the geopotential difference height at 300 hPa and wind difference at 300hPa (OSE-CNTL). Over eastern China, where more AMV are used, a trough is strengthend. The strengthend trough, as it moves to the east, modified the prediction of precipitation in the vicinity of Japan.

This modification makes better precipitation forecast in the eastern part (kanto and toukai area) of Japan closer to RA in OSE (shown in Fig. 6).



00UTC 06UTC 12UTC 18UTC

Figure 5 : Weather Charts and RA (September 11, 2005).
Upper: 6hourly Weather Charts. Lower: RA is previous 3hours precipitation. The unit of RA is millimeter(mm).

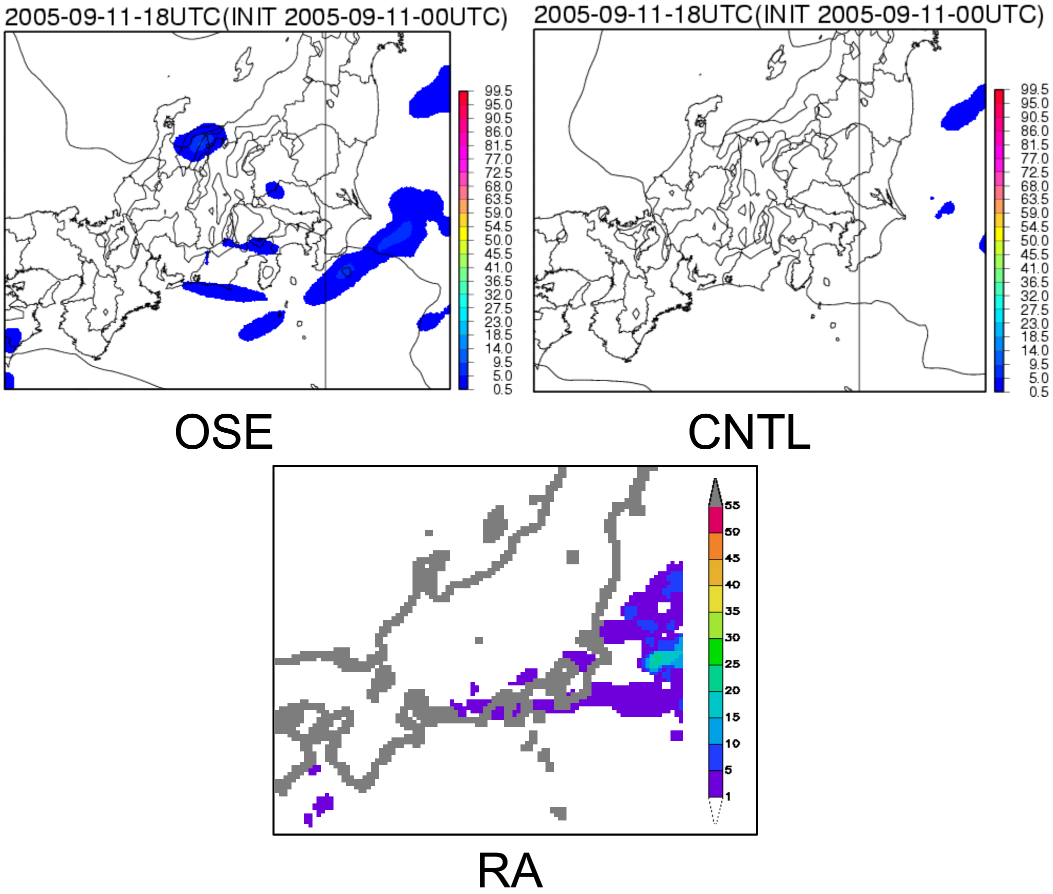


Figure 6 : Comparison of 18-hour precipitation forecasts (18UTC September 11, 2005) between OSE (upper a left panel) and CNTL. (upper a right panel)
Initial time is 00UTC September 11,2005. They are verified against RA (bottom panel) The unit of forecast precipitation (**previous 3hours precipitation**) and RA (**previous 3hours precipitation**) are **millimeter(mm).**

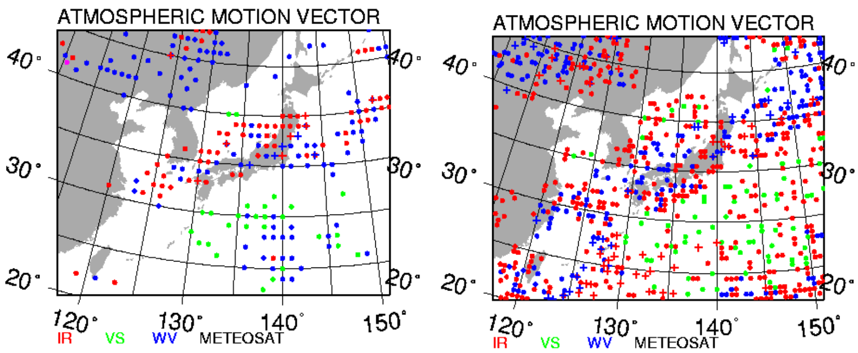


Figure 7 : Coverage of AMV in the assimilation for 00UTC September 11,2005.
Left : CNTL (Used AMV data:238 points). Right : OSE (Used AMV data:752 points)

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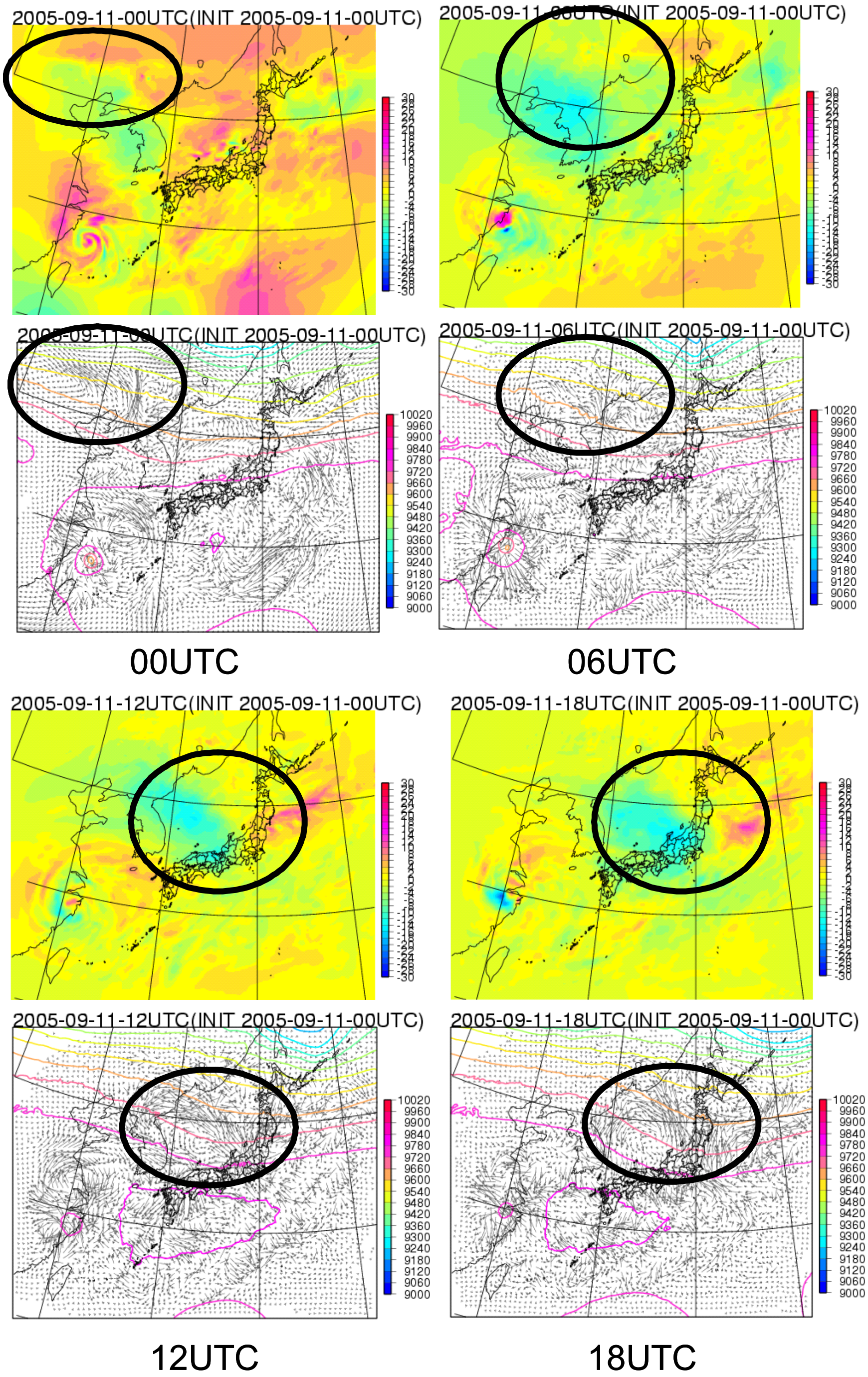

Figure 8 : Analysis and **forecast of 300 hPa (OSE-CNTL) .**
OSE-CNTL of geopotential height at 300hPa (upper panel of each time : unit is meter) and wind at 300hPa (lower panel of each time : unit is knots) at 00,06,12 and 18 UTC. Colored contours in the lower panels indicate geopotential hight (m) in OSE. The trough in question is indicated by black circles (see text).

5. SUMMERY

To use the HD-AMV data in operation, JMA investigated usage of them with Meso 4D-VAR in JMA-MSM. As an appropriate thinning method, the equal-distance thinning method was applied. The thinning interval was set to approximately 150km. Observation errors were set to the same value as the operational ones.

A case study shows the HD-AMV data in Meso 4D-VAR gives better analysis by deepening trough over eastern China which results in a better precipitation forecast in the vicinity of Japan.

JMA is continuing to investigate the impact of the HD-AMV data in Meso 4D-VAR to see if the thinning interval and observation errors are appropriate.

6. REFERENCES

Imai, T., (2006) Status of atmospheric motion vector in JMA. Eighth International Wind Workshop, China.

Bouttier, F. and Courtier, P.,(2002) Data assimilation concepts and methods. ECMWF Meteorological Training Course Lecture Series, pp 1-59.