Upgrade of the operational JMA non-hydrostatic mesoscale model

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1 Introduction

The Japan Meteorological Agency (JMA) has been operating the mesoscale model(MSM) since March 2001 to provide short time scale forecasts for preventing disaster. MSM covers the domain near Japan which expands 3600 km from east to west, and 2900km from north to south.

While the first MSM was a hydrostatic model with 10-km horizontal resolution and 18-hour forecast 4 times a day, it was replaced by a non-hydrostatic model (JMANHM) on Sep.1, 2004[1] with the same domain, horizontal resolution, forecast time and frequency as the hydrostatic one. The differences between the former hydrostatic model and JMANHM were not only in dynamics frame, but also in many physical processes such as cloud microphysics and Kain-Fritsch cumulus convective parameterization scheme.

In March 2006, its horizontal and vertical resolution and forecast frequency was enhanced corresponding to the renewal of supercomputer system : horizontal resolution was increased to 5-km, the number of vertical layers were raised from 40 to 50, and 15-hour forecasts are operated every 3 hours, or 8 times a day[2]. Physical processes were also improved so that it could give more accurate forecasts, especially for precipitation and surface temperature and wind.

We also plan to extend forecast time from 15 to 33 hours 4 times a day out of 8 time forecasts in May 2007. In this report, the specifications of JMANHM of the next version which is planned to replace the current operational MSM in May 2007 is mentioned. The current operational MSM and the improved MSM are denominated MSM0603 and MSM0705 respectively below.

2 Specifications of MSM0705

The specifications of MSM0705 compared with MSM0603 are shown. Although the trigger of this replace of MSM model is to expand forecast time from 15 hours to 33 hours, many processes (mainly physical processes) are improved from the current one.

Basic frame The forecast domain, horizontal resolution, and number of grids of MSM0705 are the same as MSM0603.

Dynamics The generalized hybrid vertical coordinate is introduced instead of z^* coordinate[3]. While the model planes at lower layers are following terrain, those at higher layers are made horizontal to reduce errors of calculating pressure gradient force and advection.

Turbulence process Improved Mellor-Yamada Level 3 scheme[4] is implemented[5], in which parameters on the closure assumption are revised from original Mellor-Yamada model by referring to the latest LES results, and time integration of variables on turbulence(ex. TKE) is made more stable. This scheme provides more accurate expression of boundary layer. As the surface flux scheme, the scheme by Beljaars and Holtslag[6] is adopted instead of Louis[7] on land and Kondo[8] on sea.

Radiation process The clear sky radiation scheme is replaced by that of the latest operational global model of JMA(GSM), which reduces biases of heating rate by long wave radiation. Cloud fraction and cloud water which are needed by radiation scheme to evaluate the effect of clouds are calculated by partial condensation scheme instead of by the diagnosis from relative humidity and total precipitation water. The normal distribution on vapor amount is assumed and its standard deviation is evaluated by the outputs from turbulent schemes. It makes representation of cloud more realistic. Consequently reduction of bias of shortwave radiation flux toward surface is confirmed, and more diurnal change of surface temperature is favored.

Moisture process Finite terminal velocity is given to cloud ice in cloud physics, which had been assumed not to fall. It removes excessive cloud ice which is accumulated with the progress of forecast time and make a harmful effect on radiation process. As to cumulus convective parameterization, the relative humidity based perturbation is added to the trigger function of Kain-Fritsch scheme to remove excessive precipitation by grid scale convection and precipitation is made less sensitive to terrain and surface roughness.

3 Verification of MSM0705

To display the performance of MSM0705, the statistical verifications of MSM0705 for precipitation, surface temperature, and vertical profile of temperature compared with MSM0603 (of which forecast period is simply expanded to 33 hours with MSM0603 to compare the performance of models) in July 2006 (summer term) and January 2006 (winter term) are shown.

In verifying precipitation, threat score and bias score are evaluated comparing with radar observations calibrated by rain gauge observations with 20-km verification grid. Fig.1 shows the time series of threat score and bias score for precipitation of 10-mm per 3 hours in summer and 5-mm per 3 hours in winter with forecast time. The threat score of MSM0705 is better than MSM0603 through almost forecast time in both summer and winter.

Mean error (or bias) and root mean square error (RMSE) of surface temperature for each valid time compared with AMeDAS (Automated Meteorological Data Acquisition System of JMA: about 900 points which provide temperature and wind observations

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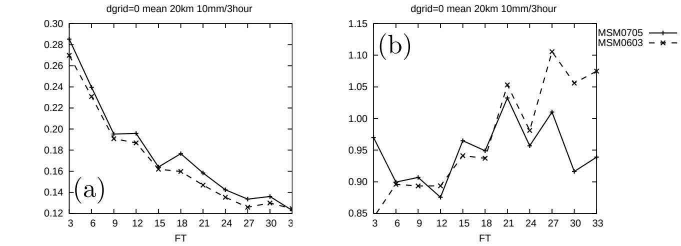

Fig. 1: Verification of precipitation. (a) Time sequence of threat score for 10 mm per 3 hours in summer. (b) Same as (a) but of bias score.Solid line, dashed line indicate MSM0705 and MSM0603 respectively.

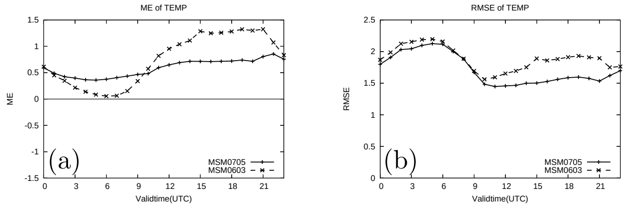

Fig. 2: Verification of surface temperature for each valid time. (a) Time sequence of ME in summer. (b) Same as (a), but of RMSE.

across Japan) are displayed in Fig.2. The diurnal changes of bias become smaller, or the more realistic diurnal changes of surface temperature and wind are exhibited. (In this summer term, bias in the daytime is positive and the positive bias becomes increased, but this case is unusual and bias in the daytime usually is negative. The smaller diurnal change of bias should be attracted.)

Bias and RMSE of vertical profile of temperature at forecast time 33 hours compared with sonde observations are shown in Fig.3. Decrease of bias and RMSE is found, especially in summer term.

In this way, it is confirmed that MSM0705 is superior to MSM0603.

4 Example of forecast by MSM0705

Example of forecast by MSM0705 is shown in Fig.4. Although the position of rainband differs a bit from the observation, MSM0705 gives much better expression for the rainband than the current MSM.

5 Conclusion and remarks

MSM is improved by many development, especially in physical processes, and will be operational in May

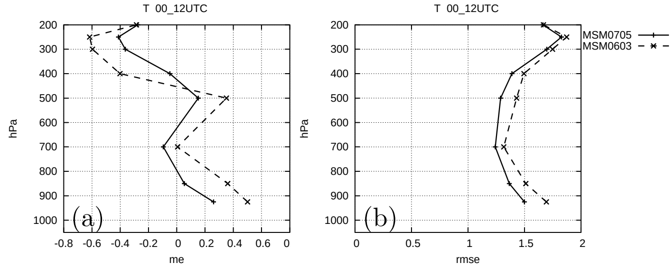

Fig. 3: Verification of vertical profile of temperature at forecast time 33 hours. (a) Vertical profile of ME in summer. (b) Same as (a) but of RMSE.

2007. Further developments to advance dynamical and physical processes more and to operate in higher resolution are going on.

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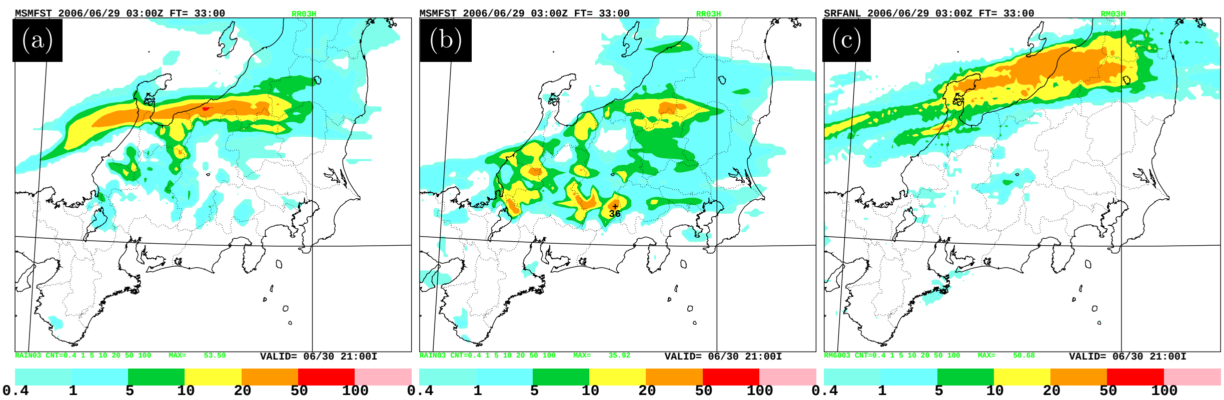

Fig. 4: (a) Forecasted 3-hour accumulated precipitation at forecast time 33 hours by MSM0705. Initial time is 0300 UTC 29 Jun 2006. (b) Same as (a), but by MSM0603. (c) observation at the time corresponding to the forecasts.