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The verification of high-resolution precipitation forecasts of the operational JMA mesoscale model

Tomonori SEGAWA and Yuki HONDA (Numerical Prediction Division/Japan Meteorological Agency)
E-mail to: t-segawa@met.kishou.go.jp

1. Introduction

The Japan Meteorological Agency (JMA) has been operating a mesoscale numerical weather prediction system (hereafter MSM) since March 2006 using the JMA non-hydrostatic model (JMANHM) with a horizontal grid spacing of 5 km. The regional spectral model (RSM) of JMA operationally provides a 51-hour weather forecast over Japan and East Asia. The forecast time of MSM is planned to be extended from 15 up to 33 hours for 4 times a day from May 2007 (hereafter NEW-MSM). The forecast domain of MSM is shown in Fig.1 and the specifications of these models are shown in Table 1. In order to evaluate the performance of NEW-MSM, verifications were carried out under the same conditions as in operational run.

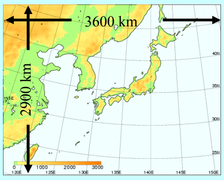


Fig.1. Forecast Domain of MSM

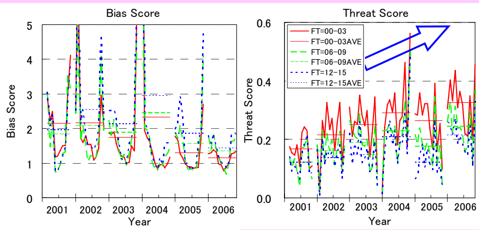
	RSM	MSM	NEW-MSM
Horizontal Resolution	20 km	5 km	
Horizontal Grids	325×257	721×577 (3600×2900 km)	
Initial Time (UTC)	00, 12	00, 03, 06, 09, 12, 15, 18, 21	
Forecast Time	51 hours	15 hours	15 hours (00,06,12,18UTC) 33 hours (03,09,15,21UTC)
Analysis System	4 Dimensional variational (4DVar)		
Boundary Conditions	GSM	RSM	
Main Purpose	Short-Range Forecast	Disaster Prevention, Aviation Safety	Disaster Prevention, Part of Short-Range Forecast, Short-term Aviation Forecasts

Table1. Details of MSM, RSM and NEW-MSM

2. Forecast Performance of MSM

Figure 2 shows the monthly threat and bias scores of MSM. The details of verification are shown in Table 2. The verification is done against "Radar–Raingauge Analyzed Precipitation" (hereafter R-A). The bias score has come gradually close to 1. Although the threat score has been changed monthly, it has been gradually improved since March 2001.

Figure 3 is the case study of "Baiu Front" caused heavy rainfall in the central Japan. The forecast of MSM is more realistic than that of RSM (Threshold: more than 20mm/3h, orange area). The area covered with weak precipitation by RSM is larger than that by MSM.

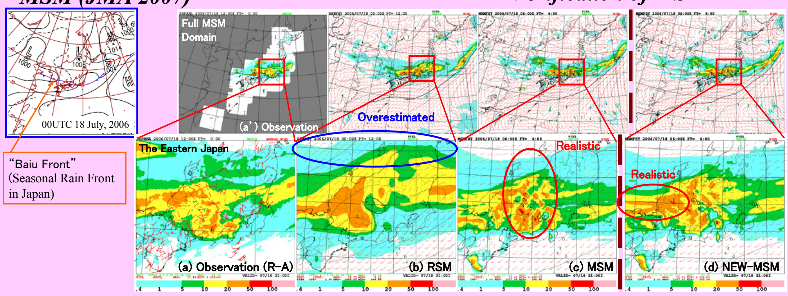


"FT" denotes a forecast time from initial time. "AVE" denotes an annual average.
In the winter, the accuracy of the R-A is degraded by loss of radar observable area, so bias scores have shown tendencies of overestimation of precipitation.

Fig.2. Statistical verification of the operational MSM (JMA 2007)

	MSM
Verification Grid Size	20km×20km
Amounted Time	3 hours
Initial Time	00,06,12,18UTC (until 28 Feb. 2006) 00,03,06,09,12,15,18,21UTC (from March 2006)
Forecast Time	00–03, 06–09, 12–15 (h)
Threshold of Precipitation	10mm/3h
Verification Term	March 2001– December 2006
Verification Domain	Japan and around sea
Observation Data	Radar–Raingauge Analyzed Precipitation (2.5–km mesh: until Feb.2006 1–km mesh: from March 2006)

Table2. Details of Statistical Verification of MSM

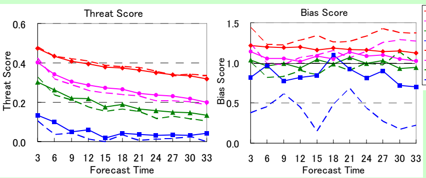


White area in (a') shows the target of verifications. (a) shows 3 hourly accumulated precipitation by R-A, (b), (c) and (d) show 3 hourly forecast precipitation by RSM, MSM and NEW-MSM, respectively.

Fig.3. 3 hourly precipitation of "Baiu Front", Valid time: 1200UTC 18 July 2006

3. Performance of 33-hour forecasts by NEW-MSM

Figure 4 shows the threat and bias scores against forecast time by NEW-MSM and RSM. The details of verification are shown in Table 3. The bias score of NEW-MSM is close to 1, and that of RSM is particularly larger than 1 for weak precipitation all the time. Although the threat scores of NEW-MSM are almost better than that of RSM, the score of NEW-MSM is sometimes poorer than that of RSM for weak precipitation. As shown in Fig.3(d), NEW-MSM represents the more realistic precipitation.



"MSM1mm" denotes the score of NEW-MSM for 1mm/3h.

Fig.4. Time Sequences of Threat and Bias scores by NEW-MSM and RSM

	NEW-MSM	RSM
Verification Grid Size	40km×40km	
Amounted Time	3 hours	
Initial Time	03,09,15,21UTC	00,12UTC
Forecast Time	33 hours	
Threshold of Precipitation Intensity	1, 5, 10, 30mm/3h	
Verification Term	Summer (31 days, from 1 July 2006) Winter (31 days, 22 Dec. 2005)	
Number of Initials	248(summer) 248(winter)	62(summer) 62(winter)
Verification Domain	Japan and around sea	
Observation Data	Radar–Raingauge Analyzed Precipitation (1–km mesh)	

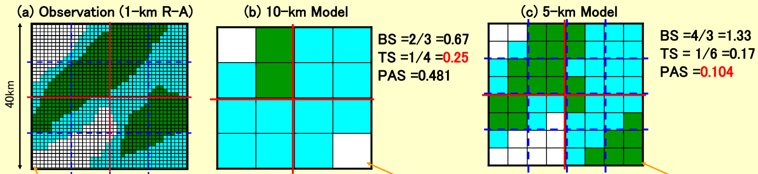
Table3. Details of Statistical Verification of NEW-MSM

4. Why is the statistical verification score of NEW-MSM poorer than that of RSM ?

Although the subjective verification of NEW-MSM is better than that of the RSM and MSM, the score of the statistical verification of binary categorical forecast by NEW-MSM is sometimes poorer than that with RSM (Fig.4).

As shown in Fig.5, it is evident that the forecast result of 5km-model is more realistic than that of 10-km model. The number of false alarm grids by 5-km model is larger in number than that by 10-km model. Therefore, the threat score of 5-km model is poorer than 10-km model.

This discrepancy comes from the fact that the threat score using precipitation data averaged over a verification grid is inappropriate to the verification of high-resolution precipitation forecasts. This is because the process of averaging smoothes out the peak of the grid value of precipitation which might be represented better in the high-resolution model. So, the benefit of high-resolution model would be lost if the model is evaluated by threat score. Thus, it is necessary that both the intensity and the coverage of precipitation forecasts are assessed at the same time.



10-km Model	Observed	No-Observed
Forecasted	1	1
No-Forecasted	2	12

5-km Model	Observed	No-Observed
Forecasted	1	3
No-Forecasted	2	10

The light blue area represents the precipitation intensity more than 1mm/3h, and the green area represents that of more than 5mm/3h. Both contingency table and PAS use the threshold of 5mm/3h. The contingency table uses 10-km verification grids (blue dashed line). PAS is evaluated with 20-km verification grid (red lines).

Fig.5. Schematic diagrams to compare the threat and bias scores with PAS, and contingency tables

5. Precipitation Area Score (PAS)

a) Definition of PAS

$$PAS = \frac{1}{N}\sum_{i=1}^{N}(RPf_i - RPo_i)^2,$$

where

1) RPf : Ratio of forecasted precipitation area over the threshold in a verification grid.

2) RPo : Ratio of observed precipitation area over the threshold in a verification grid.

3) N : Total number of verification grids in target domain. PAS in one verification grid where both RPf and RPo are zero is not calculated like the threat score.

b) Characteristics of PAS

1) $0 \le PAS \le 1$: When the forecast is perfect, PAS=0.

2) PAS is tolerant of the position error of forecast and observation within a verification grid. If RPf=RPo in one verification grid, PAS of this grid is zero.

3) It is possible to evaluate the high-resolution deterministic forecasts and low-resolution forecasts simultaneously by taking a verification grid as the lower-resolution model grid.

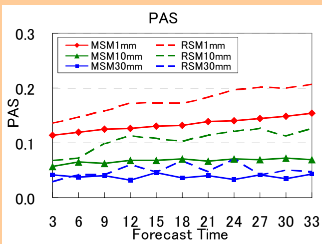
4) The formulation of PAS is very similar to that of "Brier Score".

c) Examination of Verification of NEW-MSM and RSM using PAS

1) PAS of NEW-MSM is better than that of RSM against all thresholds and forecast time (Fig.6).

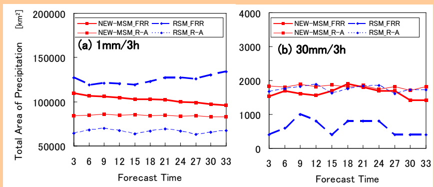
2) As the threshold becomes larger, PAS decreases on the whole.

3) This does not mean the accuracy of precipitation forecasts for heavy rainfall is higher, but that the differences between RPf and RPo of rare events are generally smaller.



"MSM1mm" denotes the score of NEW-MSM for 1mm/3h. The dashed lines denote PAS by RSM. The details of this verification are shown in table3.

Fig.6. PAS of NEW-MSM against Forecast Time



The red lines represent NEW-MSM, and the blue lines RSM. The thick lines denote total area of precipitation by NEW-MSM and RSM, and the thin lines denote that by R-A. "FRR" denotes the forecasted precipitation.

Fig.7. Total Area of Precipitation of NEW-MSM against Forecast Time

6. Summary and future issue

1. The precipitation forecasts of MSM have been improved since its operational use in March 2001 and will get better at the next upgrade in May 2007.

2. The verification using PAS is shown as follows:

(2.1) NEW-MSM is obviously superior to RSM for the 1mm/3h and 10mm/3h precipitation forecasts. Even if the forecast time is longer, the rate of the deterioration of NEW-MSM is slower than that of RSM. This result is contrary to one derived from the threat score.

(2.2) NEW-MSM is still better than RSM for even 30mm/3h precipitation forecasts.

3. PAS can be elaborated to a skill score using some forecast as criteria. And the formulation of PAS can be modified to be equitable by excluding the effect of random forecast.

4. PAS can become a verification tool to compare the low-resolution probabilistic forecasts and the high-resolution deterministic forecasts at the same time.

References

Japan Meteorological Agency, 2007: *OUTLINE OF THE OPERATIONAL NUMERICAL WEATHER PREDICTION AT THE JAPAN METEOROLOGICAL AGENCY. Appendix to WMO Numerical Weather Prediction Progress Report*, JMA, Tokyo. 194pp.

Segawa, T. and Honda. Y., 2007: Verification method to evaluate simultaneously both intensity and coverage of precipitation forecast. *CAS/JSC WGNE Res. Act. in Atmos. and Ocea. Modelling.*