Verification method to evaluate simultaneously both intensity and coverage of precipitation forecast

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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 with a horizontal grid spacing of 5 km. 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 MSM0705) (Hara et al. 2007). In order to evaluate the performance of MSM0705, verifications were carried out with a new method which could assess simultaneously both the intensity and the coverage of precipitation forecasts.

2. Problems in verification for high-resolution precipitation forecasts

The accuracy of MSM against "Radar-Raingauge Analyzed Precipitation" (hereafter R-A) has been gradually improved since March 2001, although it has been changed monthly (JMA 2007). According to the subjective verification of MSM0705, the precipitation forecasts became very realistic. However, the statistical verification score of binary categorical forecast by MSM0705 is sometimes poorer than that by the regional spectral model of JMA (hereafter RSM) using a horizontal grid spacing of 20 km (Fig.1). The details of verification are shown in Table 1.

Figure 2 gives schematic diagrams to show distinctions of scores between 10-km model and 5-km model. When the green grids are noticed, it is evident that the forecast result of 5-km model is more realistic than that of 10-km model. On the other hand, the threat score of 5-km model is poorer than that of 10-km model because the number of false alarm grids by 5-km model are larger in number than that by 10-km model (Fig.2(e) and (f)).

This discrepancy comes from the fact that the threat score using a 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 the threat score. Therefore, it is necessary that both the intensity and the coverage of precipitation forecasts are assessed at the same time.

3. Precipitation Area Sore

The precipitation area score (PAS) is defined as

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

where

RPf (or RPo): Ratio of forecasted (or observed) precipitation area over the threshold in a verification grid.

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

The characteristics of PAS are shown as follows:

(1) It has a range of 0 to 1, 0 for a perfect forecast.

(2) It 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 designed to assess both the intensity and the coverage of precipitation forecasts at the same time.

(4) The score can evaluate high-resolution forecasts without the process of averaging which smoothes out the peak of the grid value of precipitation.

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

The results of verifications using Fig.2(a)-(c) are shown in Fig.2(f). It becomes evident that PAS of 5-km model is better than 10-km model, even if threat scores of 5-km model are poorer than that of 10-km model. Thus, PAS makes the disagreement small between the subjective verification and the objective verification.

4. Examination of verification of MSM0705 and RSM using PAS

As shown in Fig.3, the results of verification using PAS are shown as follows:

(1) MSM0705 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 MSM0705 is slower than that of RSM. This result is contrary to one derived from the threat score (Fig.1).

(2) MSM0705 is still better than RSM for even 30mm/3h precipitation forecasts. As shown in

Fig.4, the forecasted precipitation area and the observed precipitation area by R-A which are arranged initial times of MSM0705 are nearly equal. On the other hand, the forecast area of RSM is smaller than the observed one. Thus, judging from these results, it is considered that non-forecasting is better than forecasting somewhere in the case of heavy rainfall.

(3) As the threshold becomes larger, PAS decreases on the whole. However, 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.

5. Concluding remarks

PAS makes the disagreement small between the subjective verification and the objective verification, when the objective verification of high-resolution forecast is worse than that of low-resolution forecast although the high-resolution forecast is more realistic than the low-resolution one.

PAS of MSM0705 is better than that of RSM against all thresholds and forecast time, even if threat score of MSM0705 is poorer than that of RSM.

The formulation of PAS is very similar to that of “Brier Score”. Thus, it will be possible to compare the low-resolution probabilistic forecasts and the high-resolution deterministic forecasts using a lower –resolution verification grid at the same time.

References

Hara, T. et al., 2007: Upgrade of the operational JMA non-hydrostatic mesoscale model. *CAS/JSC WGNE Res. Act. in Atmos. and Ocea. Modelling.*

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

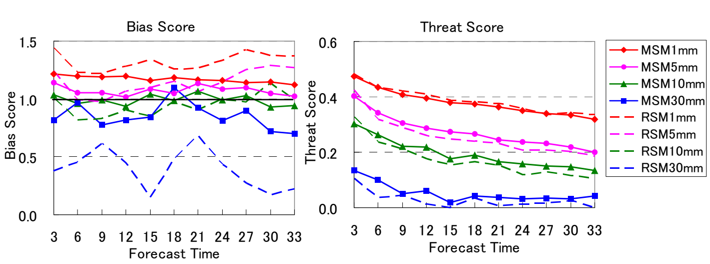
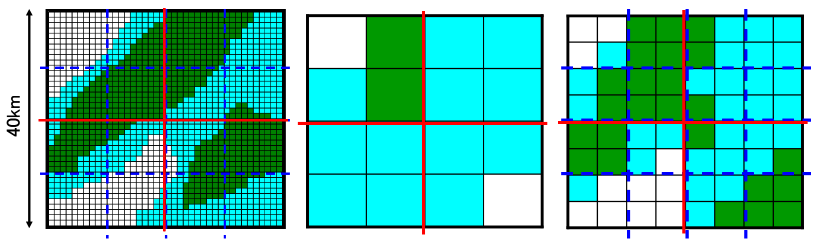


Fig.1. *Time sequences of bias and threat scores by MSM0705 and RSM.* “MSM1mm” denotes the score of MSM0705 for 1mm/3h.

	MSM0705	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)	

Table 1. *Details of statistical verification of MSM0705.*

(a) Observation (1-km R-A) (b) 10-km Model (c) 5-km Model



(d)

	Obs.	No-Obs.
Fcst.	1	1
No-Fcst.	2	12

(e)

	Obs.	No-Obs.
Fcst.	1	3
No-Fcst.	2	10

(f)

	Bias score	Threat score	PAS
10km model	0.67	0.25	0.481
5km model	1.33	0.17	0.104

Fig.2. *Schematic diagrams to compare the threat and bias scores with PAS, contingency tables, and verification results.*
The light blue area represents the precipitation intensity more than 1mm/3h, and the green area represents that of more than 5mm/3h. (a): Observation of R-A with 1-km grids. (b): Forecasts of model with 10-km grids. (c): Forecasts of model with 5-km grids. (d): The 2x2 contingency table of 10-km model with 10-km verification grid. (e): Same as in (d) but with 5-km model. Both contingency table and PAS use the threshold of 5mm/3h. Contingency tables use 10-km verification grids (blue dashed line). (f): Results of verification using contingency tables and PAS. The PAS is evaluated with 20-km verification grid (red lines).

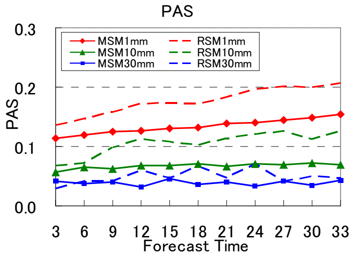


Fig.3. *PAS of MSM0705 against forecast time.*
“ MSM1mm” denotes the score of MSM0705 for 1mm/3h. The dashed lines denote PAS by RSM. The details of this verification are shown in table 1.

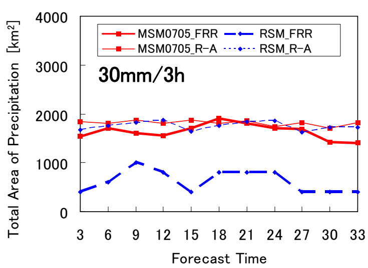


Fig.4. *Total area of precipitation of MSM0705 against forecast time.*
The red lines represent MSM0705, and the blue lines RSM. The thick lines denote total area of precipitation by MSM0705 and RSM, and the thin lines denote that by R-A. “FRR” denotes the forecasted precipitation.