Comparisons of Global and Regional Ensemble Prediction Systems at NMC

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1. Abstract

The quasi-operational global ensemble prediction system (GEPS) at NMC has been upgraded since December 2006 by the use of the breeding of growing mode (BGM) as initial perturbation strategy. Since 2005 World Weather Research Programme (WWRP) has launched Beijing 2008 Olympic Games Meso-scale Ensemble Prediction Research and Development Project (B08RDP), based on B08RDP and practical needs of short-range weather forecasting service for Beijing 2008 Olympic Games, a regional ensemble prediction system (REPS) has been developed at NMC. The initial perturbation strategy of the REPS is BGM, and lateral boundary conditions are from the GEPS. The multi-physics technique is used to represent the model perturbation in the REPS.

The four verification measures are used to compare the general skill, and reliability and resolution attributes of two systems during the Olympic Games: 1) continuous ranked probability score (CRPS) and its decomposition (reliability and resolution); 2) the reduced centered random variables (RCRV); 3) Brier score; 4) the relative operating characteristic (ROC) curve and area under ROC (AROC). The bootstrap resampling technique has been applied into the above-mentioned scores to determine the significance of skill difference between GEPS and REPS. Results indicate that compared to GEPS, the REPS generally performs significantly better than GEPS for the short-range precipitation forecast. It is shown that advantages of REPS over GEPS come from its better reliability and resolution (discrimination) attributes both. Also, the further investigation of reliability difference between two systems reveals that REPS has significantly less bias and better dispersion attribute.

2. The Brief Introduction of GEPS and REPS

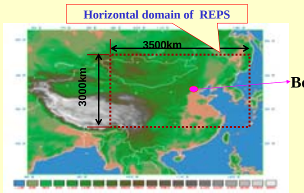
Configurations of GEPS

- **Model**: spectral model T213 with horizontal resolution of 0.5625 degree.
- **Vertical levels**: 31 levels from surface to 10 hPa.
- **Initial perturbation method:** Breeding of Growing Mode (BGM).
- **Model perturbation:** none
- **Ensemble member: 15**

Configurations of REPS

- **Model:** Weather Research and forecasting (WRF) model with horizontal resolution of 15 km.
- **Vertical levels:** 35 levels from surface to 10 hPa.
- **Simulation domain:** Eastern China.
- **Initial perturbation method:** BGM of WRF model cycle.
- **Lateral boundary conditions:** from GEPS.
- **Model perturbation:** Multi-parameterization method.
- **Ensemble member :15**

Horizontal domain of REPS



Beijing

3. Description of Verification Data

■ **Validated period:** 36 cases during 2008 Olympic Games (July 20 – August 24) are used to compare the REPS and GEPS.

■ **Validated variables:**

6h accumulated precipitation, six periods are validated: 1: 00-06h; 2: 06-12h; 3: 12-18h;
4: 18-24h; 5: 24-30h; 6: 30-36h

■ **Verification Data:**

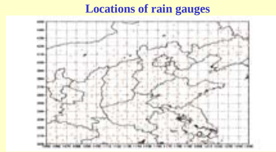
Observation: 400 rain gauges over North China, which are from B08RDP observation database.

GEPS results: from TIGGE database at 1.0 degree, which have been interpolated from 0.5625 degree into 1.0 degree.

REPS results: from decoded B08RDP NMC REPS at 0.15 degree.

GEPS and REPS are interpolated at rain gauges for verification.

Locations of rain gauges



4. Verification Measures and Results

(1) Continuous ranked probability score (CRPS) and its decomposition

CRPS measures the distance between the predicted and observed cumulative density functions (CDFs) of interested variables.

➢ **Basic formulation:** $CRPS=\int_{-\infty}^{\infty}\left[P(x)-H(x-x_a)\right]^2 dx$

Where $P(x)$ and $H(x\text{-}xa)$ are predicted and observed CDFs, respectively. Observed CDFs is a Heaviside function:

$$H(x-x_a)=\begin{cases}0 & x\le x_a\\ 1 & x>x_a\end{cases}$$

➢ **The CRPS calculation and its decomposition**

The calculation of CRPS and its decomposition are based on the method proposed by Hersbach H. (2000). The formulation of discretized CRPS can be written as follows:

$$CRPS=\sum_{i=0}^{N}\left[\alpha_i p_i^2+\beta_i(1-p_i)^2\right]$$

where $p_i=i/N$, the calculation of α_i and β_i for different situations:

obs. x_a falling into the bin i

$0<i<N$	α_i	β_i
$x_a>x_{i+1}$	$x_{i+1}-x_i$	0
$x_{i+1}>x_a>x_i$	x_a-x_i	$x_{i+1}-x_a$
$x_a<x_i$	0	$x_{i+1}-x_i$

obs. x_a is an outlier

outlier (left)	α_0	β_0
$x_a<x_1$	0	x_1-x_a

outlier (right)	α_N	β_N
$x_N<x_a$	x_a-x_N	0

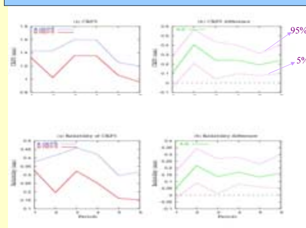
$$CRPS=\mathrm{Reli}+CRPS_{pot}$$

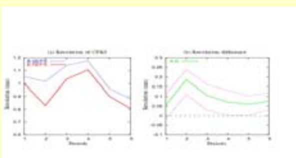
$$\mathrm{Reli}=\sum_{i=1}^{N}g_i(o_i-p_i)^2,\qquad CRPS_{pot}=U-\mathrm{Resol}=\sum_{i=0}^{N}g_i o_i(1-o_i)$$

where $g_i=\alpha_i+\beta_i$ $\quad o_i=\dfrac{\beta_i}{\alpha_i+\beta_i}$

Due to uncertainty term is independent of system, so $CRPS_{pot}$ can be used to evaluate the resolution information of EPS. **CRPS and its reliability and $CRPS_{pot}$ all are negatively oriented, that is, smaller values indicate higher skill**.

Bootstrap resampling method is used in all measures to give the significance of score difference. 90 % confidence bound with confidence interval of 5%-95% is used.





(2) The Reduced Centered Random Variable (RCRV)

RCRV is score proposed by Talagrand et al. (1999) to evaluate the reliability property of EPS, which gives the **bias** and **dispersion** information. Modified RCRV by Candille et al. (2007) is used in this study:

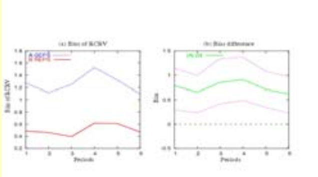
$$y=\frac{x_0-x_m}{\sqrt{\sigma_0^2+\sigma^2}}$$

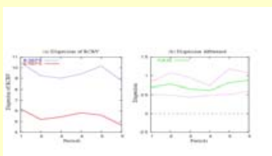
Where x_0 is the observation for certain variable, and σ_0 is the observational error. x_m and σ are ensemble mean and standard deviation of corresponding ensemble prediction.

➢**Bias**: The average of y can be used to measure the bias between ensemble mean and observation.

➢ **Dispersion feature:** the standard deviation of y gives the information about agreement of ensemble spread and observational error, which can characterize the dispersion of EPS.

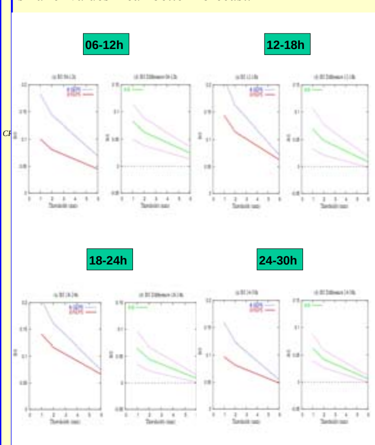
A perfect reliable system has no bias (value 0) and a dispersion equal to 1.





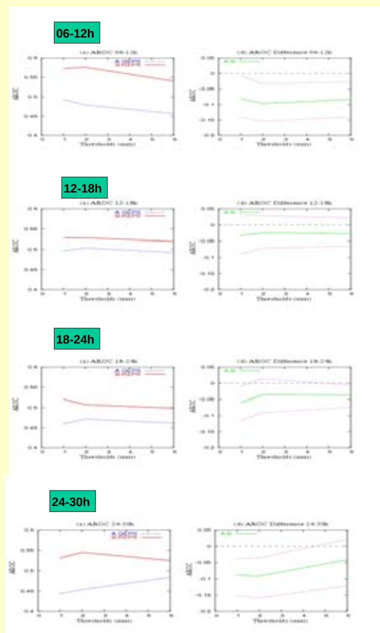
(3) Brier Score (BS)

BS is a common measure of probabilistic binary forecasts. A perfect system has BS of value 0, and smaller values mean better forecast.



(4) The Relative Operating Characteristic (ROC)

ROC is a measure to provide the statistical discrimination capability of ensemble forecasts. The area under ROC (AROC) is an integrated measure of the ROC score. A perfect AROC score has value 1.



5. Summary

In brief, the main results of this work are as follows:

1) Most of verification measures show that REPS generally significantly performs better than GEPS for precipitation forecast.
2) The advantages of REPS over GEPS come from its better reliability and better resolution (discrimination) attribute.
3) The superior reliability of REPS can be characterized with less bias and better dispersion attribute.

6. Discussion

1) Current comparison results seem to meet the expectation that people have to REPS. However, we still need to recall two unfavorable factors for GEPS in current comparisons.
   - Data source of GEPS results used here might be not be very fair to the current comparison for the performance of GEPS.
   - The lack of model perturbation probably is another important factor for the poor performance of GEPS.
2) Verification for other variables still need to be done before give conclusive conclusion.

7. References

Brier, G. W., 1950: Verification of forecasts expressed in terms of probability. *Mon. Wea. Rev.* **78**, 1-3.

Candille, G., C. Cote, P. L. Houtekamer, and G. Pellerin,2007: Verification of an ensemble prediction system against observations. *Mon. Wea. Rev.* **135**, 2688-2699.

Efron, B., and R. Tibshirani, 1993: *An introduction to the Bootstrap*. Chapman & Hall, 436 pp.

Hersbach. H., 2000: Decomposition of the continuous ranked probability score for ensemble prediction system. *Wea. Forecasting*, 15, 559-570.

Jolliffe, I. T., and D. B. Stephenson, 2003: *Forecast Verification: A Practitioner's Guide in Atmospheric Science*. Wiley and Sons, 240 pp.

Talagrand, O., R. Vautard, and B. Strauss, 1999: Evaluation of probabilistic prediction systems. *Proc. Workshop on Predictability*, Reading, United Kingdom, ECMWF, 1-25.