Application of Breeding of Growing Mode ensemble method in seasonal prediction of climate system model

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1. Abstract

A newly designed Breeding of Growing Model (BGM) method for climate models was used to generate perturbations of initial condition for sub-seasonal to seasonal forecasts of Beijing Climate Center. Our results show that the BGM ensembles reduced the modelled error of atmospheric circulation over most area of the globe. The RMSE of 500hPa geopotential height predicted by BGM ensembles was reduced by 10% in May and 3% in summer relative to the Lagged Average Forecasting(LAF) ensembles method. The temporal correlation coefficient (TCC) skills of 500hPa geopotential height and 200hPa zonal wind were superior to the LAF ensembles over Eurasia from May through August. The BGM ensembles was much better to predict the precipitation and surface air temperature over Asia and the western Pacific within one month lead time, but not beyond one month.

2. Background and Objective

Background Seasonal forecasts based on Coupled General Circulation Models (CGCMs) are receiving more and more attention. However, the initial condition uncertainty has a great influence on the seasonal forecast skill based on CGCMs. And Ensemble forecasting from perturbed initial conditions is one of the most important strategies to improve the prediction accuracy.

The three commonly used methods for weather forecasting are LAF, BGM and singular vectors(SVs). Although the ensemble methods are well-suited for weather and extended weather forecasting, the research on seasonal scale ensemble forecasting needs further investigation.

Objective This study aims to establish a suitable BGM initial ensemble method in the seasonal forecast system based on BCC-CSM model for Beijing Climate Center, where LAF ensemble method is still used. The forecast skill will be compared to that with LAF ensemble method to test the application prospects of the BGM method.

3. Model, Method and Experiments

Model The BCC-CSM2-MR, the climate model we used, was developed by Beijing Climate Center (BCC) of China Meteorological Administration (CMA).

Method We designed a BGM ensemble method for seasonal forecast. The main difference between BGM ensemble method which we designed for seasonal forecast and the weather BGM method was the breeding cycle time. We tuned the time scale of breeding cycle and found the error growth rate of saturate after 4 cycles (20 days) when the breeding cycle was set to 5 days (Fig.2). This approximately meets the requirements for the seasonal forecast.

Fig.1 Schematic diagram of BGM initial Condition Perturbations

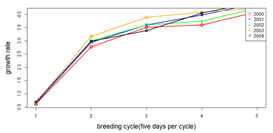

Fig.2 Trend of Growth Rate with breeding cycle in different years.

Experiments A set of 15-year (2000-2014) reforecast experiments were carried out using BGM and LAF ensemble methods. They all had 9 members, one of which was the control forecast. And these experiments started at May 1 and predicted for four months.

Besides, the LAF ensemble forecast was designed to end at the same termination time for the forecast, but initialized at different lagging times for every three days.

Observations: ERA-Interim(for atmospheric fields) and GPCP(for precipitation)

Metrics: Temporal correlation coefficient (TCC) and root mean square error (RMSE). .

4. Global Results

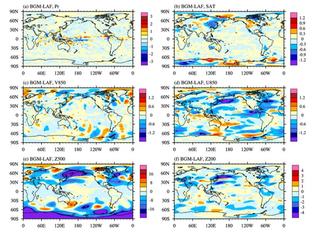

Fig.3 Difference of RMSE between BGM and LAF ensemble forecasts in May.

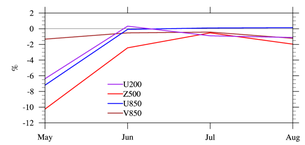

Fig.4 Change (%) of RMSE averaged over the globe predicted by BGM ensemble forecasts relative to LAF ensemble forecasts.

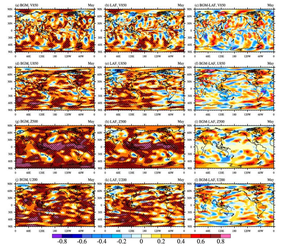

Fig.5 TCC between the BGM ensemble forecast and the observation, between the LAF ensemble forecasts and the observation and the difference the BGM and LAF ACCs. The crossed regions are above the 90% confidence level.

Fig.3 shows the BGM ensemble forecasts had little influence on the RMSE of precipitation except in the tropical Pacific compared to the LAF ensemble forecasts. The RMSE of surface air temperature over northeastern Asia was reduced in the BGM ensemble forecasts. Among the four atmospheric variables (V850, U850, Z500, Z200), the RMSE shows obvious decrease for U850 and U200 in most area of the Northern Hemisphere, and for Z500 in the middle and high latitudes of the globe.

As can be seen in Fig.4, the RMSE decreases most prominently in May for each variable. The reduction of the RMSE for Z500 and V850 could extends to the whole summer. The Z500 decreases most prominently among the four variables.

The warmer the color in Fig.5, the higher the TCC skill score. As we can see, the TCC skills of the four circulation field variables (V850, U850, Z500, U200) have been improved significantly over most area of the globe within one-month lead time.

5. Results of Eurasia and the Western Pacific

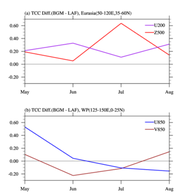

Fig.6 Difference of TCC between BGM and LAF ensemble predictions

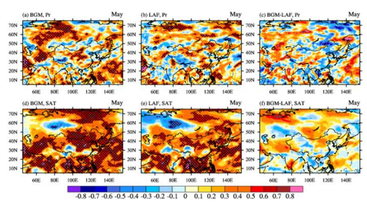

Fig.7 TCC skills of precipitation and surface air temperature for the BGM ensemble prediction and LAF ensemble prediction, and the difference between them.

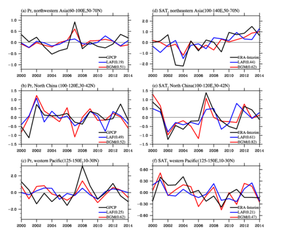

Fig.8 anomalies of Precipitation and Surface air temperature predicted by BGM and LAF ensembles.

The simulations of U200 and Z500 used the BGM ensemble forecasts achieved better results in Eurasia among four consecutive months (May, June, July and August). While in the Western Pacific region, the TCC of U850 and V850 had 53% and 10% improvement respectively in BGM ensemble forecasts in first month (May), but, in the following months, the BGM was not advanced obviously compared to the LAF method.

Fig.7 shows precipitation was distinctly elevated in northwestern Asia, northern China, and the western Pacific, while the surface air temperature (SAT) was improved in northeastern Asia, northern China, and the western Pacific.

Fig.8 shows the precipitation and surface temperature anomalies averaged over northwestern Asia, North China, and western Pacific, which passed the significant test in Fig.7, covering 15 years (2000–2014). It can be seen that all anomalies correlation coefficient of precipitation and surface temperature in the BGM ensemble forecasts were higher than the LAF.

6. Discussion

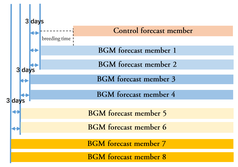

Fig.9 Schematic diagram of forecasting combined with BGM and LAF methods

However, the BGM ensembles cannot get substantially improvement compare with the LAF ensembles in the predicting skills longer than one month.

In addition, another method we designed is shown in the figure above. Combing the BGM and LAF methods, we used the same number of members to do the same experiments as before. Unfortunately, it has no obvious improvement for long-term forecasting.

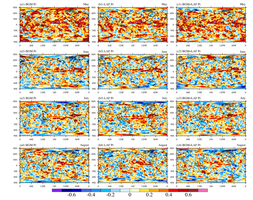

Fig.10 TCC skills of precipitation

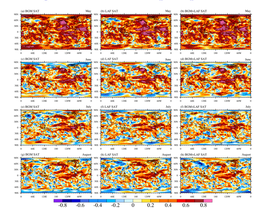

Fig.11 TCC skills of precipitation and surface air temperature

7. Conclusions

We designed a BGM ensemble method for BCC model to solve the problem of sub-seasonal to seasonal forecasting and made a comprehensive comparison with the LAF ensemble methods.

- We observed that the time period of breeding cycle of BGM was the most critical parameter to tune for climate forecasting. We chose to rescale the analysis error every five days and the analysis error saturated after four breeding cycle.
- We showed that the BGM ensemble forecasting can reduce the simulation errors of U200, V850, U850, Z500, and Z200 in the first month(May) over most area of the globe. What's more, improvements of U850 and Z500 lasted throughout the Summer.
- Precipitation and surface air temperature predicted by the BGM ensemble forecasting were much better than LAF method over Asia and the western Pacific within one-month lead time.

8. References

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