Article ID: 1006-8775(2009) 01-0102-04

STUDY OF THE EFFECTS OF REDUCING SYSTEMATIC ERRORS ON MONTHLY REGIONAL CLIMATE DYNAMICAL FORECAST

ZENG Xin-min (曾新民)[1, 2, 3], XI Chao-li (席朝笠)[1, 4]

(1. Institute of Meteorology, PLA University of Science and Technology, Nanjing 211101 China; 2. Key Laboratory of Regional Climate-Environment Research for Temperate East Asia, Chinese Academy of Sciences, Beijing 100029 China; 3. Key Laboratory for Mesoscale Severe Weather of Ministry of Education, Nanjing 210093 China; 4. Air Force Meteorological Observatory of Zhangjiakou, Zhangjiakou 075000 China)

Abstract: A nested-model system is constructed by embedding the regional climate model RegCM3 into a general circulation model for monthly-scale regional climate forecast over East China. The systematic errors are formulated for the region on the basis of 10-yr (1991-2000) results of the nested-model system, and of the datasets of the Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP) and the temperature analysis of the National Meteorological Center (NMC), U.S.A., which are then used for correcting the original forecast by the system for the period 2001-2005. After the assessment of the original and corrected forecasts for monthly precipitation and surface air temperature, it is found that the corrected forecast is apparently better than the original, suggesting that the approach can be applied for improving monthly-scale regional climate dynamical forecast.

Key words: climatology; monthly regional climate; dynamical forecast; systematic errors

CLC number: P456.7 **Document code:** A **doi:** 10.3969/j.issn.1006-8775.2009.01.018

1 INTRODUCTION

Due to the increasing demand of operational services, short-term climate forecast has been widely investigated using climate models. When a regional climate model (RCM) is used for dynamical forecast, its initial and boundary conditions need to be input from the results of a general circulation model (GCM). Because of the complexity of the two-way nesting, most nested-model systems employ one-way nesting with no feedback from RCMs to GCMs [1]. Therefore, it is necessary to improve both RCMs and GCMs in the dynamical forecast of regional climate. Currently GCM improvements focus on the development of more realistic physics parameterizations, as well as the increase in model spatial resolutions [2, 3]. While for RCMs, research mainly emphasizes the physics parameterizations, schemes for nesting and lateral boundary conditions, and horizontal resolutions [4], e.g., by using the National Center for Atmospheric Research (NCAR) regional climate model RegCM, it is found that with the increase in grids of the model buffer zone, the bias of model results relative to observations is reduced [1]. In addition, ensemble forecast approach is also employed in modeling studies, e.g., using a 9-layer spectral GCM and a RCM, Wan et al.[5] applied an ensemble forecast approach for reducing the random errors due to the sensitivity of the GCM to initial conditions, and utilized a temporally moving averaging method to eliminate the unrealistic fluctuations of the GCM results, which leads to a successful monthly regional climate forecast.

It is noteworthy that the so called “climate shift” or systematic errors, commonly existing in climate models, can strongly affect the accuracy of model dynamical forecast [6]. However, current studies of this aspect generally focus on GCMs, whereas little, if any, has been done on RCMs. Hence, in this paper, we establish

---

Received date: 2008-01-16; **revised date:** 2009-04-10

Foundation item: National Natural Science Foundation of China (40875067, 40675040); Knowledge Innovation Program of the Chinese Academy of Sciences (IAP09306); National Basic Research Program of China. (2006CB400505)

Biography: ZENG Xin-min, senior research scientist, mainly undertaking atmospheric model simulation and forecast.

E-mail for correspondence author: xmzen@sohu.com

PDF created with pdfFactory trial version www.pdffactory.com

the “systematic errors” for monthly climate over the investigated region (i.e., East China) using a nested-model system, through which the monthly forecast over five years (i.e., 2001 – 2005) is corrected, and then assess the impact of the correction on the monthly regional climate dynamical forecast.

2 NESTED CLIMATE MODELS AND SYSTEMATIC ERRORS

To balance the model precision and computational efficiency, a global model developed by the P.L.A. University of Science and Technology, i.e., T63L9, is introduced in this study, as well as the regional climate model RegCM3[1], developed by the Abdus Salam International Centre for Theoretical Physics at Trieste, Italy, whose surface runoff scheme is improved in the context of Zeng et al.[7]. Centered at (28 ºN, 112 ºE), the model domain covers a large part of the continental China and surrounding oceanic areas with 80×80 grid points at 40-km horizontal resolution and 14 vertical layers. Besides, the model top is set at 50 hPa. For each experiment aimed at monthly climate forecast, the model integration spans the period from the twenty-second day of a month to the end of the next month, i.e., totally about 40 days.

The most essential way to “eliminate” the systematic errors between simulated averages and corresponding observations is to perfect the algorisms of the model, which is, however, a long and arduous journey for modelers. An alterative way is to integrate the model for a period long enough to get to an equilibrium state that can be taken as the model climate averages, which are employed for subtracting from model-forecasted results. Yet it is a great burden in computation for regional hydrological models to carry out several tens or up to a hundred years of integration. Due to the fact that more climatological 30-yr simulation is very large in computational amount, and that there is little difference between the 10-yr and 30-yr model averages, as a first step, the 10-yr (1991－2000) hindcast averages from the nested models are taken as the model climate averages. The differences between these averages, and CPC Merged Analysis of Precipitation[2] and National Meteorological Center (NMC) analysis of temperature[3] are applied to reducing the systematic errors of the nested-model system.

3 ASSESSMENT OF FORECAST

Currently, the assessment of operational short-term climate forecast is quantified by some parameters in China, such as the forecast score (P), anomaly correlation coefficient (ACC), skill score (SS), and threat score (TS) [8]. As listed in Table 1 (appearing at the end of the paper) for the monthly-precipitation parameters averaged over 2001 – 2005, due to the correction of “eliminating” the errors, the P value, averaged over 12 months, reaches 63.3%, about 3 percentage points higher than the original; the minimum and maximum of the P averages are increased to some extent, while the variability within the annual time scale is also reduced. For June, July and August, the months during the rainy season, the P values steadily fall within 60% – 68%. This indicates a quite high level of forecast, as compared to results from both Chinese and international monthly forecasts [9]. For ACC, values are increased for most months after the correction, which leads to a slight overall increase. Besides, the skill scores SS1 and SS2 (with respect to random forecast and climate-average forecast, respectively) show overall increases after the correction.

Also listed in another table (omitted) are the parameter values for monthly surface air temperature averaged over the same period, showing a significant improvement and a quite high forecast level [9] due to the correction. Except for April, the other months show the P scores higher than 60%, which results in a significant overall increase to the level of 66.3%. For ACC, the sign of all original values is negative, whereas it turns positive except for December after the correction, indicating a correlation to some extent. In addition, both SS1 and SS2 values show the increases in the numbers of months with positive skill scores and, apparently, in the average overall scores.

As a whole, the correction of reducing systematic errors leads to, on average, an apparent improvement in the multiyear forecast. For individual months (Fig.1), the number of months with improvement is much larger than that without, and the increase amplitude in the P score is much larger than the decrease one (e.g., for warm-season temperatures). Moreover, the corrected forecast shows a more stable forecast level.

When we turn to individual cases (e.g., Fig.2), it is found that generally, due to the removal of systematic errors, the corrected forecast for spatial distribution is closer to observational analyses, whereas the forecasted distribution for temperature, relative to that for precipitation, shows higher consistency with observations.

For analyses of other aspects, refer to the Chinese edition of the journal.

---

[1] http://www.ictp.trieste.it/~pubregcm/RegCM3/

[2] CMAP; http://dss.ucar.edu/catalogs/atmlists/precip.html

[3] http://dss.ucar.edu/datasets/ds090.2

PDF created with pdfFactory trial version www.pdffactory.com

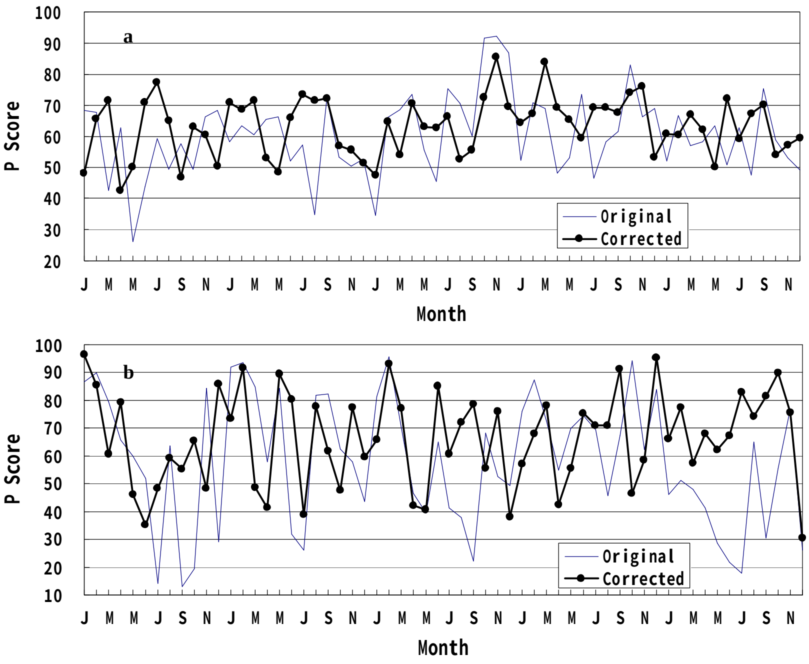

Fig.1 Comparison of the P prediction scores for (a) precipitation and (b) surface air temperature in each month from 2001 to 2005.

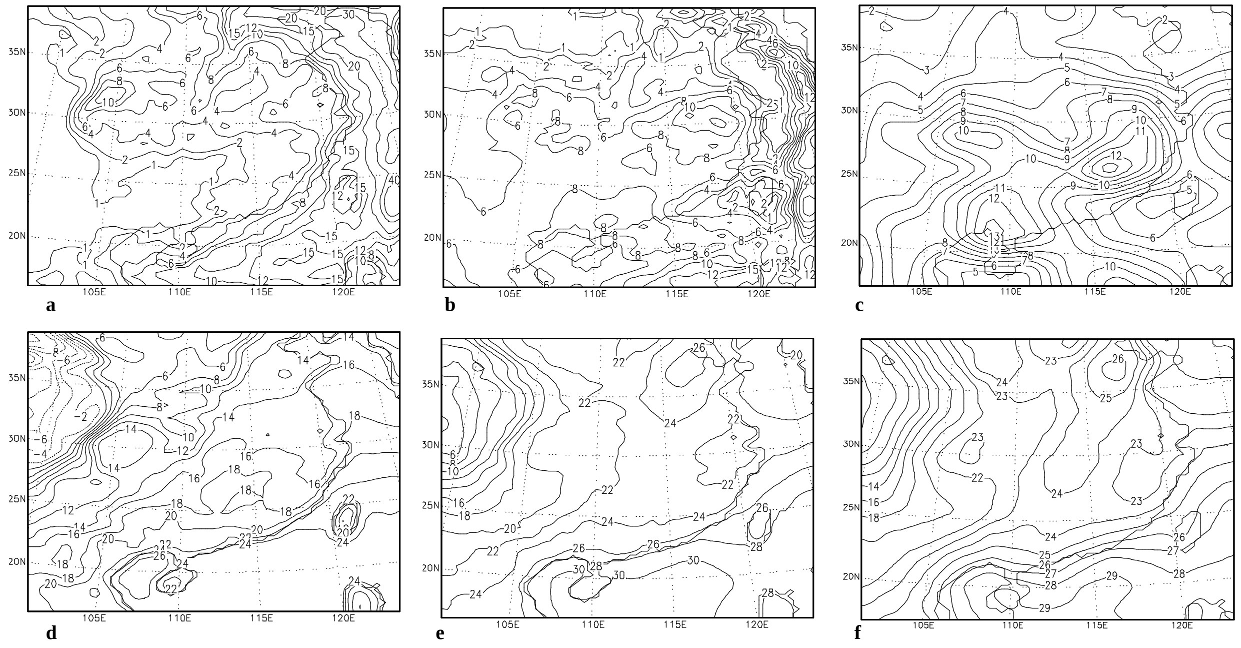

Fig.2 Predicted and observed precipitations (a: Before corrected; b: Corrected; c: CMAP data; Units: mm/d) and temperatures (d: Before corrected; e: Corrected; f: NMC analysis; Units: °C) for June, 2003.

4 CONCLUDING REMARKS

In this paper, a monthly regional climate forecast over East China is carried out by nesting a GCM (i.e., T63/L9) with a regional climate model (i.e., RegCM3). In the context of the monthly observational analyses (i.e., CMAP for precipitation and NMC analyses for temperature) and model results of the nested-model system over 10 years (1991 – 2000), a series of systematic errors are constructed, through which the original model forecast over 2001 – 2005 is corrected, and the impact of the correction on the forecast is assessed as well.

Due to the correction, the monthly forecast score for precipitation (surface air temperature) is, on average, increased from the original value of 60.2% (58.0%) to 63.3 (66.3%), showing apparent improvements in precipitation, particularly in

PDF created with pdfFactory trial version www.pdffactory.com

temperature, over the original forecast. It can also be seen that most overall values of the assessment parameters, such as the forecast score, anomaly correlation coefficient, and skill score, are increased except for the threat score that shows an opposite inclination. While the monthly forecast scores are increased because of the correction, the fluctuations in the forecast score within the annual scale are reduced due to the fact that the correction takes effect mostly from the climate average states, and this leads to a more stable forecast level and a decrease in the threat score. It seems that there is no strong correlation between the forecast for precipitation and that for temperature. Besides, as shown in some individual cases, the forecasted distribution for temperature, relative to that for precipitation, is in higher consistency with observations after the correction.

In general, though only a single kind (i.e., equivalent to one sample) of initial conditions are provided to the models, the nested-model system shows a more stable level of forecast due to the “elimination” of the systematic errors, which has the same influence as the ensemble forecast to some extent, further suggesting the deficiency of the dynamical approach and the importance of combination of the dynamical and statistical approaches. In short, combining the dynamical approach, as a dominant one, with the statistical approach [10] is practical to improve the dynamical forecast of monthly regional climate.

It should be noted that the overall performances of current operational GCMs, generally featured with resolutions higher than that in this study, are generally better. Hence, the approach proposed in this study can be used for current monthly or seasonal climate forecast that is carried out by higher resolution, better performance GCMs and RCMs, through which the forecast level for regional climate would possibly be further improved.

REFERENCES:

[1] GIORGI F, MEARNS L O. Introduction to special section: Regional climate modeling revisited [J]. J. Geophys. Res., 1999, 104(8): 6335-6352.

[2] WANG Zai-zhi, WU Guo-xiong, LIU Ping, et al. The development of GOALS/LASG AGCM and its global climatological features in climate simulation, I-Influence of Horizontal Resolution [J]. J. Trop. Meteor., 2005, 21(3): 225-237.

[3] WANG Zai-zhi, YU Ru-cong, WANG Peng-fei, et al. The development of GOALS/LASG AGCM and its global climatological features in climate simulation, II-The increase of vertical resolution and its influences [J]. J. Trop. Meteor., 2005, 21(3): 238-247.

[4] ZHAO Zong-ci, LUO Yong. Advance on investigations of reginal climate modeling since 1990 [J]. Acta Meteor. Sinica, 1998, 56(2): 225-246.

[5] WAN Qi-lin, LIANG Jian-yin, SHI Yong-nian. The numerical forecast test for monthly-scaleregional climate change [J]. J. Trop. Meteor., 1996, 12(4): 349-355.

[6] LI Chong-yin. Introduction to Climate Dynamics [M]. Beijing: China Meteorological Press, 1995, 183-188.

[7] ZENG X M, ZHAO M, SU B K, et al. Effects of subgrid heterogeneities in soil infiltration capacity and precipitation on regional climate: A sensitivity study [J]. Theor. Appl. Climatol., 2002, 73(2): 207-221.

[8] CHEN Gui-ying, ZHAO Zhen-guo. Assessment methods of short range climate prediction and their operational application [J]. Quart. J. Appl. Meteor., 1998, 9(2): 178-185.

[9] WANG Shao-wu, ZHU Jing-hong. Evaluation of short-term climate prediction [J]. Quart. J. Appl. Meteor., 2000, 11(S1): 1-10.

[10] REN Hong-li, CHOU Ji-fan. Analogue correction method of errors by combining both statistical and dynamical methods together [J]. Acta Meteor. Sinica, 2005, 63(6): 988-993.

Citation: ZENG Xin-min and XI Chao-li. Study of the effects of reducing systematic errors on monthly regional climate dynamical forecast. *J. Trop. Meteor.*, 2009, 15(1): 102-105.

Table 1 Values of the parameters of assessment for precipitation over 2001-2005.
(For each parameter, upper row values represent the original, whereas lower row ones denote the corrected)

month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	mean
P	53.1	66.9	59.5	61.6	52.9	53.1	60.3	52.2	65.3	67.3	65.7	65.1	60.2
	59.2	**66.3**	**70.6**	**58.0**	**53.5**	**67.3**	**66.9**	**66.2**	**63.5**	**65.1**	**67.9**	**54.5**	**63.3**
ACC	-0.10	0.13	-0.12	0.09	-0.14	0.17	0.06	-0.05	0.24	0.11	0.05	0.02	0.04
	-0.13	**0.03**	**0.19**	**0.07**	**-0.11**	**0.13**	**0.23**	**0.04**	**-0.03**	**0.07**	**0.17**	**-0.11**	**0.05**
SS1(%)	-12.7	8.8	-3.7	3.3	-10.4	-13.4	7.3	-9.3	12.2	13.8	12.6	-0.0	0.7
	6.2	**16.8**	**8.7**	**-5.3**	**-16.3**	**1.3**	**7.6**	**3.5**	**-0.8**	**1.3**	**10.2**	**-19.8**	**1.1**
SS2(%)	6.4	24.3	13.9	19.7	8.3	5.8	23.0	9.2	27.1	28.4	27.4	16.9	17.5
	22.1	**30.9**	**24.1**	**12.6**	**3.4**	**18.0**	**23.3**	**19.8**	**16.3**	**18.0**	**25.4**	**0.5**	**17.9**
TS(%)	26.0	29.0	28.4	19.4	22.0	13.6	8.6	10.4	18.4	32.0	33.4	50.2	24.3
	26.4	**21.4**	**30.4**	**16.8**	**13.0**	**19.0**	**11.0**	**5.2**	**21.6**	**20.6**	**23.8**	**38.6**	**20.7**

PDF created with pdfFactory trial version www.pdffactory.com