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SIMULATION OF PRESENT CLIMATE OVER EAST ASIA BY A REGIONAL CLIMATE MODEL

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Abstract: A 15-year simulation of climate over East Asia is conducted with the latest version of a regional climate model RegCM3 nested in one-way mode to the ERA40 Re-analysis data. The performance of the model in simulating present climate over East Asia and China is investigated. Results show that RegCM3 can reproduce well the atmospheric circulation over East Asia. The simulation of the main distribution patterns of surface air temperature and precipitation over China and their seasonal cycle/evolution, are basically agree with that of the observation. Meanwhile a general cold bias is found in the simulation. As for the precipitation, the model tends to overestimate the precipitation in northern China while underestimate it in southern China, particularly in winter. In general, the model has better performance in simulating temperature than precipitation.

Key words: regional climate model; climate simulation; evaluation; East Asia region; China

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1 INTRODUCTION

The advantage of the high resolution of regional climate models (RCMs) makes them more capable in capturing small scale weather and climate systems and reproducing fine scale climatological features introduced by local topographical forcings as compared to traditional low-resolution global models. RCMs have become important tools in regional climate studies [1]. Located in the East Asian monsoon region, China is a country with complex topography and unique climate and weather systems. Research shows that the resolutions of the models are particularly important in better simulating the precipitation here [2]. A number of studies have been carried out in simulating the regional climate over the region by these models [3, 4]. However, due to previous limitation of computation capabilities, the duration of the simulations are usually only in a range of a couple of months to a few years, which is not enough to be considered in the context of "climate". Following the rapid developments in climate models and computer technology, it becomes necessary and possible for further studies concerning the topic. In this study, a regional climate model (the ICTP RegCM3) is employed in simulating present climate over East Asia and China. The model is nested in a one-way mode to the ERA40 Re-analysis data from the ECMWF. A total of 15-year's length simulation has been conducted. Performances of the model in reproducing the climate over East Asia and China are validated through comparisons between the simulation and the observation.

2 MODEL, DATA AND EXPERIMENT DESIGN

The model used in the present work is the Regional Climate Model RegCM version 3 (RegCM3) developed at the Abdus Salam International Center for Theoretical Physics (available at http://

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www.ictp.it/~pubregcm) [5-7], with improvements in various physical packages including the use of the CCM3 radiation scheme, an improved large scale parameterization scheme for clouds and precipitation, which deals with the variation of subgrid scale clouds, a new parameterization scheme for sea surface flux, and implementation of more convection parameterization schemes like the Emanuel. In addition, the processes of input and output of the model have been made to be more friendly in conducting simulations. A parallel version of the model is also provided to make the simulations much faster and more efficient [8].

The model domain encompasses the whole of China and the surrounding areas at a grid spacing of 50 km. Central point of the model is set at 36°N, 105°N, with 109 grids in the north-south direction and 160 grids in the west-east direction. The model is run at its standard configuration of 18 vertical sigma layers with the model top at 100 hPa. The Grell mass flux scheme, which is based on the enclosure assumption of Arakawa-Schubert, is used to describe convection precipitation. Fig.1 gives the model domain and topographic distribution.

Topography of the model is obtained from the 10′×10′ topographic dataset developed at the United States Geological Survey (USGS). For the vegetation cover within the Chinese territory, observed data from the Institute of Botany, Chinese Academy of Sciences [9] are employed, and satellite-derived GLCC data by USGS are used for areas outside China. The initial and lateral boundary conditions updated every 6 hours to drive the model are derived from the ERA40 Re-analysis data of ECMWF. An exponential relaxation method is used as boundary conditions. Sea surface temperature of the OISST data from NOAA is used in the simulation. The model simulation period is from October 1, 1986 to January 1, 2002, for a total of 15 years and 3 months. The first 3 months is considered as the spin-up time and is not analyzed in the following text.

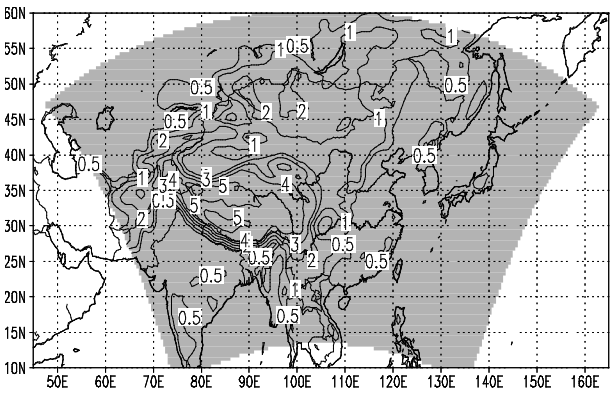

Fig.1 Model domain and topographic distribution (unit: km).

The ERA40 Re-analysis, the dataset from Climate Research Unit (CRU)[10] and the dataset developed by Xie et al. [11] are used to validate the simulated atmospheric circulation over East Asia and the surface air temperature and precipitation over China, respectively.

3 ATMOSPHERIC CIRCULATION VALIDATION OVER EAST ASIAN

The simulated and re-analyzed multi-year mean 500 hPa geopotential height for both winter and summer are presented in Fig.2. It is shown in the figure that the model reproduces well the general circulation in the region. The simulation in winter (as indicated by the dashed line in Fig.2a) is quite similar to the re-analysis (solid line in Fig.2a), although a deeper East Asia trough can be found in the simulation. The simulated summer circulation pattern (dashed line in Fig.2b) also shows consistence with that of the re-analysis (solid line in Fig.2b), except that the western Pacific subtropical high is simulated to be weaker and extended eastward as compared to the re-analysis. Tab.1 gives the results of statistical verification of the spatial correlation coefficients and standard deviation of the simulated and re-analyzed 500 hPa geopotential height, which have followed the formula in Zhou et al. [12]

Tab.1 Statistical verification of the spatial correlation coefficients and standard deviation of the simulated and re-analyzed 500 hPa geopotential height

month	1	2	3	4	5	6	7
corr.coef.	0.998	0.999	0.999	0.998	0.998	0.997	0.995
standard dev./gpm	15.4	10.9	12.4	10.5	8.4	6.5	6.6
month	8	9	10	11	12	mean	
corr.coef.	0.996	0.998	0.998	0.998	0.998	0.998	
standard dev./gpm	6.4	7.4	9.1	13.9	15.6	10.3	

4 VALIDADATION OF SURFACE AIR TEMPERATURE AND PRECIPITATION OVER CHINA

The simulated and observed surface air temperature in China for both winter and summer are shown in Figs.3a–3d. The simulated surface air temperature shows generally good agreement with observations. However, a wide spread cold bias is found in winter (Fig.3a) compared to the observation

(Fig.3b). The cold bias can be in excess of 3°C in portions over South China. Meanwhile, a warm bias can be found in parts of Northeast China. The cold bias exists in the summer simulation as well, but to a less extent (Figs.3c & 3d).

The simulated and observed precipitation over China in winter and summer are shown in Figs.4a-4d, respectively. The model reproduces well the general precipitation pattern over China, characterized by more of it in summer than winter, and by maxima over South and Southeast China and a decrease towards the North and Northwest. It also captures well the peak precipitation centers over the mountains. The model simulates more precipitation in North and Northwestern China, and less of it in Southeast China. This is more pronounced in winter, which leads to an inland displacement of the maxima. Overall, the model exhibits a general tendency of underestimating the high-low precipitation distribution in the region.

The simulated less rainfall in South China and more rainfall in North China could be related to the following possibilities: 1) There are some problems with the model physics when applying to the region, e.g. the Grell mass flux scheme may be more suitable for mid-latitudes rather than the tropical and subtropical areas of China. 2) The larger discrepancy found in winter than in summer, which is characterized by the underestimation in South China, indicates that the large-scale precipitation scheme used in the model remains to be improved. 3) The ERA40 dataset also shows discrepancy as compared to the observation, e.g., a smaller value of multi-year mean precipitation in

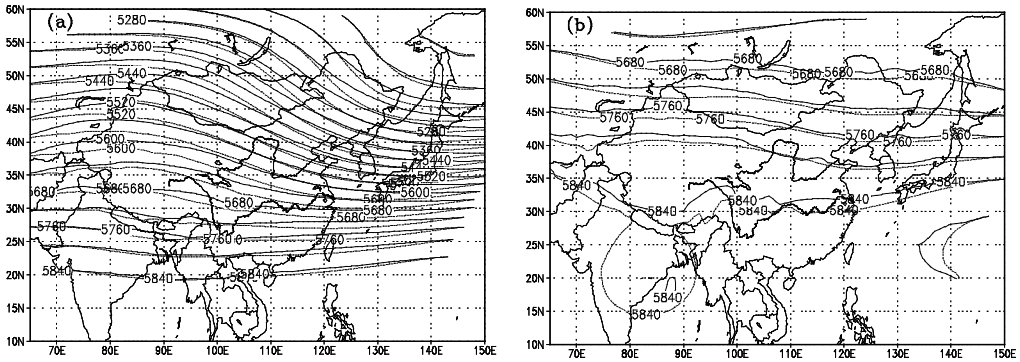

Fig.2 500 hPa mean geopotential height (unit: gpm). a. winter simulation (dashed line) and re-analysis (solid line); b. summer simulation (dashed line) and re-analysis (solid line);

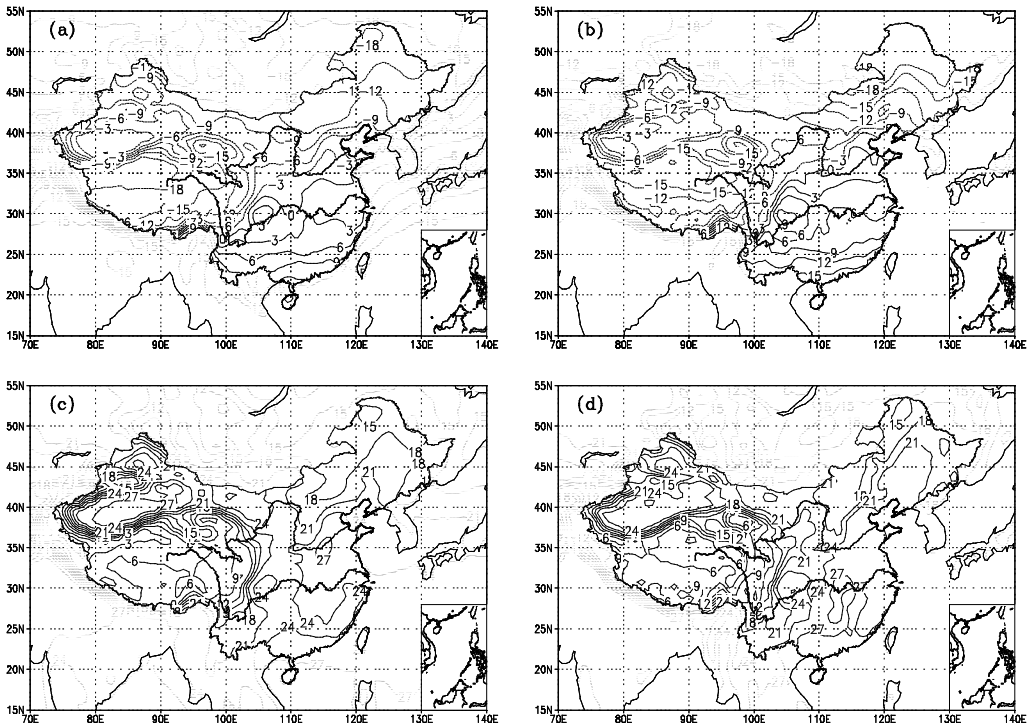

Fig.3 Distribution of mean temperature in China (unit: °C). a. winter simulation; b. winter observation; c. summer simulation; d. summer observation.

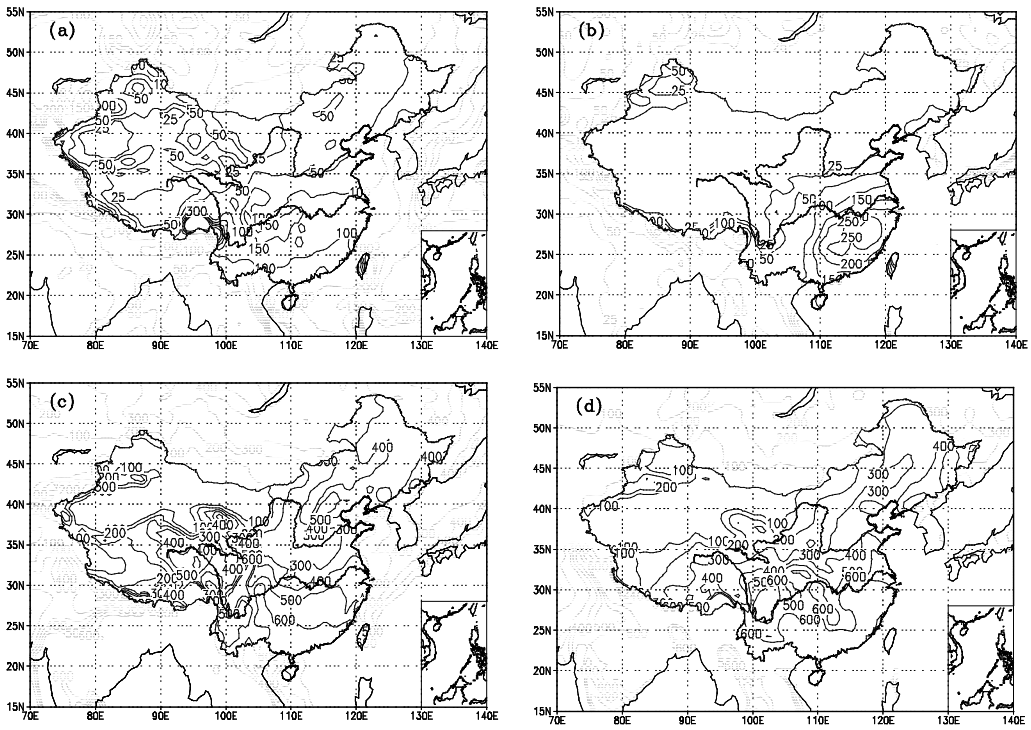

Fig.4 Distribution of mean precipitation in China (unit: mm) a. winter simulation; b. winter observation; c. summer simulation; d. summer observation.

South China, and a warm bias in high-latitude of East Asia, particularly during the winter (Figure omitted).

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

5 SUMMARY AND DISCUSSIONS

A regional climate model, the ICTP RegCM3, is employed to conduct a duration of 15-year simulation over East Asia at a horizontal grid spacing of 50 km. Validation of the model performance is carried out focusing on the atmospheric circulation in East Asia, and surface air temperature and precipitation over China. In general, RegCM3 reproduces the observed spatial patterns of the mean atmospheric circulation over East Asia. The simulated basic features of spatial distribution and seasonal cycle of surface air temperature and precipitation over China also agree with that of the observation. However, a generally cold bias is found in simulating the surface air temperature. The model shows an overestimation of precipitation in North China and an underestimation of it in South China. Finally, East Asia and China is a region of difficulty in simulating the present climate due to the presence of monsoon [1]. Although a better simulation can be usually found with the high resolution RCMs [2], further investigation and possible developments in the model dynamics and physics are needed to achieve a better reproduction of the present climate for the region.

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