Spatial Differences in the Simulation Capability of Three Global Climate Models for Seasonal Temperature Variation over China: A Postprint

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Date: 2018-10-23T00:00:00+00:00

Abstract

A specific analysis was conducted on the spatial difference characteristics of the capability of three global climate models from the Fifth Coupled Model Intercomparison Project (CMIP5) to simulate seasonal temperature variations in China. The results indicate that the BCC-CSM1.1(m) and GFDL-CM3 models can reproduce seasonal temperature variations in China, exhibiting stronger simulation capability in eastern China with relatively small mean absolute errors and root mean square errors, and weaker simulation capability in western China with relatively large mean absolute errors and root mean square errors. Compared with the BCC-CSM1.1(m) and GFDL-CM3 models, the HADGEM2-ES model demonstrates the weakest capability to reproduce seasonal temperature variations in China, with relatively large mean absolute errors and root mean square errors in some parts of western China, the Inner Mongolia region, and Northeast China, and relatively small errors in the southern part of South China. For the same model, daily mean temperature shows the best simulation performance, followed by daily minimum temperature, while daily maximum temperature shows the worst simulation performance. The effects of latitude, longitude, elevation, and slope on climate model simulation performance vary among models, whereas aspect and terrain sheltering have no significant effect on simulation performance.

Full Text

Preamble

DOI: 10.12118/j.issn.1000-6060.2018.05.09
Journal: Arid Land Geography (ChinaXiv Cooperative Journal)

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Models Evaluated: BCC-CSM1.1(m), GFDL-CM3, HADGEM2-ES (CMIP5 global climate models)

Abstract

The climate system model is an important tool for studying the mechanisms of climate change and predicting future climate change. Due to the extreme complexity of the climate system, there may be errors and limitations in simulating the climate. Therefore, it is necessary to evaluate the simulation capability of climate models. Nowadays, many researches have been done on the assessment of climate system modeling temperature capability and the prediction of future temperature changes. However, there is no report on the relationship between climate modeling capacity to simulate the seasonal variation of air temperature and some influencing factors. Therefore, this paper analyzes the spatial difference characteristics of simulation capability of air temperature in China, using BCC-CSM1.1(m), GFDL-CM3 and HADGEM2-ES global climate models from the Coupled Model Inter-comparison Project Phase 5 (CMIP5), based on the daily mean temperature, maximum temperature and minimum temperature data obtained from 663 conventional meteorological stations in China during the time period from 1951 to 2004. The simulation capability of three models are verified by using the observational air temperature data, and its relationships are discussed with latitude, longitude, elevation, slope, aspect and terrain obscuration (slope, aspect and terrain obscuration are obtained from 500m×500m digital elevation model). The results showed that the BCC-CSM1.1(m) and GFDL-CM3 model can reproduce the seasonal variation of air temperature in China. The mean absolute error and root mean square error of daily mean temperature and daily minimum temperature simulated by models are smaller in Northeast China, North China, South China and East China, the simulation capability is stronger than those in the other areas. However, in Western China, the simulation capability is relatively weak characterized by large mean absolute and root mean square errors. Compared with the daily mean and minimum temperature, the mean absolute error and root mean square error of daily maximum temperature simulated by models are larger in North China and Northeast China. The capability of reproducing the seasonal variation of air temperature in China from HADGEM2-ES model is the weakest if compared

with the results from the BCC-CSM1.1(m) and the GFDL-CM3 models, and its mean absolute error and root mean square error were increased from south to north with larger errors in parts of Western China, Inner Mongolia and Northeast China, and smaller errors in the southern part of South China. For the three models, BCC-CSM1.1(m) model is the best in the simulation of the air temperature in China, followed by the GFDL-CM3 and HADGEM2-ES models. For each model, the simulation of the daily mean temperature is the best, followed by the daily minimum temperature, and the daily maximum temperature is the worst. The latitude, longitude, elevation and slope have different influences on the simulation effect of climate models among different models. The BCC-CSM1.1(m) and the GFDL-CM3 models have high simulation capability in low and high latitudes, low longitude, low slope and areas of an altitude less than 2000 meters. The HADGEM2-ES model has high simulation capability in low latitude areas and 112°E nearby areas. The aspect and terrain obscuration have no significant impact on the simulation effect of climate models.

Keywords: global climate models; air temperature; spatial difference

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2.2 Spatial Distribution of Simulation Errors

The spatial distribution characteristics of simulation errors for the three models show distinct regional patterns. The BCC-CSM1.1(m) and GFDL-CM3 models demonstrate relatively small mean absolute errors (MAE) and root mean square errors (RMSE) for daily mean and minimum temperatures in Northeast China, North China, South China, and East China, indicating stronger simulation capability in these regions. In contrast, Western China exhibits relatively weak simulation performance with larger errors.

For daily maximum temperature, the models show larger MAE and RMSE in North China and Northeast China compared to other regions. The HADGEM2-ES model shows the weakest capability in reproducing seasonal temperature variation among the three models, with errors increasing from south to north. Particularly large errors occur in Western China, Inner Mongolia, and Northeast China, while smaller errors are found in the southern parts of South China.

[TABLE:N] Table 2: Evaluation results of air temperature simulated by CMIP5 global climate models in China

2.3 Relationships with Geographic Factors

The relationships between simulation errors and geographic factors (latitude, longitude, altitude, slope, aspect, and terrain obscuration derived from 500m×500m digital elevation model) vary among models. The BCC-CSM1.1(m) and GFDL-CM3 models perform well in low and high latitude regions, low longitude areas, low-slope terrain, and regions below 2000 m elevation. The

HADGEM2-ES model shows better performance in low-latitude areas and regions near 112°E.

Aspect and terrain obscuration do not significantly impact model simulation performance. The analysis reveals that latitude, longitude, altitude, and slope have model-dependent influences on simulation accuracy. For BCC-CSM1.1(m) and GFDL-CM3, errors are generally smaller in areas with moderate latitudes, lower longitudes, and gentler slopes. The HADGEM2-ES model exhibits a distinct spatial pattern with better performance in southern latitudes and specific longitudinal zones.

[FIGURE:N] Fig. 3: Spatial distribution of root mean square error of air temperature in China simulated by global climate models

[FIGURE:N] Fig. 4: Changing rules of the mean absolute error (MAE) of daily mean air temperature simulated by BCC-CSM1.1(m) model varying with (a) latitude, (b) longitude, (c) altitude, (d) slope, (e) aspect, and (f) terrain obscuration

[FIGURE:N] Fig. 5: Changing rules of the mean absolute error (MAE) of daily mean air temperature simulated by GFDL-CM3 model varying with (a) latitude, (b) longitude, (c) altitude, (d) slope, (e) aspect, and (f) terrain obscuration

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Note: Figure translations are in progress. See original paper for figures.