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A Quick Report on a Dynamical Downscaling Simulation over China Using the Nested Model

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Abstract This paper describes a dynamical downscaling simulation over China using the nested model system, which consists of the modified Weather Research and Forecasting Model (WRF) nested with the NCAR Community Atmosphere Model (CAM). Results show that dynamical downscaling is of great value in improving the model simulation of regional climatic characteristics. WRF simulates regional detailed temperature features better than CAM. With the spatial correlation coefficient between the observation and the simulation increasing from 0.54 for CAM to 0.79 for WRF, the improvement in precipitation simulation is more perceptible with WRF. Furthermore, the WRF simulation corrects the spatial bias of the precipitation in the CAM simulation.

Keywords: dynamical downscaling, WRF, CAM

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1 Introduction

Due to coarse resolution, the performance of global circulation models (GCMs) is limited in simulating regional climate variability, especially for complex terrain. Therefore, statistical and dynamical methods have been developed to improve regional climate simulations. Dynamical downscaling, an important dynamical method (Castro et al., 2005; Murphy, 1999), is the approach in which regional climate models (RCMs) are forced by lateral boundary conditions from GCM or global data reanalysis at regular time intervals. Because the RCMs use finer surface parameters and more complicated parameterization schemes, dynamical downscaling can significantly improve the simulation ability for regional climates over various areas of the world (De Sales and Xue, 2006; Dickinson et al., 1989; Fennessy and Shukla, 2000; Giorgi and Mearns, 1991; Jones et al., 1995, 1997; Misra et al., 2003; Walsh and McGregor, 1995). Over East Asia, dynamical downscaling also shows predominance compared to GCM simulations (Fu, 2003; Gao et al., 2002, 2008; Ju and Wang, 2006; Ju et al., 2007; Park et al., 2008; Wang et al., 2003).

Although most previous dynamical downscaling studies over China utilize RegCM, we use the Weather Research and Forecasting Model (WRF). The WRF was initially developed and tested for simulation and forecasting of weather, it has recently been adapted to simulate climate. This WRF model has been used for short-term regional climate variability (Lo et al., 2008; Qian et al., 2010); however, the performance of the WRF as a dynamical downscaling method in long-term simulations over China remains to be determined. To address this issue, we developed a new nested climate model and evaluated its simulations.

2 Models and data

2.1 Atmospheric global circulation model

The GCM model used in this study is the coupled Community Atmosphere Model version 3 (CAM3)-Community Land Model version 3 (CLM3) model (Collins et al., 2004; Oleson et al., 2004), which consists of the CAM3 and CLM3. For CAM, we employ the finite volume dynamical core with a horizontal resolution of 2° latitude by 2.5° longitude and 26 levels in the vertical direction. CLM has 10 unevenly spaced vertical soil layers, up to five snow layers, and one vegetation layer. The CAM simulation consists of Atmospheric Model Intercomparison Project (AMIP)-type integrations (Phillips, 1996) forced by observed global SSTs. The integration period is from 1 September 1977 to 31 December 2002 with output interval of six hours. The first four years (1977–80) are considered as the spin-up period, and the output of the remaining years is used as the lateral boundary conditions for the WRF model.

2.2 Regional climate model

The regional climate model is WRF version 3.2, and the integration domain covers all of mainland China; the integration domain has 120 grids along the East-West direction and 90 grids along the North-South direction, with the center at 35°N, 105°E (Fig. 1). We used 60 km grid spacing and 31 sigma levels with the model top at 50 hPa. The parameterization options selected for the WRF simulation include the WRF Single-Moment 6 class microphysics scheme, Rapid Radiation Transfer Model (RRTM) long-wave radiation scheme, Dudhia short-wave radiation scheme, the unfied Noah land-surface model, and the Yonsei University boundary layer scheme. Initial

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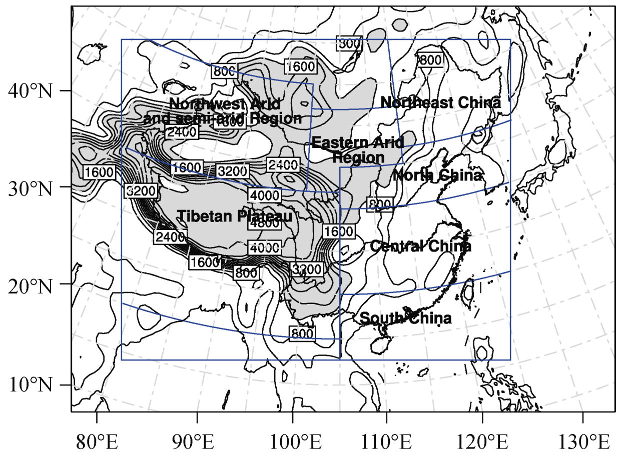

Figure 1 Domain and topography (meters) for model simulation and subregions for detail analysis. Contour intervals are 400 m, and values greater than 1000 m are shaded.

conditions and lateral boundary conditions are all from CAM output. SST data, deep soil temperature and green fraction data were updated every six hours. The simulation period is from 1981 to 2002, with the first two years (1981–82) as the spin-up period, and the following result is used for comparison.

2.3 Observational data

The temperature data used for model validation is the gridded daily temperature data of the China Meteorological Administration (cn05) at 0.5°×0.5° resolution. The cn05 data is constructed from the interpolation of 751 observing stations in China over the period of 1961–2005 (Xu et al., 2009). The precipitation data is from the Xie East Asia daily gridded rainfall data at 0.5°×0.5° resolution; this precipitation data is constructed over East Asia from 1978 to 2003 using gauge observations at over 2200 stations collected from several individual sources (Xie et al., 2007).

3 Results

The validation and comparison of the two model results are based on the observations. Given the different horizontal resolution, we interpolated the model fields onto the same grids as the cn05 data for comparison.

3.1 Temperature

Figure 2 shows the annual mean temperature from observation and model simulations. The observations (Fig. 2a) indicate higher temperatures over South China and lower temperatures over the Tibetan Plateau and northern China. In general, the temperature gradually decreases northward and westward. One exception is in the Tarim Basin and Junggar Basin, where the temperature is relatively higher due mainly to the high albedo of the deserts in these regions.

The CAM and WRF can both capture the large-scale characteristics of temperature over China (Fig. 2). The spatial correlation coefficients between observations and simulations are 0.94 for CAM and 0.96 for WRF. Due to finer resolution, the WRF can reproduce detailed local features of Chinese temperature distribution, especially in the Tibetan Plateau, Sichuan Basin, and Northeast China. For the simulated temperature values, WRF also presents better performance, showing less temperature bias as compared to the CAM simulation.

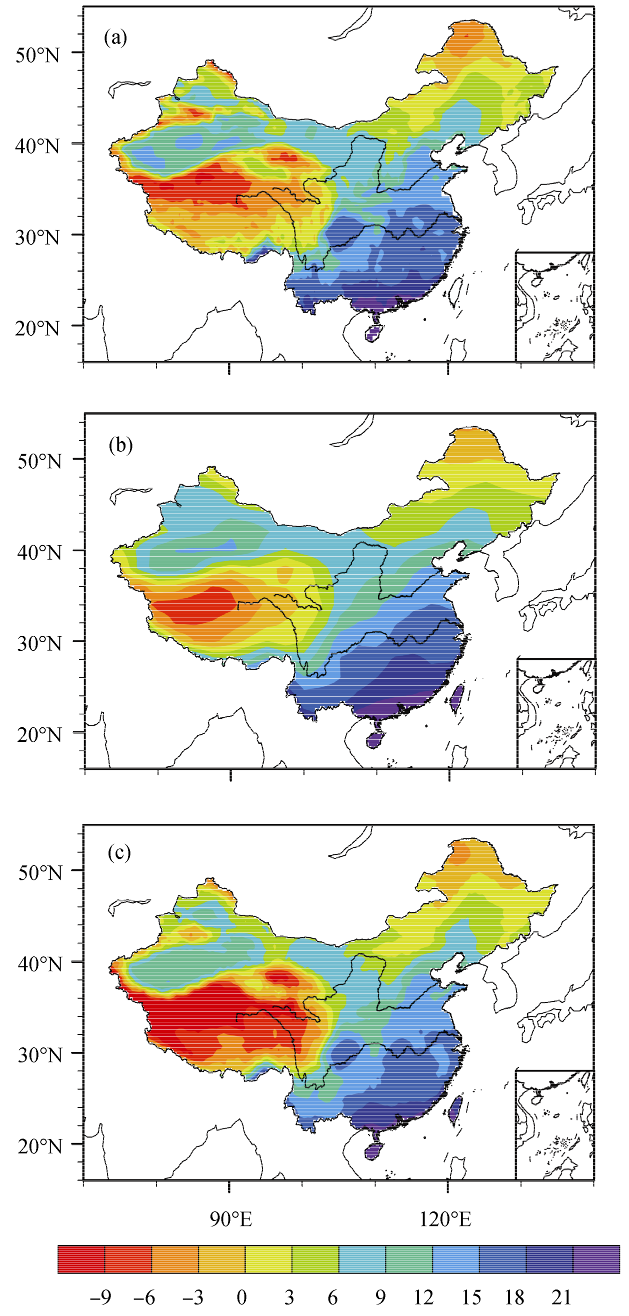

Figure 2 The 20-year annual mean temperature (°C) of (a) the cn05 data, (b) the CAM simulation (Correlation: 0.937; RMSE: 2.992), and (c) the simulation of the WRF force by CAM output (Correlation: 0.96; RMSE: 2.857).

3.2 Precipitation

The WRF simulates precipitation much better than

CAM. As shown in Fig. 3, WRF can more accurately reproduce the observed precipitation distribution features; maximum precipitation mainly occurs over South China, and the precipitation decreases northwestward, with the minimum value over Northwest China, particularly over the Tarim Basin (Fig. 3a). Conversely, the CAM simulates the maximum precipitation over Central China, which disagrees with the observations. The spatial correlation coefficients between the observations and simulations are 0.54 for CAM and 0.79 for WRF. Value comparison shows that the simulated bias of the WRF is much less than that of the CAM (Fig. 3).

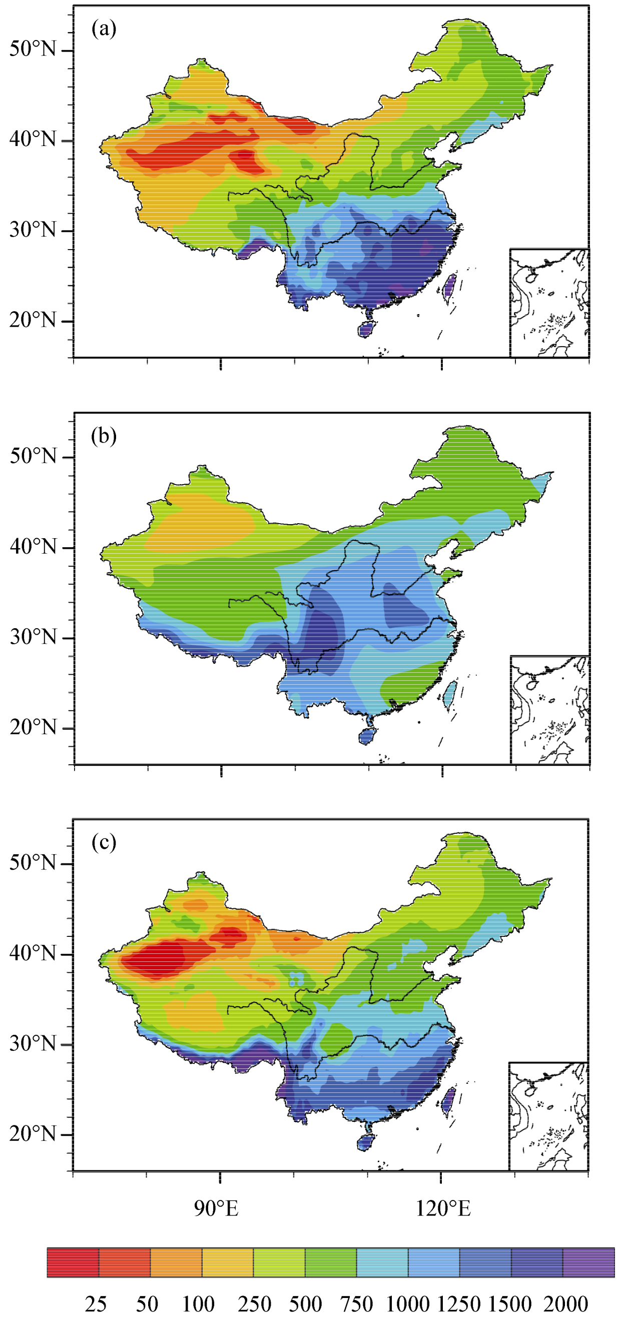

Figure 3 The 20-year annual mean precipitation (mm) of (a) the Xie data, (b) the CAM simulation (Correlation: 0.542; RMSE: 1.403 mm d^{-1}), and (c) the simulation of the WRF force by CAM output (Correlation: 0.791; RMSE: 0.983 mm d^{-1}).

The above comparisons show the WRF to be superior to CAM and that dynamical downscaling is of value in regional climate simulation.

It is well known that the ability of GCMs to simulate precipitation is quite poor; However, the nested-model dynamical downscaling method can improve the model simulation of precipitation. To investigate the simulation of the temporal feature of precipitation, the time series of annual mean precipitation averaged over all the sub-regions within Mainland China are calculated (Fig. 4). In general, the improvement is significant over almost all sub-regions. As shown in Fig. 4, the WRF simulated precipitation values are closer to the observations for almost every year, especially in Northeast China, the eastern arid region, North China and the Northwest arid and semiarid regions, where the RMSEs for the CAM (WRF) were 0.57 (0.24), 1.43 (0.32), 1.32 (0.46), and 0.57 (0.16) mm d^{-1}, respectively. For other sub-regions, such as South China and the Tibetan Plateau, the amount of precipitation simulated by WRF is between observed values and the CAM values; these results indicate that the WRF can improve the simulation of precipitation in these areas.

4 Summary

In this study, the new nested model is developed using the WRF and the CAM. Comparison between the observations and model simulations shows that the WRF can improve the ability of regional climate simulation. The regional details of temperature produced by the WRF are much better than those produced by the CAM. The improvement of precipitation simulation is more apparent than temperature; the spatial correlation coefficient increases from 0.54 for the CAM to 0.79 for the WRF, and the displacement of precipitation cells can be corrected in the WRF simulation. Over different subregions of China, the WRF also shows improvement over the CAM.

In an attempt to investigate the dynamical downscaling ability of the WRF nested with the CAM, this paper addressed several issues. The WRF can reduce the RMSE of precipitation over China, but it shows little ability in simulating the inter-annual variation of precipitation just as CAM does. This weakness is because the inter-annual variation simulated by the WRF is driven by the boundary conditions that are exclusively from the CAM model. An important remaining issue is to illustrate how well the nested model system can represent the summer monsoon system of China. Further analysis of the simulation of the summer monsoon system should be conducted in the future.

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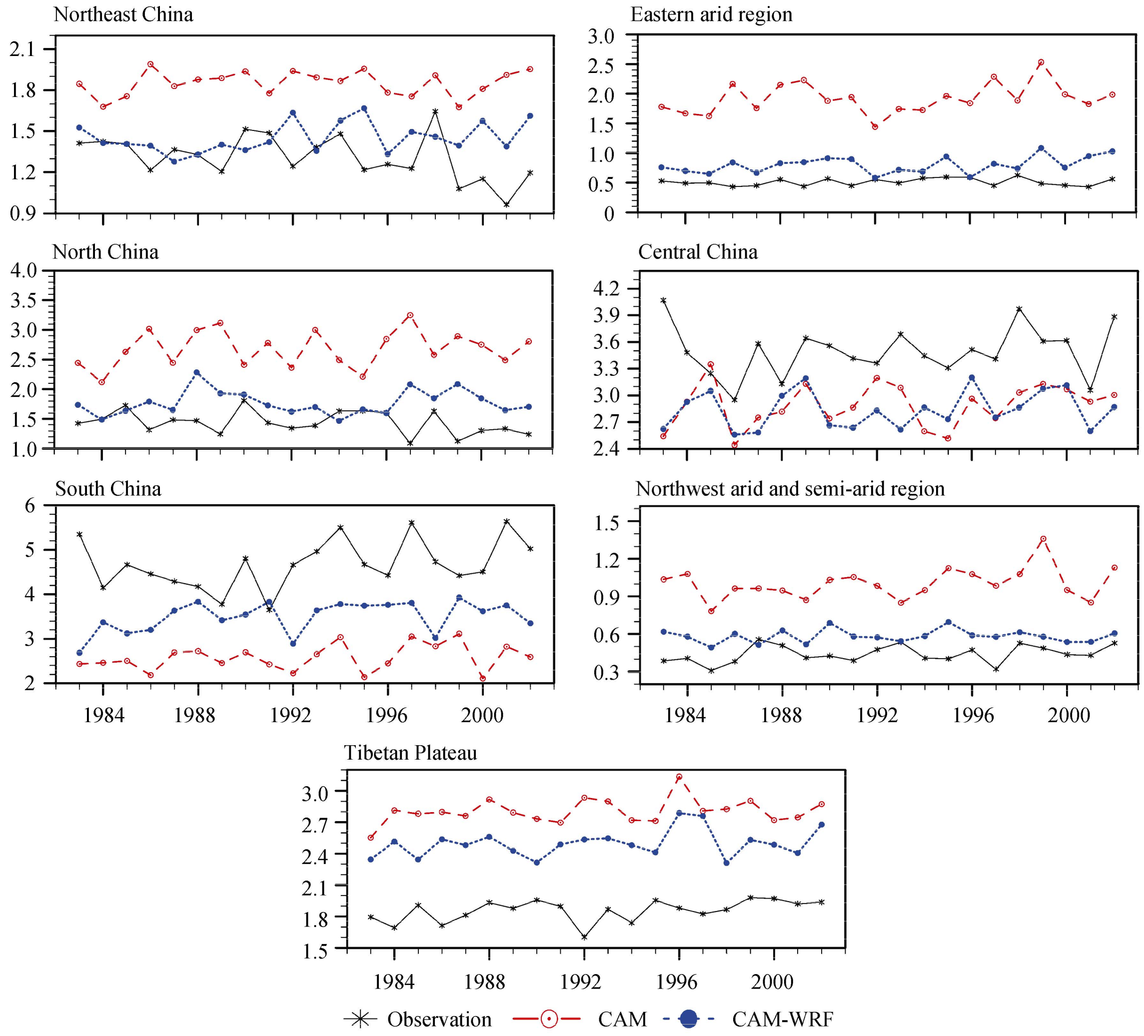

Figure 4 Time series of annual mean precipitation (mm d^{-1}) averaged over subregions, which are indicated in Fig.1.

References

Castro, C. L., R. A. Pielke Sr., and G. Leoncini, 2005: Dynamical downscaling: Assessment of value retained and added using the Regional Atmospheric Modeling System (RAMS), *J. Geophys. Res.*, **110**, D05108, doi:10.1029/2004JD004721.

Collins, W. D., P. J. Rasch, B. A. Boville, et al., 2004: *Description of the NCAR Community Atmosphere Model (CAM 3.0)*, NCAR Tech. Note NCAR/TN-464+ STR, Natl. Cent. for Atmos. Res., Boulder, Colorado, 226pp.

De Sales, F., and Y. Xue, 2006: Investigation of seasonal prediction of the South American regional climate using the nested model system, *J. Geophys. Res.*, **111**, D20107, doi:10.1029/2005JD006989.

Dickinson, R. E., R. M. Errico, F. Giorgi, et al., 1989: A regional climate model for the western United States, *Climatic Change*, **15**, 383–422.

Fennessy, M. J., and J. Shukla, 2000: Seasonal prediction over North America with a regional model nested in a global model, *J. Climate*, **13**, 2605–2627.

Fu, C., 2003: Potential impacts of human-induced land cover change on East Asia monsoon, *Glo. Planet. Change*, **37**, 219–229.

Gao, X., Y. Shi, R. Song, et al., 2008: Reduction of future monsoon precipitation over China: Comparison between a high resolution RCM simulation and the driving GCM, *Meteor. Atmos. Phys.*, **100**, 73–86.

Gao, X., Z. Zhao, and F. Giorgi, 2002: Changes of extreme events in regional climate simulations over East Asia, *Adv. Atmos. Sci.*, **19**, 927–942.

Giorgi, F., and L. O. Mearns, 1991: Approaches to the simulation of regional climate change: A review, *Rev. Geophys.*, **29**, 191–216.

Jones, R. G., J. M. Murphy, and M. Noguer, 1995: Simulation of climate change over Europe using a nested regional-climate model. I: Assessment of control climate, including sensitivity to location of lateral boundaries, *Quart. J. Roy. Meteor. Soc.*, **121**, 1413–1449.

Jones, R. G., J. M. Murphy, M. Noguer, et al., 1997: Simulation of climate change over Europe using a nested regional-climate model. II: Comparison of driving and regional model responses to a doubling of carbon dioxide, *Quart. J. Roy. Meteor. Soc.*, **123**, 265–292.

Ju, L., and H. Wang, 2006: Modern climate over East Asia simulated by a regional climate model nested in a global gridpoint general circulation model, *Chinese J. Geophys.*, **49**, 52–60.

Ju, L., H. Wang, and D. Jiang, 2007: Simulation of the last glacial maximum climate over East Asia with a regional climate model nested in a general circulation model, *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **248**, 376–390.

Lo, J. C.-F., Z.-L. Yang, and R. A. Pielke Sr., 2008: Assessment of three dynamical climate downscaling methods using the Weather Research and Forecasting (WRF) model, *J. Geophys. Res.*, **113**, D09112, doi:10.1029/2007JD009216.

Misra, V., P. A. Dirmeyer, and B. P. Kirtman, 2003: Dynamic downscaling of seasonal simulations over South America, *J. Climate*, **16**, 103−117.

Murphy, J., 1999: An evaluation of statistical and dynamical techniques for downscaling local climate, *J. Climate*, **12**, 2256−2284.

Oleson, K. W., Y. Dai, G. Bonan, et al., 2004: *Technical Description of the Community Land Model (CLM)*, Tech. Note NCAR/TN-461+ STR, Natl. Cent. for Atmos. Res., Boulder, Colorado, 174pp.

Park, E.-H., S.-Y. Hong, and H.-S. Kang, 2008: Characteristics of an East-Asian summer monsoon climatology simulated by the RegCM3, *Meteor. Atmos. Phys.*, **100**, 139−158.

Phillips, T. J., 1996: Documentation of the AMIP models on the world wide web, *Bull. Amer. Meteor. Soc.*, **77**, 1191−1196.

Qian, Y., S. J. Ghan, and L. R. Leung, 2010: Downscaling hydroclimatic changes over the western US based on CAM subgrid scheme and WRF regional climate simulations, *Int. J. Climatol.*, **30**, 675−693.

Walsh, K., and J. L. McGregor, 1995: January and July climate simulations over the Australian region using a limited-area model, *J. Climate*, **8**, 2387−2403.

Wang, Y., O. L. Sen, and B. Wang, 2003: A Highly Resolved Regional Climate Model (IPRC-RegCM) and its simulation of the 1998 severe precipitation event over China. Part I: Model description and verification of simulation, *J. Climate*, **16**, 1721−1738.

Xie, P., M. Chen, S. Yang, et al., 2007: A gauge-based analysis of daily precipitation over East Asia, *J. Hydrometeor.*, **8**, 607−626.

Xu, Y., X. Gao, Y. Shen, et al., 2009: A daily temperature dataset over China and its application in validating a RCM simulation, *Adv. Atmos. Sci.*, **26**, 763−772.