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An application of hybrid downscaling model to forecast summer precipitation at stations in China

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ABSTRACT

A pattern prediction hybrid downscaling method was applied to predict summer (June–July–August) precipitation at China 160 stations. The predicted precipitation from the downscaling scheme is available one month before. Four predictors were chosen to establish the hybrid downscaling scheme. The 500-hPa geopotential height (GH5) and 850-hPa specific humidity (q85) were from the skillful predicted output of three DEMETER (Development of a European Multi-model Ensemble System for Seasonal to Interannual Prediction) general circulation models (GCMs). The 700-hPa geopotential height (GH7) and sea level pressure (SLP) were from reanalysis datasets. The hybrid downscaling scheme (HD-4P) has better prediction skill than a conventional statistical downscaling model (SD-2P) which contains two predictors derived from the output of GCMs, although two downscaling schemes were performed to improve the seasonal prediction of summer rainfall in comparison with the original output of the DEMETER GCMs. In particular, HD-4P downscaling predictions showed lower root mean square errors than those based on the SD-2P model. Furthermore, the HD-4P downscaling model reproduced the China summer precipitation anomaly centers more accurately than the scenario of the SD-2P model in 1998. A hybrid downscaling prediction should be effective to improve the prediction skill of summer rainfall at stations in China.

1. Introduction

China is located in East Asia, and the variability of its summer (June–July–August) precipitation is largely dominated by the East Asian Summer Monsoon (EASM). The monsoon system is characterized not only by unique seasonal changes but also by the interannual and interdecadal variability of the winter and summer monsoons (Tao and Chen, 1987; Wang et al., 2001; H.J. Wang, 2001, 2002). Furthermore, the EASM often leads to severe disasters, which makes accurate predictions on the interannual variability of EASM important for both the society and economy of China.

General Circulation Models (GCMs) have become one important tool for conducting seasonal predictions. GCMs can predict large-scale atmospheric circulation systems better, but they show a relatively low overall ability to simulate the EASM precipitation (Wang, 1997; Wang et al., 2000, 2004; Sperber et al., 2001; Kang et al., 2002; Gao et al., 2011).

Different downscaling techniques had been developed as tools for interpolating large-scale information into local or regional variables. Statistical downscaling (SD) was a popular approach that uncovered the stable relationship between one or several large-scale meteorological variables (predictors), such as atmospheric circulation, and local-scale variables (predictand). This relationship was exploited to predict regional elements by projecting large-scale information onto local-scale variables (Zorita and Von Storch, 1999; Fernández-Ferrero et al., 2009). A SD scheme can use both GCM outputs and the

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preceding atmospheric circulation variables of observations as predictors to make predictions (e.g., Wang and Qian, 2010). Thus, local precipitation can be forecasted by well-predicted large-scale circulation data from GCMs and the observational variables that are strongly correlated with the predictand (Wu et al., 2012). Statistical downscaling is widely used because it can largely eliminate the impact of model biases and capture the statistical relation using predictors from GCM and observational data, respectively.

Most SD schemes were based on regression or similar methods (Fan et al., 2012; Giorgi et al., 2001; Benestad, 2004; Lang and Wang, 2010; Guo et al., 2011; Liu et al., 2011). Murphy (2000) established a SD method based on linear regression relationships between surface temperature or precipitation and a range of atmospheric predictor variables to predict climate change in Europe. Chu et al. (2008) used 500-hPa geopotential height and sea level pressure as predictors of downscale precipitation over north Taiwan. Singular Value Decomposition (SVD) and Canonical Correlation Analysis (CCA) have the advantage of selecting pairs of spatial patterns that are optimally covariated and correlated, respectively, among the linear statistical methods. Uvo et al. (2001) applied SVD to estimate the average rainfall over some parts of Japan and concluded that the major rainfall features had been captured. Paul et al. (2008) developed a SVD-based regression model to downscale the monthly rainfall over East Asia, and they predicted the annual rainfall tendency at the end of the 21st century. A number of studies have focused on the seasonal precipitation and temperature over regions (Mao and Li, 1997; Huang and Huang, 2000; Zhang et al., 2006; Jia et al., 2010) and stations of China (Chen et al., 2012; Sun and Chen, 2012). However, few studies have used both the previous and simultaneous predictors to predict the summer rainfall in China with the coupled patterns of statistical correlation (e.g., SVD) between the predictor and predictand. Thus, this study aims to develop a hybrid SD to forecast the summer precipitation at stations over China. In particular, the downscaling scheme was developed to estimate summer rainfall based on the establishment of links between large-scale circulation patterns and regional rainfall with the SVD method. The predictors were chosen from simulated GCM outputs and reanalysis variables. The results of the downscaling method based on multi-predictor experimental datasets will be analyzed.

Section 2 introduced the GCMs, the observational data and the method used to establish the downscaling scheme. The relationship between the predictors and predictand was analyzed in Section 3. The GCMs' prediction skill evaluations of two of the predictors were shown in Section 4. Section 5 analyzed results of the downscaling. The conclusions and discussions were presented in Section 6.

2. Data and method

2.1. Data

The predictand was the summer precipitation at 160 stations over China, the locations of which were shown in Fig. 1(a). Station-based observed monthly rainfall data from 1960 to 2001 were obtained from the National Climate Center of the China Meteorological Administration. The observed data were used not only to develop the SD technique but also to validate the skill of the prediction scheme.

The simultaneous predictor data were taken from three global coupled ocean–atmosphere DEMETER (Development of a European Multi-model Ensemble System for Seasonal to Interannual Prediction) model outputs. The DEMETER project was conceived to produce nine ensemble members of 6-month long predictions by running a number of state-of-the-art global coupled ocean–atmosphere models on a single supercomputer with common archiving and diagnostic software (Palmer et al., 2004). The initial conditions for the atmospheric and land states in the DEMETER models were provided by the ECMWF 40-yr Reanalysis (ERA-40) (Uppala et al., 2005) four times each year on the 1st day of February, May, August and November with a spatial resolution of 2.5° in latitude and longitude. Starting from 1 May, the hindcast data used in the study were the outputs of three selected DEMETER models: CNRM (Centre National de Recherches Météorologiques, France), ECMWF (European Centre for Medium-Range Weather Forecasts, UK) and UKMO (Met Office, UK). These models were chosen because they have more extensive hindcast data than the other models of the

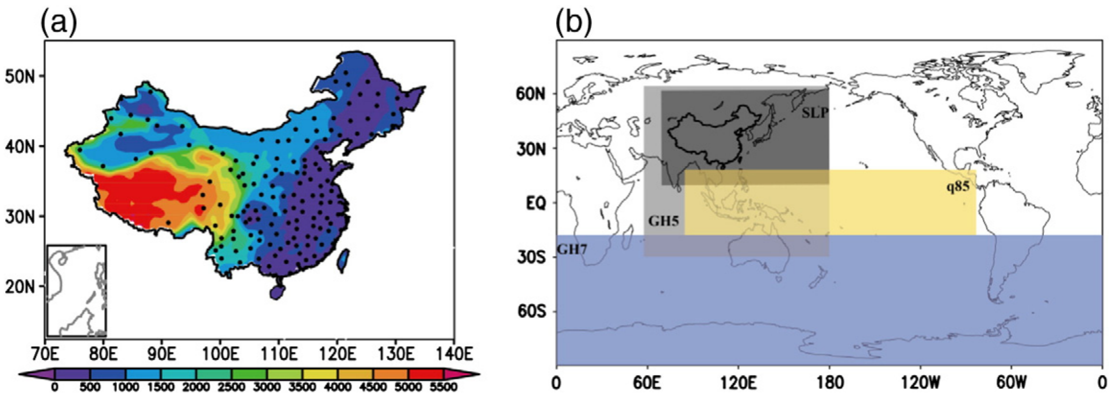

Fig. 1. A China topography map with 160 station locations. Shading in China denotes the topography (m), and the dots show the locations of 160 stations over China. The gray, dark gray, yellow and blue rectangles represent domains of predictors GH5, SLP, q85 and GH7, respectively.