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The role of land surface schemes in the regional climate model (RegCM) for seasonal scale simulations over Western Himalaya

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RESUMEN

La predicción del clima en el Himalaya occidental es una tarea compleja debido a la gran variabilidad de las barreras orográficas en cuanto a altitud y orientación. Las características de la superficie también desempeñan un papel importante en las simulaciones climáticas, y requieren una representación adecuada en los modelos. En este estudio se utilizaron dos esquemas de parametrización de la superficie terrestre (LSPS, por sus siglas en inglés) para analizar la precipitación estacional en la región del Himalaya: el esquema de transferencia biosfera-atmósfera (BATS, por sus siglas en inglés) y el modelo común de la tierra (CLM, por sus siglas en inglés), v. 3.5, acoplados con el modelo regional del clima RegCM, v. 4. El análisis abarca nueve estaciones invernales diferentes (tres con precipitación excesiva, tres con precipitación normal y tres con déficit de precipitación). Los datos del reanálisis II de los Centros Nacionales de Predicción Ambiental (National Centers for Environmental Prediction, NCEP) del departamento de energía estadounidense se utilizaron como condiciones iniciales y limítrofes para el modelo RegCM. Para aportar condiciones superficiales limítrofes al modelo RegCM se utilizaron parámetros geofísicos similares (resolución de 10 min) a los del Mapa Geofísico de Estados Unidos. Se evalúa el desempeño de dos LSPS (CLM y BATS) acoplados con el RegCM en comparación con datos de temperatura superficial y de una malla de precipitación de la Oficina de Meteorología de la India. Se encontró que los datos simulados de precipitación y temperatura superficial están mejor representados en el CLM que en el BATS cuando se comparan con las observaciones. Más aún, se calculan varios parámetros estadísticos como el sesgo, el error cuadrático medio, el coeficiente de correlación espacial y niveles de aptitud (como el nivel equitativo de aptitud y la probabilidad de detección) para evaluar las simulaciones del RegCM utilizando ambos LSPS. Los resultados indican que el error cuadrático medio disminuye y el coeficiente de correlación espacial se incrementa con el uso del CLM en comparación con el BATS. El nivel equitativo de aptitud y la probabilidad de detección también indican que el desempeño del modelo para simular la escala de la precipitación estacional es mejor con el CLM que con el BATS. En general, estos resultados sugieren que el desempeño del RegCM acoplado con el CLM mejora la aptitud del modelo para predecir la precipitación invernal (15 a 25%) y la temperatura (10 a 20%) en el Himalaya occidental.

ABSTRACT

Climate prediction over the Western Himalaya is a challenging task due to the highly variable altitude and orientation of orographic barriers. Surface characteristics also play a vital role in climate simulations and need appropriate representation in the models. In this study, two land surface parameterization schemes (LSPS), the Biosphere-Atmosphere Transfer Scheme (BATS) and the Common Land Model (CLM, version 3.5) in the regional climate model (RegCM, version 4) have been tested over the Himalayan region for nine distinct winter seasons in respect of seasonal precipitation (three years each for excess, normal and deficit). Reanalysis II data of the National Centers for Environmental Prediction (NCEP)/Department of Energy (DOE) have been used as initial and lateral boundary conditions for the RegCM model. In order to provide land surface boundary conditions in the RegCM model, geophysical parameters (10 min resolution) obtained from the United States Geophysical Survey were used. The performance of two LSPS (CLM and BATS) coupled with the RegCM is evaluated against gridded precipitation and surface temperature data sets from the India Meteorological Department (IMD). It is found that the simulated surface temperature and precipitation are better represented in the CLM scheme than in the BATS when compared with observations. Further, several statistical analysis such as bias, root mean square error (RMSE), spatial correlation coefficient (CC) and skill scores like the equitable threat score (ETS) and the probability of detection (POD) are estimated for evaluating RegCM simulations using both LSPS. Results indicate that the RMSE decreases and the CC increases with the use of the CLM compared to BATS. ETS and POD also indicate that the performance of the model is better with the CLM than with the BATS in simulating seasonal scale precipitation. Overall, results suggest that the performance of the RegCM coupled with the CLM scheme improves the model skill in predicting winter precipitation (by 15-25%) and temperature (by 10-20%) over the Western Himalaya.

Keywords: Western Himalaya, land surface schemes, regional climate model.

1. Introduction

The Western Himalayan region receives a substantial amount of precipitation in the form of snow during the winter months (December, January and February [DJF]). Precipitation over this region shows a large inter-annual variability and is vital for several sectors such as agriculture/horticulture, transportation, tourism, hydropower projects and water resources and management. Excess precipitation over this region causes landslides/avalanches and impacts livelihoods and infrastructure. Due to the complex orography, nonlinear interactions of land-atmosphere processes and insufficient observed datasets, seasonal-scale prediction of precipitation over such a heterogeneous region is one of the challenging tasks for meteorologists. Since the heterogeneity of the mountain region plays a dominant role in modulating the regional climate (Pielke *et al.,* 1990; Dickinson, 1995), an advanced land surface parameterization scheme (LSPS) in a model may be able to improve the prediction skill over the mountain region.

Henderson-Sellers and Dickinson (1993) found in their study that more than 30% of the lower boundary conditions for the earth surface are provided through land-atmosphere interface in global climate models and in the case of regional climate modeling systems, this percentage can be even higher. Since the exchange of momentum and energy between land surface and the atmosphere affects prognostic variables such as surface temperature, precipitation, etc., a better representation of surface boundary conditions in a model is very important. Ding *et al.* (1998) examined the role of different land surface processes and found that the efficiency of a regional climate model (RCM) in the simulation of precipitation is increased when an improved land-surface parameterization scheme is used. A few studies have been carried out on the impact of different land LSPS in the simulation of upper air circulation associated with precipitation (Pielke *et al.,* 2003; Singh *et al.,* 2007; Dutta *et al.,* 2009; Kar *et al.,* 2014; Tiwari *et al.,* 2014) over the Indian region. It was found that LSPS plays a crucial role in seasonal scale simulation over the Indian region. However, most of these studies have been conducted for the Indian summer monsoon season and so far there are no such studies for the