ADVANCES IN CLIMATE CHANGE RESEARCH 4(2): 117–126, 2013
www.climatechange.cn
DOI: 10.3724/SP.J.1248.2013.117

CHANGES IN CLIMATE SYSTEM

A Simulation Study on Climatic Effects of Land Cover Change in China

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Abstract

The regional climate model RegCM4 was used to investigate the regional climate effects of land cover change over China. Two 24-year simulations (1978–2001), one with the land cover derived from the MODIS data and the other with the CLCV (Chinese land cover derived from vegetation map) data, were conducted for a region encompassing China. The differences between the MODIS and CLCV data reflect characteristics of desertification and degradation of vegetation in China. Results indicate that the land cover change has important impacts on local climate through mechanisms related to changes in surface energy, water budgets and macro-scale circulation. In summer, the land cover change leads to a decrease in surface air temperature over southern China, a reduction in precipitation and an increase in surface air temperature in the transitional climate zone and the northern Tibetan Plateau, and an increase in inter-annual variability of surface air temperature in the marginal monsoon zone and northwestern China. Strengthened southwesterly winds increase precipitation to some extent in central and eastern Inner Mongolia by enhancing water vapor transport. In winter, enhanced northerly winds, bringing more dry and cold air, lead to a reduction in precipitation and temperature over areas south of the Yellow River.

Keywords: land cover change; regional climate change; RegCM4; CLM3.5

Citation: Yu, Y., and Z.-H. Xie, 2013: A simulation study on climatic effects of land cover change in China. *Adv. Clim. Change Res.*, **4**(2), doi: 10.3724/SP.J.1248.2013.117.

1 Introduction

Land cover plays an important role in the water and energy balance between land and atmosphere. Changes in land cover affect surface albedo, surface roughness, soil water and thermal characteristics, which further influence the climate. Due to the combined effects of natural climate variability, overgrazing, reclamation of land for cultivation, deforestation, and other human activities, land cover has significantly changed and further influences the natural environment, climate variability and extreme weather events [*Li and Ding*, 2004]. Therefore, studies on the effect of land cover change on climate improve our understanding of climate change and the natural environment. *Charney* [1975] first studied the potential impact of vegetation changes in desert border regions in the 1970s. Hereafter, many studies showed that a wide range of changes in vegetation cover has impacts of varying degrees on the regional climate and the natural environment and the impact degrees depend on the studies' temporal and spatial scales and the environment sensitivity of an area [*Shukla et al.*, 1990; *Xue*, 1996; *Douglas et al.*, 2000; *Zhang et al.*, 2009a; 2009b]. Researches in China have also provided insights on the climate effects of land cover changes,

Received: 20 March 2013
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but these studies typically used only one vegetation type in a model grid with unlikely and unrealistic experimental designs such as replacing grassland with desert or vice versa over extended areas [*Zhou and Chen*, 1995; *Lü and Chen*, 1999; *Ding et al.*, 2005; *Gao et al.*, 2007; *Zhang et al.*, 2009a; 2009b; 2009c].

In this study, we chose two land cover datasets which basically reflect land cover changes in China during the end of the 20th century. One is the CLCV data (Chinese land cover derived from vegetation map) [*Chen and Xie*, 2009], which is based on the 1:1,000,000 Vegetation Atlas of China [*Hou*, 2001], representing the land surface conditions from the 1980s to the 1990s. The other dataset is the MODIS data (moderate resolution imaging spectroradiometer) [*Lawrence and Chase*, 2007], which is based on satellite remote sensing data from November 2000 to October 2001. Consistent with previous studies on land cover changes [*Zha and Gao*, 1997; *Piao and Fang*, 2001; *Liu et al.*, 2002a; *Zhang et al.*, 2005b], the differences between the MODIS and CLCV datasets demonstrate characteristics of desertification and degradation of vegetation over China at the end of the 20th century. Using the regional climate model RegCM4 with its land surface scheme CLM3.5, in which plant functional types are simultaneously considered in one model grid, the regional climate effects of land cover changes over China were investigated. Two 24-year simulations (1978–2001) using both land cover datasets were conducted for a region encompassing China.

2 Land surface data and study domain

For its integration in the Community Land Model, *Lawrence and Chase* [2007] developed the MODIS land surface dataset based on the MODIS satellite remote sensing data from November 2000 to October 2001. For reducing the uncertainties of satellite data, *Chen and Xie* [2009] developed the CLCV dataset based on the Vegetation Atlas of China (1:1,000,000). The data reflects the land surface conditions from the 1980s to the 1990s. On the simulation, they investigated the impacts on land surface processes. The CLCV data production process began with the classification of vegetation maps into 8 categories: bare soil, forest, shrub, grass, crop, glacier, lake and wetland. Secondly, needleleaf and broadleaf forests were divided into evergreen and deciduous forests using the AVHRR (advanced very high resolution radiometer) Continuous Fields Tree Cover of the University of Maryland. Then the proportion of forest cover in the vegetation maps was identified. Thirdly, using mean precipitation, temperature and accumulated temperature data from 753 weather stations in China for 40 years (1960–1999), forest, shrub, and grass were further separated into tropical, temperate, and boreal categories. In doing so, the area ratios of glacier, lake, wetland, and 16 plant functional types, which are the same as in the Community Land Model, were extracted from the vegetation maps. These vegetation types include bare soil, temperate needleleaf evergreen forest, boreal needleleaf evergreen forest, boreal needleleaf deciduous forest, tropical broadleaf evergreen forest, temperate broadleaf evergreen forest, tropical broadleaf deciduous forest, temperate broadleaf deciduous forest, boreal broadleaf deciduous forest, temperate broadleaf evergreen shrub, temperate broadleaf deciduous shrub, boreal deciduous shrub, arctic C3 grass, non-arctic C3 grass, C4 grass, and crops. Both datasets have a resolution of 0.5° latitude by 0.5° longitude.

In our study, we reduced the 16 plant functional types to 6 broad categories for convenience of comparison. The differences of MODIS and CLCV (Fig. 1) show an increase in bare soil and degradation of natural vegetation over China. The scope of desertification in northern China is consistent with the results of *Zha and Gao* [1997] and *Zhang et al.* [2005b]. We can detect serious desertification over the transitional climate zone including Inner Mongolia, Ningxia province, and south of Gansu province. Moreover, significant desertification also exists in the Qilian Mountains, Kunlun Mountains, Tianshan Mountains, and the central and western Tibetan Plateau (Fig. 1a&1e). *Piao and Fang* [2001] showed that the NDVI (normalized difference vegetation index) in the western Tibetan Plateau and Northwest China decreased significantly during the last two decades of the 20th century. Land cover changes in Northeast China are consistent with the