A numerical simulation study of the impacts of vegetation change on regional climate in China

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Abstract

By using the regional climate model (RegCM_NCC), two modeling experiments are undertaken to investigate the regional climate impacts of changed vegetation cover in China, one with heavy desertification in North of China and another with reforestation in Northwest China. Results indicate that these land cover modifications in large regions not only have significant local and regional effects on rainfall and air temperature, but also have far-reaching effects on the East Asian monsoon, so being one of main influence factors of the regional climate change.

Keyword: land cover change, regional climate, numerical simulation

Model Introduction

The regional climate model (RegCM_NCC) used in the study is developed based on the second generation of the regional climate model of NCAR/RegCM2 (Giorgi et al., 1993a, b). By modifying and assembling the various physical process parameterization schemes in the RegCM2, the RegCM_NCC has been established during 1996-2000 and has been used in climate simulation and seasonal prediction (Ding et al.,1998). Table 1 lists the details of the physical schemes options for this study, the lateral boundary data are provided every 12 hours, the sea surface temperature data is updating per 7 days. Figure1 shows the simulation domain and terrain height.

Tible1 Physical process schemes

Model Configuration	**RegCM_NCC**
Horizontal grids	60km
Vertical layers (top)	16 sigma layers (50 hPa)
Cumulus convection	Betts-Miller(Betts A K,1986)
Moisture scheme	implicit
PBL	Holtslag(Holtslag et al.,1990)
Radiation	CCM3(Kiehl et al.,1996)
Land surface	LPM Ⅱ (Shi et al.,2000)
Boundary condition	Exponential laxation
Initial, boundary data (SST)	NCEP/NCAR Reanalysis II (NOAA:OI.V2)
Simulation period	1997.12~ 1999. 02

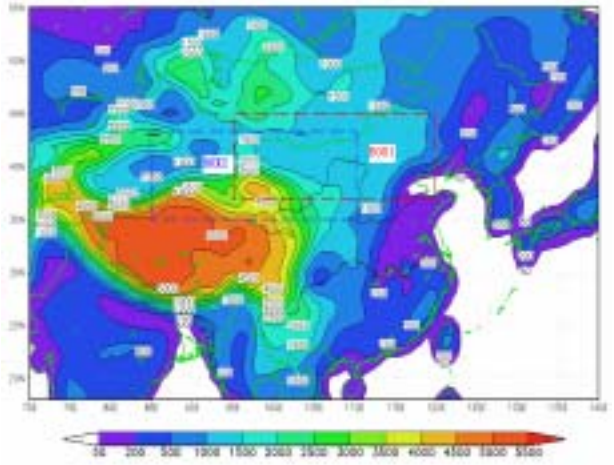

Fig.1 Model domain and terrain height

Experimental design and simulation analysis

Three experiments were carried out, there are controll run with current vegetation cover in China (hereafter CTRL), two sensitivity experiments with changed land cover in some regions. The desertifacation test area is selected in North China between 95º-120ºE and 37º-45ºN(refer as “DE” test in this paper; see the box1 in Figure1), in which area, the vegetation class was replaced with desert or semi-desert, some parameters values was changed associated with these land cover classes in LPM Ⅱ. In the reforestation experiment(refer as “RE” test), the vegetation class in Box2 between 85º-110ºE and 35º-43ºN (shows in Figure1) was replaced with various forest, it is consistent with the project of tree planting over Northwest China. Each of the experiments is integrated for 15 months (1997.12~1999.02), and the analysis is started from Mar, 1998, with the fore 3 month being regarded as the model’s “spin-up” time. The effects of land cover change on climate are investigated based on difference between vegetation sensitivity experiments and controll simulation.

Results of DE test show that heavy desertification in north of China result in rainfall decreasing over many regions, especially in North China and Northwest China, but rainfall increasing in South China. Figure2 just presents mean precipitation difference in summer between DE and CTRL, rainfall over the test area remarkable decrease tends to make the water lacked regions (such as In-Mongolian and north of Shanxi Province) more droughty. However, rainfall over Northeast China increase significantly, rainfall also increase in south of the Yangtze valley basins. In other seasons, rainfall in the test area also decrease consistently. The temperature difference change mainly over the desertification area, with temperature remarkable increasing in all seasons except for winter, with the maximum warming center value being 2ºC (shows in Figure3), but temperature in winter is cooler than CTRL, these changes would make the local climate becoming more arid and unsuitable for vegetation regrowing.

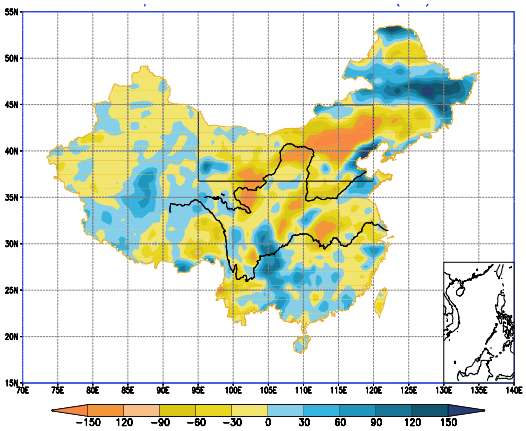

Fig.2 summer precipitation difference in DE test (DE-CTRL)（the rectangle box shows the test area）(Unit: mm/mon)

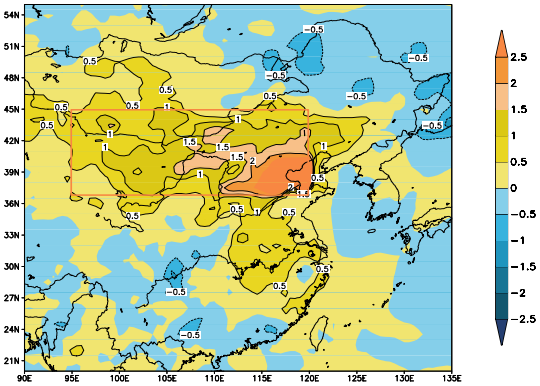

Fig.3 summer air temperature difference in DE test (DE-CTRL) (Unit: ºC)

On the contrary, the results in RE experiment are obvious different to DE , reforestation in Northwest China tends to increase local rainfall, especially in Yellow River basin, and hence, lightening drought over there in some degree, but rainfall in Yangtze valley basins and south China decrease in summer (sees in figure4), which tends to decrease flood occurrence in these regions. On the other hand, air temperature in the re-greening area become warmer in winter and cooler in summer (figure5 just shows summer temperature difference), while more moisture supply to lower layer atmosphere and near ground wind decrease, thus may be reduce dust storm weather in some regions.

Furthermore, land cover change also have obviously effects on the intensity of East Asian monsoon, results indicate that summer monsoonal flow in East China is weaken while the northwest or northeast winter monsoonal wind are enhanced in the desertification experiment. In contrast, reforestation in Northwest China results in stronger summer monsoon, with more warm and wet air transporting from south to north then make for rainfall in North China increasing, but in winter, the monsoonal wind become weak, so may be reduce the occurrence of cold events weather in some regions.

Energy analysis indicate that, in DE experiment, because of the change of character concerned to vegetation type, such as albedo, roughness length, and so on, the latent (sensible) heat flux is reduced (increased) over the degraded area, but the magnitude of the energy change is not uniformly in different season. In the RE experiment, changes of the heat flux is nearly contrary to the DE test. The solar radiation flux also presents remarkable variation in the experiments.

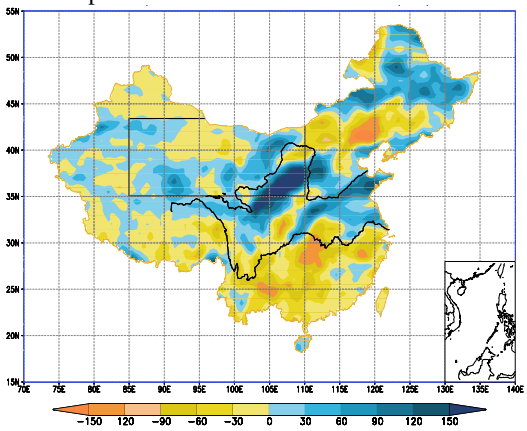

Fig.4 summer precipitation difference in RE test (RE-CTRL) (Unit: mm/mon)

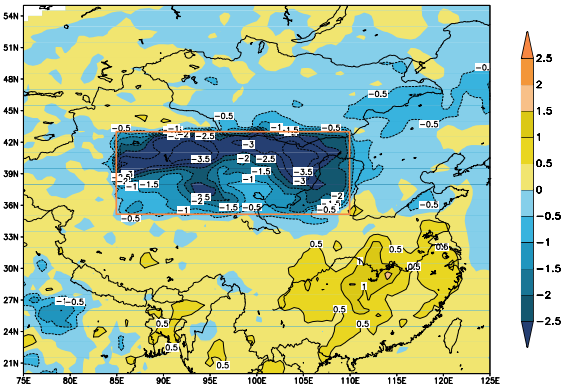

Fig.5 summer air temperature difference in RE test (RE-CTRL) (Unit: ºC)

Results and discussion

The land cover change has significant local and far-reaching effects on regional climate over China.

1. Heavy desertification in north of China result in rainfall decreasing in local and around regions, but increasing in North China and South China, with surface air temperature remarkable increasing over the test region, as a result, the local climate become more arid.

2. Reforestation in Northwest China tends to increase rainfall in Yellow River basin, and hence, lightening drought over there, but rainfall over Yangtze valley basin decrease in summer, while the local air temperature become warmer in winter and cooler in summer.

3. Vegetation change also have obviously effects on the East Asian monsoon, including the summer monsoonal flow in east China weakening while the winter monsoon enhancing after desertification. In contrast, reforestation in

Northwest China result in stronger summer monsoon and weaker monsoon in winter, which could reduce occurrence of cold events.

The investigation provide us some important clues on how land cover change affects Chinese climate, but it also has some limitations, such as, the vegetation changes is exaggerated and the experiments are performed only on more than one year, which was relatively short for climate response, therefore, the results should be testified through further study.

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