The impact of desertification on Mongolian climate and its numerical study using regional climate model (RegCM3)

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I Introduction

Mongolian territory is landlocked and surrounded by high mountains, where locates in transition zone between great Siberian taiga and Central Asian desert, which belongs to the central part of Eurasian continent. This is main reason that country climate is more continental and its ecosystem might be high vulnerable to the climate change. By the latest investigation, 70 percent (128 million ha) of pasture of Mongolia has been affected by a desertification with certain values since reindustrial period (National Report of Biodiversity, 1998).

Here we use a regional climate model (RCM) with a land surface scheme such as Biosphere-Atmosphere Transfer Scheme BATS (Dickinson *et al*., 1993), to investigate desertification issues over Mongolia. A used methodology in the study is sensitivity experiment in land cover change, which will be hypothetically desertified close to the reality as critical future scenarios in Central Asia. The control simulations are initialized and driven by NCEP (National Center for Environmental Prediction) reanalysis data and sea surface temperature. The driving fields of desertification and control simulation are dynamical identical, only different is land cover change initialization. The simulation is conducted over the Central Asia and inside the model domain Mongolia is focused in the study for the summer seasons of three years, representing wet (1994), normal (1998) and drought (2000) conditions.

The present experiment is performed with a modified version of the National Center for Atmosphere Research's (NCAR) Regional Climate Model (RegCM, Version 3). A detailed description of the NCAR RegCM can be found in Giorgi *et al*. (1993a, b) and Giorgi and Mearns (1999).

II Design of numerical experiments

The initial and boundary condition for wind, temperature, surface pressure, and water vapor are taken from NCEP reanalysis data.

In this simulation the soil and root water content is initialized using of Giorgi and Bates method (1989). The control and sensitivity experiments are initialized on April 25 for each 1994, 1998, and 2000. The runs are integrated until September 1st for a period 4 months. Chosen years are selected from precipitation anomaly records as wet (1994), normal (1998) and dry (2000) year in last decade.

The model domain covers central part of Asia and the grid defined on rotated Lambert Conformal Mercator map projection. The domain is centered at 45.0° N and 105.0° E in Mongolia. It comprises 101 × 71 grid points with horizontal grid spacing of 60 km. The region focus for analysis is Mongolian. The simulations are initialized at 00 UTC 25 of April 1994, 1998 and 2000 and integrated for 4 months simulation with 5 days spinning up.

III Experimental results

Comparisons are made over focus region centered on the Mongolia, which extends from 41.5° N to 52.0° N, and 87.5° E to 120° E.

1. Control integration

The validation of the control integration is done against observation from Climate Research Unit, University of East Anglia, UK. (CRU data) Temporal evolution is compared against for monthly temperature and precipitation using meteorological daily data of 62 stations over Mongolia in 1994, 1998 and 2000.

Generally, the model is able to capture the monthly climate variability and but there is small temperature underestimation in dry year and precipitation overestimations in all years.

The spatial representation of temperature and precipitation over Mongolia is well. However, there is slight underestimation of temperature in Great Lake valley, high mountainous and eastern Mongolian region in 1998 and 2000. The precipitation overestimation is occurred in all of region of Mongolia, except some part of Gobi and Desert region in the southern region (Here is not shown figures).

2. Sensitivity experiments

The results of CTL and DSR integration for over Mongolia are summarized in Table 1. Generally, precipitation, evapotranspiration and runoff are decreased in desertification experiments for the summer seasons. The highest difference value is observed for 0.55, 0.65, 0.13 mm/d in June, respectively for the precipitation, evapotranspiration and runoff. Among these, evapotranspiration is substantially reduced in DSR experiment due to higher surface albedo, reduced vegetation coverage, reduced soil water content and reduced surface roughness.

In geographically distribution of the reduction of precipitation and evapotranspiration values, their values are observed almost whole territory of Mongolia, but highest values are occurred in central and eastern region of Mongolia. The value reaches -2 mm/d and -1.2 mm/d,

Table 1 Summary of the CTL and DSR experiments: mean of three years simulated for June, July and August.

	June			July			August		
	CTL	DSR	Δ	CTL	DSR	Δ	CTL	DSR	Δ
Hydrological cycle									
Precipitation, mm/day	2.86	2.31	-0.55	2.97	2.53	-0.43	2.67	2.36	-0.31
Evapotranspiration, mm/day	2.09	1.44	-0.65	2.26	1.66	-0.60	1.93	1.55	-0.38
Runoff, mm/day	0.38	0.25	-0.13	0.44	0.32	-0.12	0.40	0.29	-0.10
Soil moisture upper layer, mm	22.7	25.2	2.5	23.6	25.3	1.7	24.2	24.6	0.4
Soil moisture root zone, mm	228.0	143.4	-84.6	233.0	161.5	-71.6	238.4	179.4	-59.0
Surface climate									
Surface air tempeature	16.8	18.5	1.7	20.2	22.0	1.8	17.7	19.0	1.3
Anemometer relative humidity	60.4	48.8	-11.6	59.4	49.6	-9.8	62.6	55.1	-7.5

respectively for the precipitation and evopatranspiration. The mean surface air temperature over Mongolia is increased 1.3-1.8 °C in summer season. But its highest values such as 2.0-3.0 °C are occurred in area, where the grassland is assumed as desert and semi-desert.

IV Discussion and conclusion

This sensitivity study is to test desertification mechanism and its impacts on regional climate over Mongolia. Last few years (1999-2002), Mongolia has faced on severe drought and harsh winter (dzud) and it might be coincident with land surface degradation due to human activity and rising of number livestock.

Numerical experiments in this study are presented that desertification or land degradation in grassland would be affected not only regional climate but also hydrological cycle and surface energy budget. The reduction of evopatranspiration mainly occurred in desertification area, accompanied by reduced precipitation and increased surface temperature. The biggest change is occurred in central and eastern region of Mongolia. It is indicating that a decreasing precipitation trend in central Mongolia might be consistent with land degradation.

The change of land use category, which is used in sensitivity experiment, is same as pessimistic future scenarios, but close to reality with certain confidence value.

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