Numerical Experiments for the influence of the Transition Zone Migration on Summer Climate in North China

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ABSTRACT

As the position of the transition zone changes obviously, that is, as the transition zone migrates to the north or the south from present position, it affects water or heat balance between the land and the atmosphere in a considerable degree and has a profound influence on climate in North China. The experiment results in this paper indicate whether in the dry case or in the wet case of the large-scale climatological background field, the surface air temperature in a wide range of the transition zone migration and its surrounding decreases as the transition zone migrates northward. Moreover, the net upward fluxes of the surface long wave radiation and the sensible heat decrease, and the evaporation to the atmosphere increases. As the transition zone migrates southward, the results are opposite. This kind of significant thermal forcing between the land and the atmosphere can excite secondary circulation or circulation cells, which interact with the large-scale circulation systems, changing the atmospheric motion, affecting the water vapor transportation and consequently having an effect on the precipitation.

Key words: Transition zone migration, Water and heat balance, Climate in North China, Numerical simulation

1. Introduction

Many observations show that North China, especially the Plain of North China, is one of the most severe drought areas in China. The drought disasters occur with a high frequency and a wide range, and sustain a long time. Moreover, the high temperature usually accompanies the drought in the corresponding period. The summer rainfall in 1997 is less than half of normal. It is the most severe drought disaster during recent decades. The regional climate anomalies are no doubt influenced by the global climate change. However, many recent observations and numerical studies reveal that the change in the land surface process has an important effect on general circulation and climate (Ye and Chen 1992; Charney 1975; Yan and Anthes 1988; Yu and Luo 1996; Sun et al. 1996). It demonstrates that the variations of surface albedo, roughness, soil temperature, soil moisture, vegetation, etc., can change the transfers of the fluxes between the land surface and the atmosphere as well as the balance of atmospheric energy and water in a considerable degree. It is one of the most important factors affecting general circulation and climate. Particularly, the influence of vegetation becomes more and more notable (Ye 1995). It not only has influence on surface albedo, sensible heat

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and latent heat fluxes, radiation budget and water conservation and so on, but also has a significant effect on transpiration. Besides, the another important effect can connect the ground water and the atmosphere. The distribution of vegetation in North China obviously shows the regional characteristics. The demarcation lines of forest, grassland and desert are very distinct. The most important and the greatest transition zone in China starts from the east of Inner Mongolia and extends southwest to the southeastern part of the Tibetan Plateau (Ye, 1992). It represents the transitional zone of grassland and forest, also the transitional zone from the inner arid and semi-arid climate to the southeast humid and semi-humid monsoon climate. The observation analyses indicate that the vegetation in the transition zone is weak and fragile, significantly changing with variations of mankind activities or the natural environment, further causing changes of the other environmental factors. Li et al. (1992) analyzed the change of the western sector of the transition zone and found that its position moved southward about one and a half latitudes as compared with that of 6800–3900 years ago.

Therefore, in this paper we study impacts of obvious migration of the transition zone by using the numerical model. How does its northward or southward migration have an effect on the water and heat balance between the land surface and the atmosphere in some degree and consequently affect the climate in North China?

2. Numerical model and experiment design

The model used in this paper is a second-generation regional climate model (RegCM2) developed by Giorgi et al. (1993a, 1993b) at the National Center for Atmospheric Research (NCAR). The model uses a $\sigma$-coordinate in the vertical direction, $\sigma = (p - p_s) / (p_s - p_t)$, where $p_s$ is the prognostic surface pressure and $p_t$ is the pressure specified to be the model top. We choose a domain of 3000 km $\times$ 3600 km size centered in North China at 41°N and 116°E with a horizontal grid-point spacing of 60 km (Fig. 1). The nonuniform vertical structure in the model is taken with ten levels with the model top at 100 hPa. Its physical processes include the detailed radiative transfer package, the Biosphere-Atmosphere Transfer Scheme (BATS) and so on. A Kuo-type cumulus parameterization is used in the RegCM2, along with a simple scheme for resolvable scale precipitation, whereby all water in excess of saturation at a given grid point instantaneously precipitates. The model incorporates the split–explicit time integration technique so that it runs more efficiently.

The analysis data of the National Meteorological Center in China are used as the initial and lateral boundary conditions necessary to drive the model runs. The driving data have a resolution of 1.875° $\times$ 1.875° in the horizontal, are distributed on eight pressure levels from 1000 hPa to 100 hPa, and are available at intervals of 12 hours. The bilinear technique is employed to interpolate horizontally wind components, geopotential height, temperature and relative humidity to the model grid. Vertical interpolation is linear in pressure for wind and relative humidity, and linear in the logarithm of pressure for temperature. The time-dependent boundary condition is obtained by the linear interpolation of data at intervals of 12 hours and a standard relaxation procedure involving a Newtonian and a diffusion term is applied. The model topography and land-use distribution are obtained by the interpolation of NCAR topography and land-use with a resolution of 0.5° $\times$ 0.5°.

In order to consider the influence of the transition zone migration on the regional climate under different cases of the large-scale climatological background field, we choose two typical experiment cases. One is a severe drought case of summer in 1997 and represents a dry case. The other is a case of summer in 1996 in which the rainfall is much more than normal