The Influence of Vegetation Cover on Summer Precipitation in China: a Statistical Analysis of NDVI and Climate Data

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ABSTRACT

This study provides new evidence for the feedback effects of vegetation cover on summer precipitation in different regions of China by calculating immediate (same season), and one-and two-season lagged correlations between the normalized difference vegetation index (NDVI) and summer precipitation. The results show that the correlation coefficients between NDVI in spring and the previous winter and precipitation in summer are positive in most regions of China, and they show significant difference between regions. The stronger one-and two-season lagged correlations occur in the eastern arid/semi-arid region, Central China, and Southwest China out of the eight climatic regions of China, and this implies that vegetation cover change has more sensitive feedback effects on summer precipitation in the three regions. The three regions are defined as sensitive regions. Spatial analyses of correlations between spring NDVI averaged over each sensitive region and summer precipitation of 160 stations suggest that the vegetation cover strongly affects summer precipitation not only over the sensitive region itself but also over other regions, especially the downstream region.

Key words: influence, vegetation cover, summer precipitation

1. Introduction

In analyses of global change, land use/cover change and its feedback to the climate system form very substantial aspects, and the changing land use/cover pattern is considered as one of the driving forces of regional environment change superimposed on the natural changes. Over the past few decades, numerous reports of rapid loss of vegetation cover in many regions such as the deforestation and desertification in West Africa (Gornitz, 1985; FAO, 1993; Fairhead and Leach, 1998; Nicholson et al., 1998) and aridification and desertification in China's northern areas (Fu, 1994; Fu and Wen, 2002; Wang and Wu, 1999; Guo et al., 2001) have raised widespread concerns. The effects of the vegetation cover loss and increase on climate, at the regional scale, have been investigated by observation, dynamical and theoretical analyses, and model studies. But the interactions between land and atmosphere in the dynamical and theoretical analyses (Charney, 1975; Pan and Chao, 2001) have been simplified, so the regional differences in the responses of climate to vegetation cover were difficult to distinguish. Furthermore, models to describe exchanges of energy, water, and carbon dioxide between the atmosphere and biosphere have been used to simulate the impacts of land cover conversion on the regional climate, for example, the Amazon deforestation (Dickinson and Kennedy, 1992; Zeng et al., 1996; Costa and Foley, 2000), desertification in northern China (Wei and Fu, 1998), and land cover change in East China (Zhang et al., 2002). The models require global or regional scale information about the states of both the atmosphere and biosphere, and the measurements of biospheric parameters over the land surface were sparse; in particular, parameters such as biomass, albedo, leaf area index, and photosynthetic capacity have been measured at only a few sites. So the parameterization schemes in the current models were far from complete (DeFries et al., 1995), meanwhile, most models only considered the seasonal variety of vegetation cover, but could not reflect interannual variety. Some simulation results

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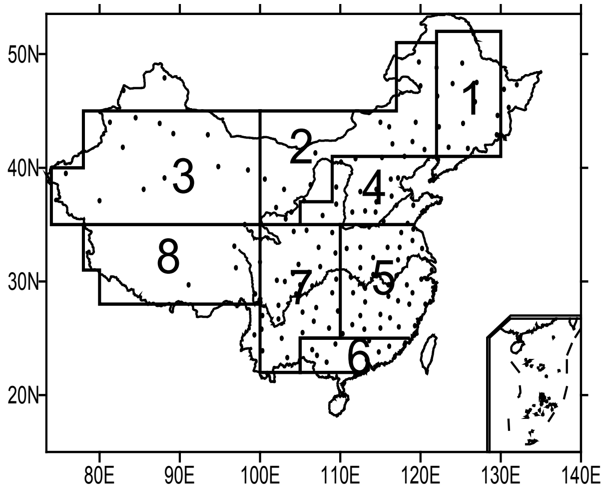

Fig. 1. Distribution of meteorological stations and classification of climatic regions. 1 Northeast China, 2 eastern arid/semi-arid region, 3 western arid/semi-arid region, 4 North China, 5 Central China, 6 South China, 7 Southwest China, 8 Tibetan Plateau.

might be inconclusive, uncertain, and sometimes conflicting (Bounoua et al., 2002). And finally, the observed data of land-surface climatology have been limited to a few points in space and time due to few field experiments (e.g., the First Field Experiment (FIFE), Sellers and Hall, 1992), and were hardly directly helpful for studying the response of regional climate to vegetation cover.

After the 1990s, the long-time and large-scale satellite datasets represented by the Pathfinder datasets developed by the Earth Observation System project of NASA and NOAA were integrated. Remote sensing data were often utilized to investigate the responses of vegetation to climate change (Braswell et al., 1997; Richard and Poccard, 1998), yet were rarely used to study the impacts of vegetation cover on the climate system. These satellite data can be an attractive tool to assess the feedback effects of vegetation.

In this study, we systematically investigate the feedback effects of vegetation cover on summer precipitation in different regions of China by immediate and lagged correlation analyses using NOAA/AVHRR normalized difference vegetation index (NDVI) data for the period of 1981–2000 and precipitation data of 160 stations from the China Meteorological Administration.

2. Data and method

The monthly NDVI data with $1^\circ \times 1^\circ$ spatial resolution from the National Oceanographic and Atmospheric Administration/Advanced Very High Resolution Radiometer (NOAA/AVHRR), for the period from July 1981 to December 2000, are used in the study. The NDVI is equal to $(N-R)/(N+R)$, where N is the reflectance measured in the near-infrared spectral band (0.725 to 1.10 μm) and R is the reflectance measured in the visible spectral band (0.58 to 0.68 μm).

Monthly precipitation data of 160 weather stations in China were obtained from the China Meteorological Administration for the period of 1951–2000 and are used here.

The study domain is divided into the eight climatic regions of China (Zhang and Lin, 1985): Northeast China, the eastern arid/semi-arid region, the western arid/semi-arid region, North China, Central China, South China, Southwest China, and the Tibetan Plateau (Fig. 1). Then, (1) the correlation coefficients between NDVI averaged in the previous winter (January and February), spring (March, April, and May), and summer (June, July, and August) and total precipitation in summer are calculated with both parameters averaged in every region; (2) the correlation coefficients between spring NDVI and summer precipitation for each of the 160 stations are calculated and the NDVI is averaged in every region. The results are used to investigate the response of the climate to the vegetation ecosystem.

3. Results

The climate is the dominant factor to classify and mark out the vegetation cover; conversely, the vegetation cover can affect the surface fluxes and consequently the climate at both regional and global scales as one of the important forces. Zero-lag correlations between NDVI and summer precipitation reflect the interactions between climate and vegetation. Obvious correlations appear in the arid and semi-arid regions (Regions 2, 3, and 4) of China, and the correlations over Regions 2 and 4 are significant at the 95% and 90% confidence levels, respectively. But the correlations are little in the other regions (Fig. 2). Figure 2 also shows that the one-and two-season lagged correlations are positive in most of the eight regions of China, but the lagged correlations over Regions 1, 3, and 4 are very small and may be meaningless. Furthermore, Region 8 has only a few data points which are located over its far east part, so the data cannot represent the whole Tibetan Plateau considering its height and complicated surface characteristics. The responses of precipitation to vegetation cover show significant differences in different regions, which could be related with the spatial structure of the general circulations. If a region in which the one-and two-season lagged correlation coefficients between NDVI and precipitation

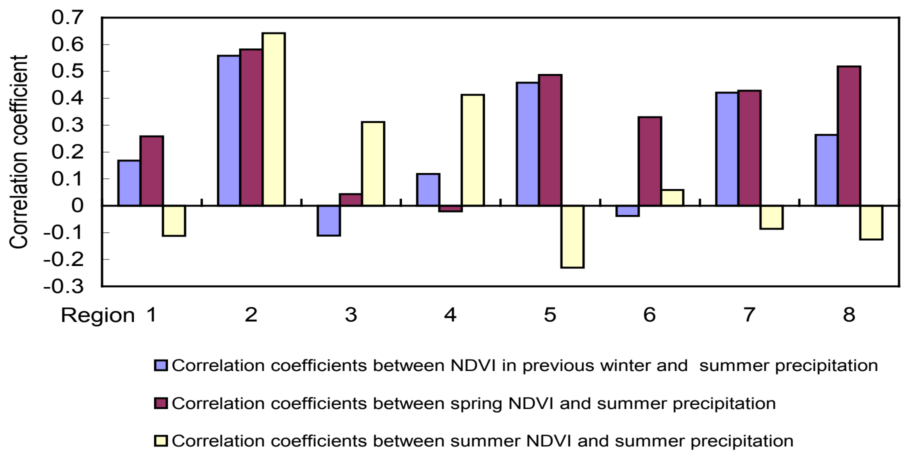

Fig. 2. The correlation coefficients between summer precipitation and NDVI in spring, summer, and the previous winter in the eight climatic regions of China, and both NDVI and precipitation are averaged over each region. r=0.3887 for the 90% significance level, 0.4555 for 95%, and 0.5751 for 99%.

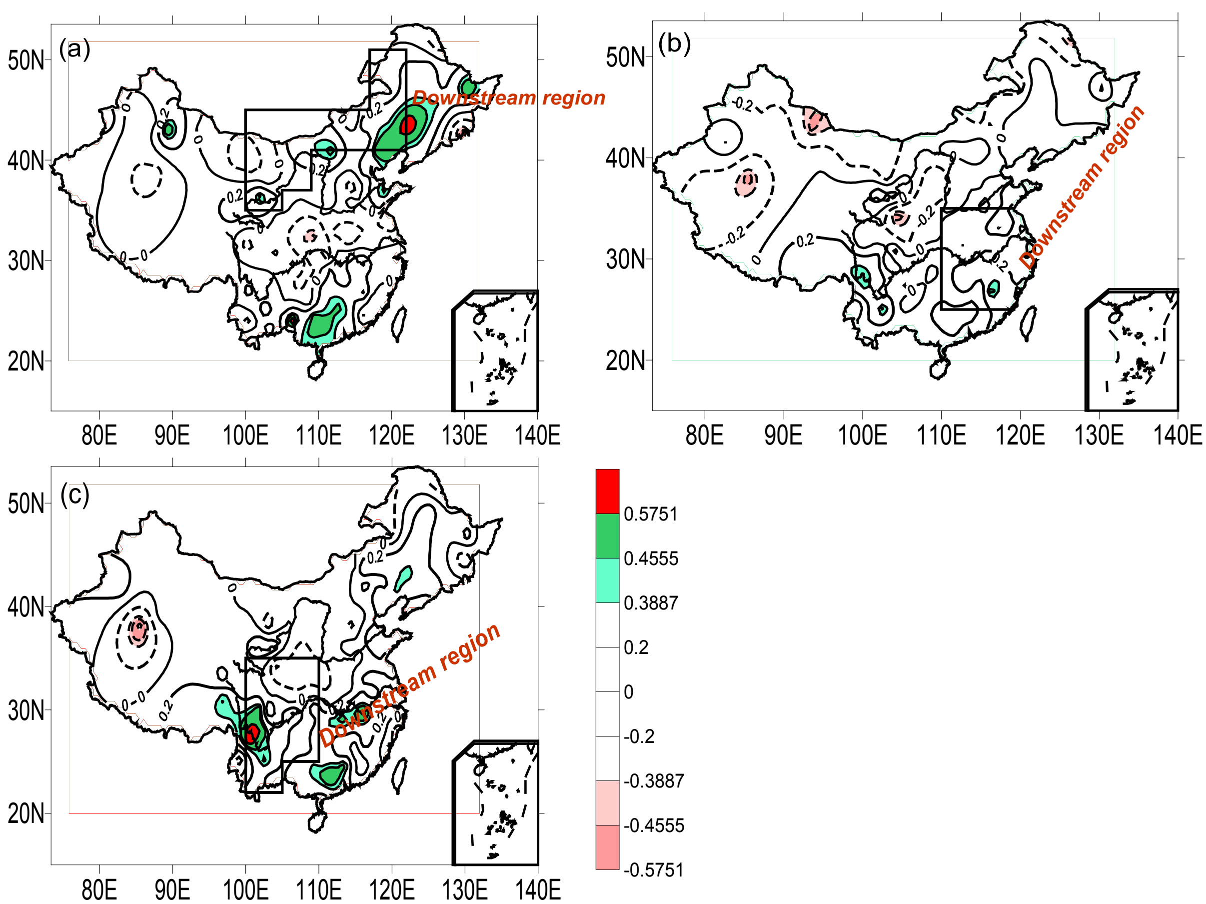

Fig. 3. The spatial patterns of the correlation coefficients between summer precipitation of 160 stations and spring NDVI averaged over (a) Region 2, (b) Region 5, and (c) Region 7.

are significant at the 90% confidence level is defined as a sensitive region of the impact of vegetation cover on precipitation, then there are three sensitive regions (eastern arid/semi-arid region (Region 2), Central China (Region 5), and Southwest China (Region 7) in China. This implies that the land cover change exerts a stronger influence on summer precipitation in the three regions. Fu and Ye (1998) pointed out there is a transitional zone of climate and ecosystem over the northern part of China (same as Region 2 in this study), and the transitional zone is a sensitive region. Zhang and Zhang (1984) showed that the deforestation played an important role in the decreased precipitation from the 1950s to 1980s over Xishuangbanna of Southwest China (Region 7). The evidence verifies the effects of vegetation change on climate in China, and is coincident with our results which suggest that the summer precipitation may be increased (decreased) about one to two seasons after a positive (negative) vegetation cover anomaly, which means an increased or decreased NDVI, in most of the eight climatic regions, especially in Regions 2, 5, and 7.

We note that the immediate and lagged correlations between NDVI and summer precipitation are all high over Region 2. Region 2 is a transitional climate zone between the humid monsoon region and the inland arid area; the transitional zone is sensitive to natural variations and anthropogenic changes based on analysis of satellite data and historical records. This is because the boundary regions of climate and ecosystems have strong gradients in climate and ecological variables and dynamic stability, and therefore are more sensitive in response to the natural and anthropogenic factors. Our study verifies further the sensitive feedback effect of vegetation cover on summer precipitation.

A most significant relationship between NDVI and precipitation occurs for the one-season lag. Figure 3 shows the spatial patterns of the correlation coefficients between spring NDVI in the three sensitive regions and summer precipitation of 160 stations in China. The correlations between spring NDVI over each sensitive region and summer precipitation of 160 stations are strongest over this region, with correlation coefficients of some stations significant at the 90%, 95%, and 99% confidence levels. China belongs to the monsoon region, and Fig. 3 also shows that vegetation changes over the sensitive regions such as the eastern arid/semi-arid region or Southwest China, strongly affect summer precipitation not only over the sensitive region itself but also over other regions, especially the downstream region along the monsoon flow.

4. Conclusion and summary

The feedback effects of vegetation cover on summer precipitation are complex, and sometimes uncertain. Using observed satellite data can shed light on the problem. We note the following.

(1) The correlations between NDVI and precipitation for the one-and two-season lags are positive in most regions of China, indicating that summer precipitation has a positive (negative) response to increased (decreased) vegetation cover changes in these regions. The lagged correlations present obvious regional differences, and the eastern arid/semi-arid region (Region 2), Central China (Region 5) and Southwest China (Region 7) are three sensitive regions of the feedback of vegetation on precipitation; this implies a more sensitive role of vegetation changes in summer precipitation in the three regions.

(2) Spatial analyses of correlations between NDVI over each sensitive region and precipitation of 160 stations suggest that the vegetation cover strongly affects summer precipitation not only over the sensitive region itself but also over other regions, especially the downstream region along the monsoon flow, and this is possibly related with the large-scale and meso-scale circulation.

Although the significant immediate and lagged correlations between NDVI and summer precipitation in the different regions of China are documented in this study, the dynamical mechanisms responsible for the feedback of vegetation cover changes need further research (Charney, 1975; Zeng et al., 1996; Feng et al., 2001; Feng et al., 2002).

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