The temporal and spatial patterns of terrestrial net primary productivity in China

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Abstract: In this paper, we use CEVSA, a process-based model, which has been validated on regional and global scales, to explore the temporal and spatial patterns of Net Primary Productivity (NPP) and its responses to interannual climate fluctuations in China's terrestrial ecosystems over the period 1981-1998. The estimated results suggest that, in this study period, the averaged annual total NPP is about 3.09 Gt C/yr and average NPP is about 342 g C/m². The results also showed that the precipitation was the key factor determining the spatial distribution and temporal trends of NPP. Temporally, the total NPP exhibited a slowly increasing trend. In some ENSO years (e.g. 1982, 1986, 1997) NPP decreased clearly compared to the previous year, but the relationship between ENSO and NPP is complex due to the integrated effects of monsoons and regional differentiation. Spatially, the relatively high NPP occurred at the middle high latitudes, the low latitudes and the lower appeared at the middle latitudes. On national scale, precipitation is the key control factor on NPP variations and there exists a weak correlation between NPP and temperature, but regional responses are greatly different.

Key words: China; terrestrial ecosystem; NPP; CEVSA; interannual variation; climate change
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1 Introduction

Net primary productivity (NPP), the key component of biogeochemical cycle in the terrestrial biosphere, is defined as the amount of dry matter produced by plants per unit of time and space. NPP reflects the capacity of plants to capture and use solar radiation and its dynamics variations control the spatio-temporal patterns of carbon sink and sources in terrestrial ecosystems. The spatio-temporal characteristics of NPP depend on the complex interactions among vegetation, soil, and climate and were intensively influenced by human activities and global environmental change (Schimel et al., 1995). Presently, the estimation of NPP dynamics on large scales (regional, national, and global) still remains large uncertainties and the underlying reasons has not been clearly elucidated. So the accurate estimation of NPP and exploration of its interrelationship with controlling factors are of great significance to enhance the understanding of spatio-temporal patterns of carbon sink and sources, reduce the uncertainties in the study of carbon cycle, and predict the future trajectory of climate change.

The patterns of NPP vary spatially with the regional environmental conditions, climatic factors, and vegetation types on spatial scales and spans from seasons, interannual to decadal levels on temporal scales. Traditionally, sample surveys and field measurements are applied to estimate NPP, but these methods are hard to extend to the estimations of NPP on large scales because of the sparse measurements network and the substantial expenditure. With the increasing accumulation of field data and improved understanding of ecosystems, modeling method has been a powerful tool in accurate estimation of NPP on large scales. Process-based ecosystem models describe mechanistic processes of ecosystem carbon cycle and their dynamic responses to changes in environmental conditions. Model simulation has been widely used in
quantification of spatio-temporal variations in ecosystem carbon fluxes and analyses of the underlying mechanisms on regional and global scales (Cao and Woodward, 1998a; Cao and Woodward, 1998b; Liu et al., 1999; Li and Ji, 2001). Modern ecosystem models are developed based on extensively tested algorithms, and have been used extensively in global change studies. As these models are driven with actual changes in environmental conditions and ecosystem pattern (such as vegetation distribution and composition), they could realistically capture the spatio-temporal patterns in terrestrial carbon fluxes and have been an essential tool to explore ecosystems to climate change and the interactions between vegetation and environmental factors.

In the last decade, many studies have been conducted to estimate the spatial patterns of China's terrestrial NPP and carbon storage in vegetation and soils (Zhu, 1993; Zhang, 1993; Zhou and Zhang, 1996; Sun and Zhu, 2001; Cheng, 2001; Liu, 2001). Moreover, few studies focus on the interannual variations of NPP and its responses to climate change. In this study, we use a biogeochemical model, CEVSA (Cao and Woodward, 1998a; 1998b), to quantify the dynamic responses of China's terrestrial NPP to climate change at 0.5° and a time step of month. The aim is to enhance the understanding of the spatio-temporal patterns of China's terrestrial NPP, its controlling factors, and the mechanisms of the responses to climate change.

2 Data and methodology

2.1 Model
CEVSA is a biogeochemical model to estimate carbon fluxes between vegetation, soils, and atmosphere, based on the process of photosynthesis, autotrophic respiration, litter production, and heterotrophic respiration (HR), which are controlled by the eco-physiological characteristics of biomes (e.g. photosynthetic pathway, leaf form, and phenology) and by environmental conditions (e.g. radiation, temperature, water, and nutrient). To couple these biological and environmental controls over ecosystem carbon fluxes, CEVSA (Cao and Woodward, 1998a; 1998b) includes three modules (Figure 1): the biophysical module calculates the transfer of radiation, water, and heat to determine canopy conductance, evapotranspiration and soil moisture; the plant growth module describes photosynthesis, autotrophic respiration, carbon allocation among plant organs, leaf area index (LAI) and litter production; the biogeochemical module simulates the transformation and decomposition of organic materials and nitrogen inputs

Figure 1 A schematic representation of CEVSA that was used in this study to estimate interannual variations in terrestrial ecosystem carbon fluxes and stocks