Chinese Science Bulletin 2003 Vol. 48 No.4 401—405

New evidence for effects of land cover in China on summer climate

ZHANG Jingyong, DONG Wenjie, YE Duzheng & FU Congbin
START Regional Center for Temperate East Asia, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China

Abstract **The effects of land cover in different regions of China on summer climate are studied by lagged correlation analysis using NOAA/AVHRR normalized difference vegetation index (NDVI) data for the period of 1981—1994 and temperature, precipitation data of 160 meteorological stations in China. The results show that the correlation coefficients between NDVI in previous season and summer precipitation are positive in most regions of China, and the lagged correlations show a significant difference between regions. The stronger correlations between NDVI in previous winter and precipitation in summer occur in Central China and the Tibetan Plateau, and the correlations between spring NDVI and summer precipitation in the eastern arid/semi-arid region and the Tibetan Plateau are more significant. Vegetation changes have more sensitive feedback effects on climate in the three regions (eastern arid/semi-arid region, Central China and Tibetan Plateau). The lagged correlations between NDVI and precipitation suggest that, on interannual time scales, land cover affects summer precipitation to a certain extent. The correlations between NDVI in previous season and summer temperature show more complex, and the lagged responses of temperature to vegetation are weaker compared with precipitation, and they are possibly related to the global warming which partly cover up the correlations.**

Keywords: NDVI, vegetation change, response of climate.

The effects of climate change on terrestrial ecosystem and its feedback are crucial in studies of global change, and one of research focuses is climate change related to land use/cover change. The feedbacks of vegetation to climate, at regional scales, are mostly investigated by observation, dynamical and theoretical analyses[1—3] and model studies to typical location or vegetation type (for example, studies of Amazon deforestation). The results of case studies cannot be extended to other regions, and even inconsistent conclusions are given in different case studies. The interactions between land and atmosphere in dynamical and theoretical analyses are simplified, so the regional differences of the responses of climate to vegetation are difficult to distinguish, but it is very important to discern and understand unambiguously them. At the same time, based on a series of land surface parameters which can be directly observed and basic physical concepts and theories, land surface process models such as BATS[4], SiB[5], LSM[6] including parameterization schemes of radiation, momentum, water and heat exchange on vegetation cover surface and water and heat processes in soil have been developed. These models can simulate energy, water and momentum flux in the soil-vegetation-atmosphere system, and one of hot research spots[7—12] is: land surface process model with good simulation capacity coupled with the general circulation model or the regional climate model is used to study the feedback effects of land cover on the climate system. But the physical processes of the current models are far from complete and the parameterization schemes of land surface models need to be further improved, especially the responses of climate to vegetation cannot be truly reproduced using these models because the relation between vegetation and atmosphere is not completely coupling and the interannual varieties of the responses of climate to land cover cannot be given in current models. Are observed data helpful for solving these problems? After the 1990s, the long-time and large-scale satellite data sets represented by pathfinder data sets developed by the earth observation system project in NASA and NOAA are integrated. Many researchers investigated the responses of vegetation to climate change utilizing remote sensing data[13—17], but they are rarely used to study the impact of vegetation cover on climate. These satellite data can be an attractive tool for studying the feedback effects of vegetation.

The feedbacks of vegetation change could accelerate or restrain climate change, and the study of the effects of land cover on the climate system will be helpful for understanding the mechanism of climate change and the summer climate prediction in China. The effects of vegetation on climate in different regions in China are systematically investigated by using NOAA/AVHRR NDVI data for the period of 1981—1994 and temperature, precipitation data of 160 stations from China Meteorological Administration in the report.

1 Data and method

The monthly NDVI data with 1° by 1° spatial resolution from the National Oceanographic and Atmospheric Administration/Advanced Very High Resolution Radiometer (NOAA/AVHRR), for the period from July 1981 to September 1994, are used in the study. The corrections of the NDVI data were performed using the Maximum Value Composite (MVC) method and so on in American Earth Resources Observation system. The NDVI is defined as

$$\mathrm{NDVI} = (\mathrm{Ch2}-\mathrm{Ch1})/(\mathrm{Ch2}+\mathrm{Ch1}),$$

where Ch1 and Ch2 represent the visible and near-infrared channel reflectances (0.58—0.68 μm and 0.725—1.10 μm), respectively. The NDVI is closely related to many parameters such as fraction of absorbed photosynthetically active radiation (FPAR), chlorophyll content, leaf area index (LAI), fractional vegetation cover and evapotranspiration rate[18—20].

Monthly mean temperature and monthly precipitation of 160 weather stations in China used are obtained from China Meteorological Administration, for the period of 1951—2000.

The study domain is divided into 8 climatic regions[21] in China: Northeast China, eastern arid/semi-arid region, western arid/semi-arid region, North China, Central China, South China, Southwest China and Tibetan Plateau (Fig. 1). Then, the correlation coefficients between monthly NDVI in previous winter (December, January and February) and in spring (March, April and May) and temperature, precipitation in summer (June, July and August) are calculated to investigate the lagged responses of climate to vegetation ecosystems.

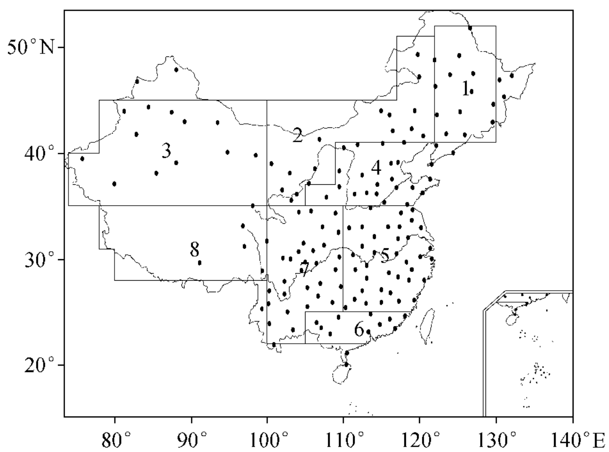

Fig. 1. Distribution of meteorological stations and classification of climatic regions. 1, Northeast China; 2, eastern arid/semi-arid region; 3, western arid/semi-arid region; 4, North China; 5, Central China; 6, South China; 7, Southwest China; 8, Tibetan Plateau.

2 Results

The correlation coefficients between NDVI in previous winter and rain in summer are displayed in Table 1, and are positive in most of eight regions in China (Fig. 2). The lagged correlations over Central China and the Tibetan Plateau are significant at 90% confidence level, and these imply that vegetation change in previous winter exerts stronger influence on summer precipitation in the two regions. But NDVI in previous winter and temperature have more complex correlations, with negative correlation coefficients in the western arid/semi-arid region, Tibetan Plateau and Central China and positive correlations in other five regions (Table 1).

The relations between spring NDVI and summer precipitation (Table 2, Fig. 3) are the same as between NDVI in previous winter and summer rain, with positive correlations in most climatic regions. Among the eight regions, the strongest correlation appears in the Tibetan Plateau (significant above 99% confidence level), and the correlation coefficient in eastern arid/semi-arid region is significant at 95% confidence level. These show the stronger responses of summer precipitation to spring NDVI occur in the two regions. The lagged correlation coefficients are a little weak over Southwest China, western arid/semi-arid region and Central China, and weaker over Northeast China, North China and South China. There are negative correlations between spring NDVI and summer temperature over western arid/semi-arid region and the Tibetan Plateau, and positive over other regions (Table 2).

Fig. 4 shows the relation between NDVI and climate. Obviously, the effects of NDVI in previous winter and spring on summer precipitation are positive, but the effects on summer temperature show relatively complicated, and there is a negative relationship between two parameters when NDVI is less than 0.15, and a positive relationship when NDVI is more than 0.15 on the whole.

All in all, the feedback effects of vegetation on climate are further proved by analyzing the lagged correlations between NDVI in previous season and summer climate. There are positive correlations between NDVI in previous season and summer precipitation in most regions in China, and these suggest that, the vegetation cover increases (NDVI in previous winter and spring becomes large), summer precipitation will increase. At the same time, the feedback effects have obvious regional character. The region in which the correlation coefficient between NDVI in previous season and precipitation is significant at 90% confidence level is defined as a sensitive region, and there are three sensitive regions (Tibetan Plateau, eastern arid/semi-arid region and Central China) of the impact of vegetation on climate especially precipitation in China. The strong correlation in the Tibetan Plateau is possibly related to the feedback mechanism of vegetation-snow-albedo because NDVI indirectly reflects the snow change in winter and spring to some extent. If the impact of snow is not considered, among the eight climatic regions in China, the most sensitive response of climate especially precipitation to vegetation change occurs in eastern arid/semi-arid region (northern part of China), and this implies that the destruction of vegetation cover in the region will lead to stronger response of climate. Fu et al.[22] stated that there is a transitional zone of climate and ecosystem over the northern part of China, and the climate could be more sensitive to vegetation changes here. The effects of vegetation on climate could be little over some regions. For example, the correlation coefficients between NDVI in previous winter and spring and summer precipitation are 0.066 and –0.040 in Northeast China, respectively. We also note that there is a complex relationship between NDVI in previous season and summer temperature possibly due to the impact of human activities.

Table 1 Correlation coefficients between NDVI in previous winter and summer precipitation, temperature

	NDVI in previous winter							
	Northeast China	Eastern arid/semi-arid region	Western arid/semi-arid region	North China	Central China	South China	Southwest China	Tibetan Plateau
Summer precipitation in corresponding region	0.066	0.308	0.0156	0.077	0.556[a)]	−0.087	0.337	0.568[a)]
Summer temperature in corresponding region	0.194	0.288	−0.359	0.388	−0.448	0.284	0.273	−0.242

a) Significant at 90% confidence level.

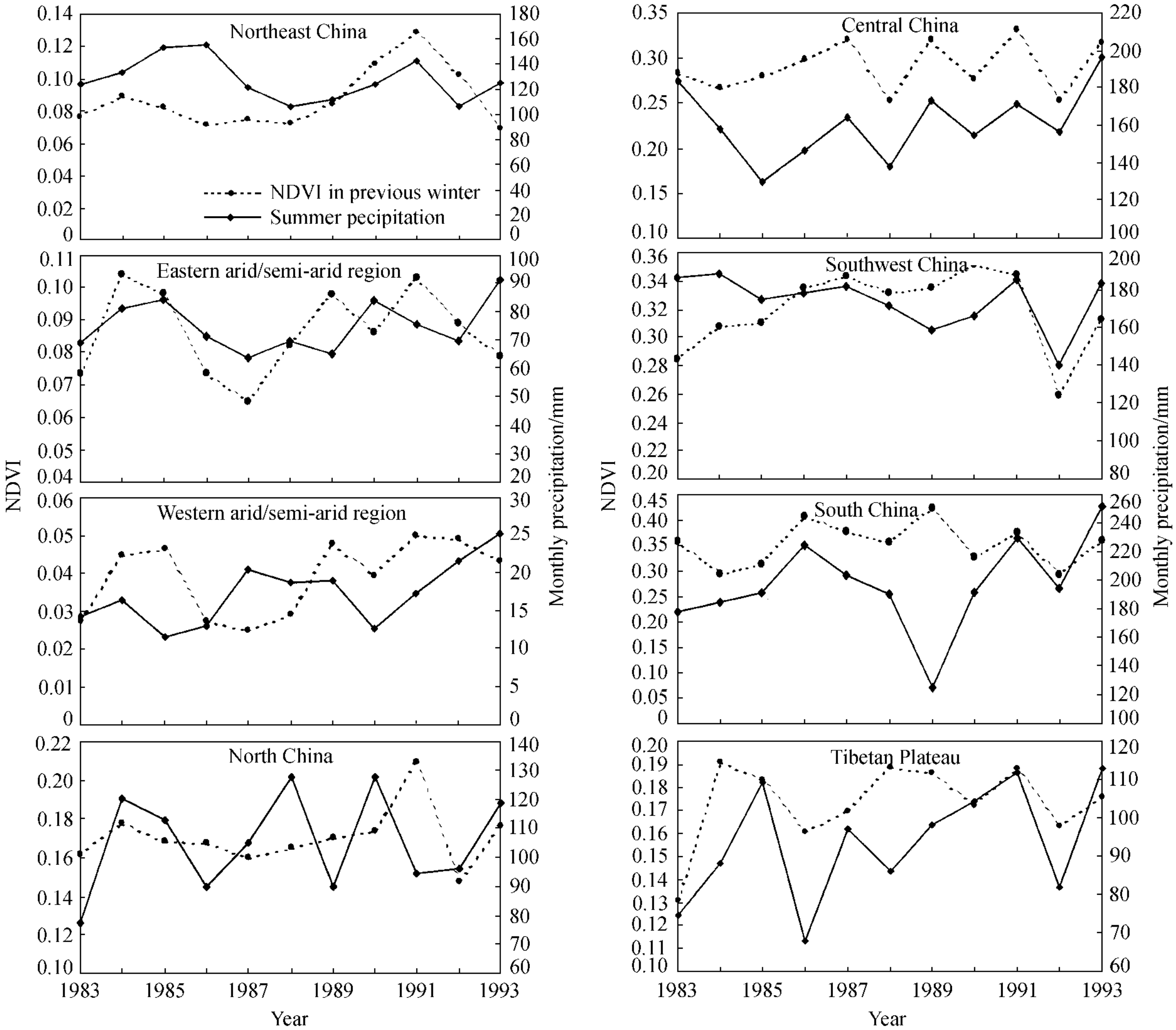

Fig. 2. Interannual variations in NDVI in previous winter and summer precipitation in eight climatic regions of China.

3 Discussion and conclusion

The responses of climate to vegetation cover in different regions of China are analyzed by using NOAA/AVHRR NDVI for the period of 1981—1994 and temperature, precipitation of 160 meteorological stations, and we verify that when NDVI in previous winter or spring increases, summer precipitation will increase in most regions, but summer temperature shows complex changes. At the same time, we note:

(1) The lagged correlations between NDVI and summer climate present obvious regional differences. The Tibetan Plateau, eastern arid/semi-arid region, Central China are three sensitive regions of the feedback effects of vegetation on climate especially precipitation, these suggest more sensitive roles of vegetation changes in summer

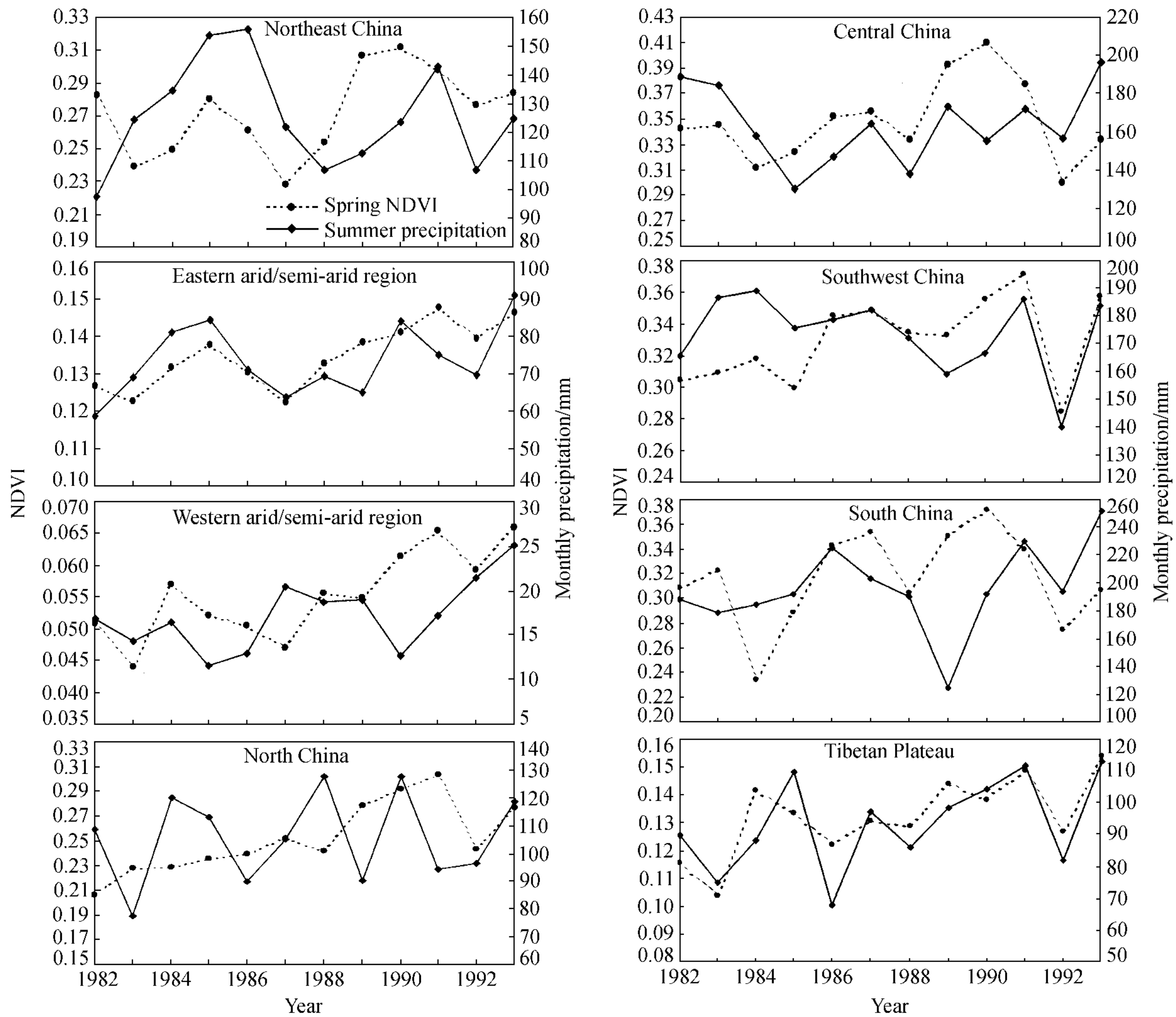

Fig. 3. Interannual variations in spring NDVI and summer precipitation in eight regions of China.

Table 2 Correlation coefficients between spring NDVI and summer precipitation, temperature

	Spring NDVI							
	Northeast China	Eastern arid/semi-arid region	Western arid/semi-arid region	North China	Central China	South China	Southwest China	Tibetan Plateau
Summer precipitation in corresponding region	– 0.040	$0.630^{a)}$	0.389	0.063	0.156	–0.014	0.474	$0.762^{b)}$
Summer temperature in corresponding region	0.176	0.198	–0.366	0.193	0.228	0.369	0.204	–0.237

a) Significant at 95% confidence level; b) at 99%.

climate in the three regions.

(2) The response of temperature to NDVI is weaker compared with precipitation, and this is possibly due to human activities such as the greenhouse gas emissions which cover up the correlations with temperature to some extent.

(3) The lagged response time of climate to vegetation cover could be 1—2 season(s).

The above results are very preliminary, and the more reliable results will be given using a longer NDVI time series in the near future. NDVI cannot completely represent vegetation changes though it is a very efficacious method today. Further works depend on profoundly understanding the impact of human activities on vegetation, climate and their relation. Based on removing human activities influence, the lagged correlations between the natural variations of vegetation and climate should be further studied.

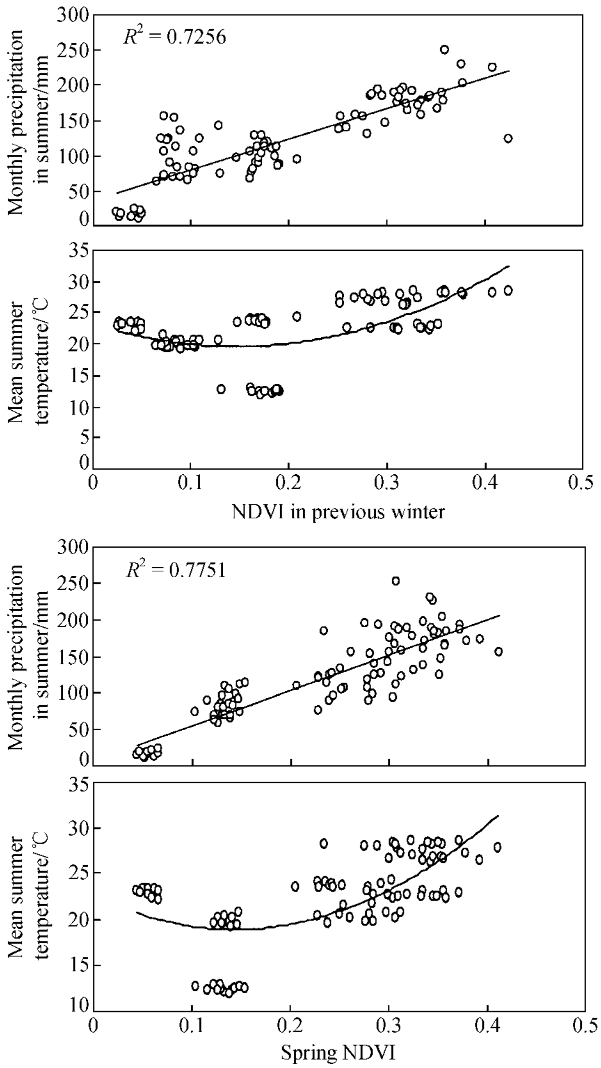

Fig. 4. The relation between NDVI and summer climate.

However, the above results offer new evidence for the effects of land cover in China on summer climate, and give regional differences of the impacts (the three sensitive regions for the impact of vegetation in previous season on climate especially precipitation are proved). Our results are helpful for how to improve vegetation conditions in China, how to orderly convert agricultural land for forest and pasture in light of local natural conditions and realize ecological and environmental benefits.

Acknowledgements This work was supported jointly by the National Key Basic Research Development Program (Grant No. G1999043408), the Key Innovation Project of the Chinese Academy of Sciences (CAS) (Grant No. ZKCX2-SW-210) and the Western Project of the CAS.

References

1. Charney, J, G., Dynamics of deserts and drought in the Sahel, Q. J. R. Meteorol. Soc., 1975, 101: 193—202.
2. Pan, X. L., Chao, J. P., The effects of climate on development of ecosystem in oasis, Advances in Atmospheric Sciences, 2001, 18(1): 42—52.
3. Zhou, G. S., Wang, Y. H., The feedback of land use/cover change on climate, Journal of Natural Resources (in Chinese), 1999, 14(4): 318—322.
4. Dickinson, R. E., Henderson-Sellers, A., kennedy, P. J. et al., Biosphere-atmosphere transfer scheme (BATS) for the NCAR CCM, National Center for Atmosphere Research, Boulder, Co, Tech Note/TN-275+STR, 1986, 66.
5. Seller, P. J., Mintz, Y., Sud, Y. C. et al., A simple biosphere model (SiB) for use within general circulation models, J. Atmos. Sci., 1986, 43(6): 505—531.
6. Bonan, G. B., Land-atmosphere CO_2 exchange simulated by a land surface process model coupled to an atmospheric general circulation model, J. Geophys. Res., 1995, 100: 2817—2831.
7. Lean, J., Rowntree, P. R., A GCM simulation of the impact of Amazonian deforestation on climate using an improved canopy representation, Q. J. R. Meteorol. Soc., 1993, 119: 509—530.
8. Lean, J., Warrilow, D. A., Simulation of the regional climatic impact of Amazon deforestation, Nature, 1989, 342: 411—413.
9. Zeng, N., Dickinson, R. E., Zeng, X. B., Climatic impact of Amazon deforestation—a mechanistic model study, J. Climate, 1996, 9: 859—883.
10. Wei, H. L., Fu, C. B., Study of the sensitivity of a regional model in response to land cover change over northern China, Hydrological Processes, 1998, 12: 2249—2265.
11. Zheng, X. Y., Eltahir, E., The response to deforestation and desertification in a model of West African monsoons, Geophys. Res. Letters, 1997, 24(2): 155—158.
12. Wang, S. W., Advance in Modern Climatological Studies (in Chinese), Beijing: Meteorological Press, 2001.
13. Braswell, B. H., Schimel, D. S., Linder, E. et al., The response of global terrestrial ecosystems to interannual temperature variability, Science, 1997, 278: 870—872.
14. Moulin, S., Kergoat, L., Viovy, N. et al., Global-scale assessment of vegetation phenology using NOAA/AVHRR satellite measurements, J. Climate, 1997, 10: 1154—1170.
15. Richard, Y., Poccard, I., A statistical study of NDVI sensitivity to seasonal and interannual rainfall variations in southern Africa, Int. J. Remote Sensing, 1998, 19(15): 2907—2920.
16. Fu, C. B., Wen, G., Variation of ecosystems over East Asia in association with seasonal interannual and decadal monsoon climate variability, Climatic Change, 1999, 43: 477—494.
17. Li, X. B., Wang, Y., Li, K. R., NDVI sensitivity to seasonal interannual rainfall variations in northern China, Acta Geographica Sinica (in Chinese), 2000, 55: 82—89.
18. Seller, P. J., Canopy reflectance photosynthesis and transpiration, Int. J. Remote Sensing, 1985, 6: 1335—1372.
19. Running, S. W., Nemanir, R., Relating seasonal patterns of the AVHRR vegetation index to simulated photosynthesis and transpiration of forests in different climates, Remote Sensing of Environment, 1988, 24: 347—367.
20. DeFries, R., Field, C. B., Fung, I. et al., Mapping the land surface for global atmosphere-biosphere models: Toward continuous distributions of vegetation's functional properties, J. Geophys. Res., 1995, 100: 20867—20882.
21. Zhang, J. C., Lin, Z. G., Chinese Climate (in Chinese), Shanghai: Shanghai Technology Press, 1985, 467—506.
22. Fu, C. B., Ye, D. Z., Towards predictive understanding of the environmental change in China on decadel to centennial scales, Global Environmental Research, 1998, 1(1&2): 83—93.

(Received September 13, 2002)