TIME LAG ANALYSIS BETWEEN VEGETATION AND CLIMATE CHANGE IN INNER MONGOLIA

Long Huiling, Li Xiaobing, Bao Yun, Huang Lingmei, Li Zhongfei*
(State Key Laboratory of Earth Surface Processes and Resource Ecology, College of Resources Science and Technology, Beijing Normal University, Beijing, China, 100875)
*Corresponding author. Tel.:+86 10 58808460; Fax: +86 10 58808460. E-mail address: xbli@ires.cn

1. INTRODUCTION

Relationship between vegetation and climate has been a hot spot in climate change researches since vegetation is a key component of land ecosystem and direct reflection of integrated effect among temperature, precipitation and solar radiation [1-3]. For the time being, the cause of vegetation change mainly focuses on climate change, CO_2 concentration, nitrogen deposition, land use and cover change caused by human activities and so on[2, 4-7]. The relation between vegetation growth and climate has been proved in both regional and global scales in earlier researches. However, there are controversies and conflicts about the effect of climate on vegetation change. The existing of time lag effects makes it more complicated to clearly understand the relation of them in different time scale, which is indispensable to reveal interaction mechanism between vegetation and climate. There is no doubt that time lag effect exists between vegetation and climate factors such as precipitation and temperature, but how long the effective time period is and whether it presents in different time scales are still unknown now.

2. DATA SOURCE

Data involved in this study includes remote sensing data and meteorology data. Twenty-five-year NOAA/AVHRR NDVI data from 1982 to 2006, originating from Global Inventory Modeling and Mapping Studies in NASA Goddard Space Flight Center, with a spatial resolution of 8km×8km and a temporal resolution of 15 days. This dataset applies a set of internationally well-known geometric, atmospheric and radiometric correction [8, 9]. In this study, we resample this data to a temporal resolution of one month using maximum composition. Besides, meteorological station data including precipitation and temperature in and outside the study area China Meteorological Administration are adopted to analyze climate status in the study period. All these data are spatialized using Kringing method to the same resolution as NDVI data.

3. METHODOLOGY

In this study, GIMMS NDVI data and meteorology data (precipitation and temperature) from 1982 to 2006 are used to do time lag analysis between NDVI and precipitation/temperature for different vegetation types in Inner Mongolia, in order to analyze the relation, time lag and accumulating effect between climate and vegetation in this area.

Based on an overview of periodic change in both vegetation and climate, time lag analysis is done in two perspectives. First, whole-time-series NDVI and precipitation/temperature time lag analysis were done in two spatial scales: pixel and vegetation type districts. The former aims to show spatial distribution characteristics and the other to present differences among different vegetation types. Second, inter-annual time lag and accumulation effects were studied in the growing season (from April to September) through time lag analysis of single month and correlation analysis in accumulated months respectively. And this was done according to different vegetation types.

4. RESULTS AND DISCUSSION

NDVI, precipitation and temperature represent periodic change from 1982 to 2006 in Inner Mongolia. Wave crest and trough of NDVI lag behind those of climate factors. Whole-time-series time lag analysis of NDVI and climate factors in pixel scale shows that precipitation and temperature affect most obviously in forest and meadow steppe, and influence decreases from northeast to west. Correlation of NDVI and precipitation presents similar spatial distribution to that of temperature. Comparing correlation coefficients in different time lags, because correlation coefficients declines obviously when time lag is three month for both precipitation and temperature, climate in current and previous two month affects vegetation growth more seriously. And the maximum effect period of precipitation and temperature is two month. Difference appears for different vegetation types. Maximum correlation coefficients appear when time lag is one month for northern warm-temperate deciduous forest, southern temperate forest-meadow steppe, temperate typical steppe, and temperate shrub-grass semi-desert and southern temperate. For other vegetation types, current month climate has more effects (Table 1).

<Table 1 near here>

Study of inter-annual time lag and accumulation effects in the growing season (from April to September) shows that vegetation growth in different month is affected by precipitation in different period and even in the same month vegetation growth is influenced by different period of climate for different vegetation types (Table 2). Take northern temperate typical steppe and the relation between NDVI and precipitation for example. From April to September, vegetation growth is affected mostly by the precipitation in April, the sum from February to May, June, July, August and August, respectively. In the same month in the growing season, in April previous one month precipitation advances vegetation growth; in steppe areas from May to July, accumulation of previous and current month precipitation seems to be more effective; and in August and September, the amount of precipitation in August plays an important role in the vegetation growth of the two month. While, temperature's influence concentrates in the starting period of the growing season, May and June.

<Table 2 near here>

Through the analysis above, we can clarify the influence of climate factors-precipitation and temperature- in different growing period. It will help understand the relationship between vegetation growth and climate. As well, it is meaningful to provide theoretical support to grassland management and degradation.

Key words: NDVI, vegetation type, temperature, precipitation, time lag effect

Table 1 Correlation between *NDVI* and precipitation/temperature in different vegetation types through whole-time-series time lag analysis

		Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅵ	Ⅶ	Ⅷ
lag=0	P	**0.7736****	0.7273**	0.7731**	**0.8068****	0.8171**	0.4497**	0.7580**	**-0.4361****
	T	**0.9084****	0.8327**	0.8588**	**0.9003****	0.8581**	0.4129**	0.7732**	**-0.5451****
lag=1	P	0.6437**	**0.7804****	**0.7824****	0.7430**	**0.8390****	**0.6709****	**0.7896****	-0.2812**
	T	0.8455**	**0.8622****	**0.8726****	0.8792**	**0.8896****	**0.5407****	**0.8348****	-0.4914**
lag=2	P	0.2937**	0.5290**	0.4911**	0.4060**	0.5344**	0.5565**	0.5196**	-0.0911
	T	0.5708**	0.6800**	0.6702**	0.6372**	0.6976**	0.5251**	0.6862**	-0.3352**
lag=3	P	-0.0995	0.1085	0.0654	-0.0273	0.0822	0.2805	0.1088	0.0957
	T	0.1359*	0.3323**	0.3036**	0.2279**	0.3316**	0.3742**	0.3634**	-0.0961
lag=4	P	-0.3847**	-0.2670**	-0.2929**	-0.3592**	-0.2967**	0.0037	-0.2112**	0.2922**
	T	-0.3462**	-0.1099	-0.1504**	-0.2481**	-0.1242*	0.1379*	-0.0590	0.1628**
lag=5	P	-0.5527**	-0.4897**	-0.5107**	-0.5487**	-0.5333**	-0.2009**	-0.4245**	0.3659**
	T	-0.7420**	-0.5390**	-0.5760**	-0.6699**	-0.5591**	-0.1381*	-0.4761**	0.3848**

While, P and T represent precipitation and temperature respectively; *, ** are used to show the correlation coefficients which are significant in 0.05 and 0.01 levels separately. Coefficient in bold is the maximum one for every vegetation type. Ⅰ, Ⅱ….. Ⅷ represent vegetation types in the study area and are expressed as follows. Ⅰ: South Cold-temperate deciduous Needle Leaf Forest; Ⅱ: Northern Warm-temperate Deciduous Forest; Ⅲ: Southern Temperate Forest-meadow Steppe; Ⅳ: Northern Temperate Meadow Steppe; Ⅴ: Temperate Typical Steppe (Ⅴ1: Northern Temperate Typical Steppe; Ⅴ2: Southern Temperate Typical Steppe); Ⅵ: Temperate Shrub-grass Semi-desert; Ⅶ: Southern Temperate Desert Steppe; Ⅷ: Temperate Shrub-semi-shrub Desert.

Table 2 Maximum inter-annual correlation coefficients between NDVI and precipitation in different months of growing season and responding duration

		Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ1	Ⅴ2	Ⅵ	Ⅶ	Ⅷ
April	P	p3	p3	p4	p1	p4	p3	p3	p1	p1
	R	-0.5361**	0.3389	0.3094	0.3023	0.1649	0.3556	0.2615	-0.5357**	-0.4629*
May	P	p3	p5+p4+p3+p2	p5	p3	p5+p4+p3+p2	p4	p5+p4+p3+p2	p5+p4+p3+p2	p4
	R	-0.3434	0.0626	0.4407*	-0.3553	0.1444	0.4451	0.3832	0.2502	-0.2090
June	P	p6+p5+p4+p3	p6	p5+p4+p3	p6+p5	p6	p5+p4+p3	p5+p4+p3	p5+p4+p3	p5
	R	0.4357*	0.3766	0.4147*	0.5845**	0.2540	0.6513	0.5536**	0.5945**	0.4831*
July	P	p6+p5+p4	p6	p5	p6+p5+p4	p7	p6+p5+p4	p4	p5	p7
	R	0.3316	0.3261	0.2173	0.4578*	0.3203	0.5516	0.4361*	0.6107**	-0.2061
August	P	p5	p8	p8	p8	p8	p7	p7	p7	p6
	R	0.3848	-0.3816	-0.2893	-0.3218	-0.2103	0.2915	0.4507*	0.4430*	0.4461*
September	P	p7	p8+p7	p6	p7	p8	p8+p7	p8+p7	p8+p7	p8+p7+p6
	R	-0.5262**	-0.3135	-0.3681	-0.4404*	0.2276	0.4243	0.4051*	0.5538**	0.5090**

While, P and R represent precipitation and correlation coefficient respectively; p1, p2……p9 are precipitation in January, February……, September; p5+p4+p3+p2 is the sum of precipitation from February to May; *, ** are used to show the correlation coefficients which are significant in 0.05 and 0.01 levels separately; Ⅰ, Ⅱ….. Ⅷ represent vegetation types in the study area and are expressed in Table 1.

5. REFERENCE

[1] Sarkar S, Kafatos M. Interannual variability of vegetation over the Indian sub-continent and its relation to the different meteorological parameters. *Remote Sensing of Environment*, 2004, 90: 268-280.

[2] Mohamed MAA, Babiker IS, Chen ZM et al. The role of climate variability in the inter-annual variation of terrestrial net primary production (NPP). *Science of the Total Environment*, 2004, 332: 123-137.

[3] Pettorelli N, Vik JO, Mysterud A, Gaillard JM, Tucker CJ, Stenseth NC. Using the satellite-derived NDVI to assess ecological responses to environmental change. *Trends in Ecology and Evolution*, 2005, 20: 503-510.

[4] Sala O E, Chapin F S, Armesto J J, Berlow E et al. Global biodiversity scenarios for the year 2100. *Science*, 2000, 287(5459): 1771-1774.

[5] Knapp A K, Smith M D. Variation among biomes in temporal dynamics of aboveground primary production. *Science*, 2001: 291: 481-484.

[6] Nemani R R, Keeling C D, Hashimoto H, Jolly W M. Climate-Driven Increases in Global Terrestrial Net Primary Production from 1982 to 1999. *Science*, 2003, 300: 1560-1563.

[7] Gao Q Z, Wan Y F, Li Y E, Sheng W P, Jiangcun W Z, Wang B S, Li W F. Trends of grassland NPP and its response to human activity in Northern Tibet. *Acta Ecologica Sinica*, 2007, 27(11): 4612-4620

[8] Pinzon J, Brown M E and Tucker C J. Satellite time series correction of orbital drift artifacts using empirical mode decomposition. In: N. Huang (Editor), Hibert-Huang Transform: *Introduction and Applications*, 2005, p167-186.

[9] Tucker CJ, Pinzon JE, Brown ME et al. An Extended AVHRR 8-km NDVI Data Set Compatible with MODIS and SPOT Vegetation NDVI Data. *International Journal of Remote Sensing*, 2005, 26(20): 4485-4498.