Terrestrial Vegetation Change Based on NDVI Time-trajectories Data in China, 1981-1999

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Abstract-**In this paper, Change vector analysis and principal components analysis in NDVI time trajectories space are powerful tools to analyse the land-cover change. The length of the change vector indicates the magnitude of the change, while its direction indicates the nature of the change . This change detection method is applied to two remotely-sensed indicators of land-surface conditions, NDVI and spatial structure, in order to improve the capability to detect and categorize land-cover change. The magnitude and type of changes and the changes in spatial structure indicator are calculated by those methods in china from 1983 to 1992.**

I. Introduction

The land surface has considerable control on the planet's energy balance, biogeochemical cycles, and hydrologic cycle, which in turn significantly influences the climate system. Therefore, the global environmental change community has attached more attention on the land cover change. Many researchers have focused on the land cover classification and change by using remotely sensed data.

Studies show that Normalized Difference Vegetation Index (NDVI), derived form the near infrared band and red band, is sensitive to the growth conditions of vegetation (such as green biomass, LAI, vegetation coverage, etc.).

II. Methodology

Change vector analysis is based on multi-band image of high Spatial Resolution[1]. We redefine a temporal vector space in order to analyze the time serial data of high temporal resolution NDVI. If we assume a monthly rate, 12 successive NDVI images will be available in a year. The value taken by the indicator under consideration can be represented by a point in the 12 dimensional temporal space and is defined by a vector. Therefore, the time serial data of NDVI in a year, for each pixel, is can be written as a 12 dimensional temporal vector:

$$P(i,x) = \begin{bmatrix} x(t_1) \\ x(t_2) \\ \cdots \\ x(t_{12}) \end{bmatrix} \qquad (1)$$

where p(i,x)is the multi-temporal vector for the pixel i in the year x, x(t) are the values of the indicator under consideration for pixel i from January to December. The magnitude of this vector, $\|P\|$, measures the accumulated value of NDVI through a year.

Based on the definition of temporal vector, it is observed that any NDVI change between two years can be described by a change vector in12-dimensional space as the following equation:

$$\Delta P(i) = P(i,y) - P(i,x) = \begin{pmatrix} y_1 - x_1 \\ y_2 - x_2 \\ \vdots \\ y_{12} - x_{12} \end{pmatrix} \qquad (2)$$

where $\Delta P(i)$, the change vector for pixel i from year x to y, contains all of changes of pixel i in every temporal-dimension. The magnitude of the change vector, $\|\Delta P\|$, calculated by the Euclidean distance between the two vector, measures the intensity of the change in NDVI[2].

$$\|\Delta P\| = \sqrt{(y_1 - x_1)^2 + (y_2 - x_2)^2 + \cdots + (y_{12} - x_{12})^2} \qquad (3)$$

The direction of $\Delta P(i)$, defined by a serial of angles, indicates the nature change processes of NDVI value in pixel i. When $\Delta P(i)$ value is over some threshold value, land cover will often correspond to be transformed from one type to another.

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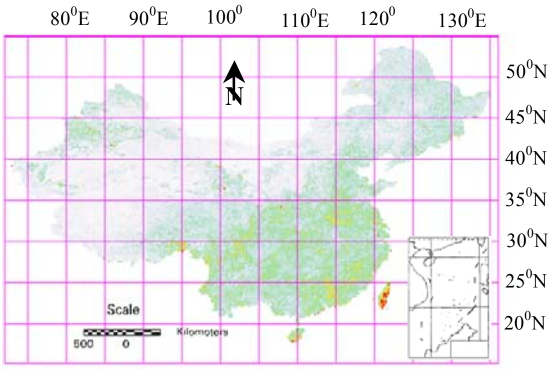

Fig.1. Density slicing of the change vector magnitude image for the NDVI (Red: high change intensities; Yellow: medium change intensities; Green: low change intensities; Offwhite: no change)

III. RESULTS AND DISCUSSIONS

A. Processes of NDVI change

Used in this study are monthly NOAA/AVHRR NDVI data spanning a 120-months period (Jan.1981–Dec.1999), provided by USGS EROS Data Center.

For every pixel, the temporal vector of NDVI in 1981 was subtracted by vector in 1999, yielding a change vector of NDVI between two years. Change vector magnitude Image for NDVI was created based on equation (3), and change vector magnitude was employed under the guidance of the technique of image segmentation to derive the NDVI change intensity map (Figure 1).

Density slicing of the change vector magnitude image provides a cartographic representation of intensity of land cover change:

1)The red stands for areas with high interannual variations. They are located in Taiwan and Hainan province with small areas. It can reflect change magnitude of NDVI in tropic monsoon region.

2)The yellow corresponds to medium change regions, located in the Pearl River Delta, Sichuan Basin and Huang-huai-hai Plain. It reflects the difference results of the vegetation variance of NDVI in farming areas and its interannual vegetation growth processes.

3)The cyan areas correspond to low change intensity of NDVI with large areas, located in south Yangtse River and Northeast China, etc.

4)The offwhite correspond to no change, located in Northwest China (excluding the northern Xinjiang). It indicates little change of the vegetation cover in decades.

B. Tendencies for NDVI Change

The change vector magnitude image for NDVI shows the change degree of land cover. The change types, however, can not be characterized because we can not find the change tends (increase, decrease or stability) from change vector magnitude image only.

Tendencies for NDVI Change are defined by the combination of the change vector magnitude for NDVI and variance of annual accumulated NDVI values, V_{NDVI} :

$$V_{NDVI} = \frac{(\sum_{i=1}^{12} y(t_i) - \sum_{i=1}^{12} x(t_i))}{\sum_{i=1}^{12} x(t_i)} \times 100\% \qquad (4)$$

The change magnitude threshold between change and no change pixels, M, is taken as the break point between low change intensity and medium change intensity (in this paper, M is taken as 21).

When a pixel yields $\|\Delta P\| \leq M$, the tendency for NDVI change is defined as stability. If a pixel yields $\|\Delta P\| > M$, the tendency for NDVI change depends on V_{NDVI} value:

$$\begin{cases} \|\Delta P\| \leq M & \text{Stability} \\ \|\Delta P\| > M, V_{NDVI} > 10\% & \text{Increase} \\ \|\Delta P\| > M, V_{NDVI} < -10\% & \text{Decrease} \\ \|\Delta P\| > M, -10\% < V_{NDVI} < 10\% & \text{Fluctuation} \end{cases} \qquad (5)$$

The image for tendencies of NDVI change has been produced (figure 2) based on equation (5). The figure shows the characteristics of NDVI change from 1981 to 1999:

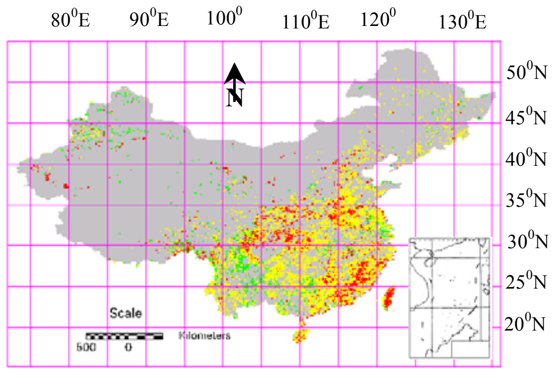

Fig.2. Types of the change vector image for the NDVI (Red: increase; Yellow: Fluctuation; Green: Decrease; Offwhite: Stability)

1)The change mainly lies in the Southeast China, Northeast China and local area in Xinjiang province.

2)The whole change tendency of NDVI is stable with smooth increasing. Increases correspond to areas mainly located in Taiwan, Fujian, Henan and Sichuan provinces, and decrements correspond to areas located in the Yunnan and Xinjiang provinces.

3)During the decade, The areas with stable NDVI, account for 79.38% and fluctuation type accounts for 14.8%. The increase type and decrease type account for 3.49% and 2.32% respectively.

C. Principle Component Analysis on NDVI change vector

The main features for NDVI change can be assessed using principal component analysis (PCA)[3,4] on the NDVI change vector data from 1981 to 1999. The results are shown in figure 3.

The loading factors of PC1 for monthly NDVI change vector are positive in every month. The loading factors of April and September play the key role, corresponding to the return green period and wither period, indicating the biomass change between 1981 and 1999 is great. PC2 indicates the speeds of monthly NDVI change, figure 3 shows the increasing tendency of change speed from January to April, decreasing from June to September, and stable in others. PC3 mainly correlate to the situation of September, reflecting the different speeds of decay between 1981 and 1999. PC4 has a correlation with the loading factor of May, reflecting the different speeds of growth during the growth period.

IV. Conclusions

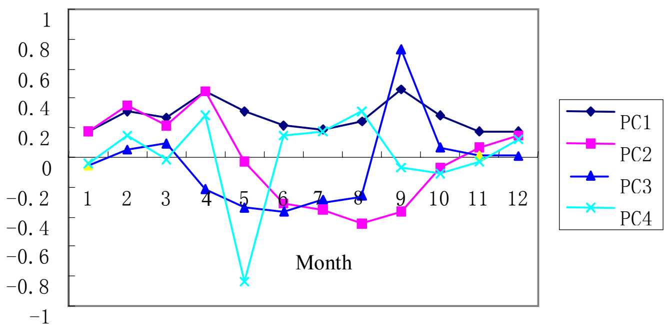

Fig. 3. Loading factors of PCA

The magnitude and type of changes in NDVI is calculated by CVA analysis in China from 1981 to 1999. Through the research, the main conclusion are drawn as follows:

1)The change vector magnitude of NDVI is apparently different between eastern and western China. Great changes of NDVI lie to the southeastern coast of China, Taiwan and Sichuan, Yunnan province (monsoon area of southeastern and southwestern China). There are few changes in Northwest China and the Qinghai-Tibet Plateau. It can be concluded that the monsoon climate and the human activity have great impacts on the land cover dynamic of eastern China (especially the different kinds of crops).

2)Land cover changes are derived by many factors (climate, hydrology, landform, soil, land use etc.). The general tendency of the climate in North China is temperature rising and precipitation decreasing(drying). No obvious changes, however, are presented in large-scale in this region. Landform types and vegetation types in North China are the key factors for NDVI changes.

Acknowledgment

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References

[1] E. F. Lambin, A.H. Strahler, "Indicators of land-cover change for change-vector analysis in multitemporal space at coarse spatial scales," *International Journal of Remote Sensing*, vol. 15, pp. 2099-2119, 1994.

[2] J. R. Jensen, "Introductory Digital Image Processing, A Remote Sensing Perspective," Prentice Hall, Upper Saddle River, New Jersey, 1996.

[3] X. LI , A.G.O.YEH, "Principal component analysis of stacked multi-temporal images for the monitoring of rapid urban expansion in the Pearl River Delta," *International Journal of Remote Sensing*, vol. 19, pp.1501-1518,1998.

[4] G. F. Byrne, "Crapper P F and Mayo K K. Monotoring Land-cover by principal component analysis of multitemporal Landsat data," *Remote Sensing of Environment*, vol. 10, pp.175-184, 1980.