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Relationship between land cover and monsoon interannual variations in east Asia

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Asian monsoon have multiple forms of variations such as seasonal variation, intra-seasonal variation, interannual variation, etc. The interannual variations have not only yearly variations but also variations among several years. In general, the yearly variations are described with winter temperature and summer precipitation, and the variations among several years are reflected by circulation of ENSO events. In this study, at first, we analyze the relationship between land cover and interannual monsoon variations represented by precipitation changes using Singular Value Decomposition method based on the time series precipitation data and 8km NOAA AVHRR NDVI data covering 1982 to 1993 in east Asia. Furthermore, after confirmation and reclassification of ENSO events which are recognized as the strong signal of several year monsoon variation, using the same time series NDVI data during 1982 to 1993 in east Asia, we make a Principle Component Analysis and analyzed the correlation of the 7th component eigenvectors and Southern Oscillation Index (SOI) that indicates the characteristic of ENSO events, and summed up the temporal-spatial distribution features of east Asian land cover´s inter-annual variations that are being driven by changes of ENSO events.

Relationship between land cover and monsoon interannual variations in east Asia XIANG Bao, LIU Ji-yuan (Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing 100101, China) 1 Introduction In recent years, with the degeneration of environment, close attention has been paid to the mechanism of land cover changes (Li, 1996), for which the global climate change plays a very important role, and the vegetation variances can represent the climate change to some extent (Chen et al., 1996; Li, 1996; Wu, 1996). Because vegetation is the natural "tie" linking the elements of soil, atmosphere and water, etc., and the dynamic change of vegetation can represent the dynamic change of land cover to a certain extent (Chen et al., 1998). It is known that the vegetation dynamic monitoring began with remote sensing, and the vegetation indexes calculated from remote sensing data are indirect indicators of vegetation growth, cover, biomass and species, etc. There are many kinds of vegetation indexes according to the remote sensing platforms and sensors. Among them the Normalized Difference Vegetation Index (NDVI) is found to provide a strong vegetation signal. Therefore, in recent years, considerable attention has been focused on the NDVI products that can be produced from the AVHRR sensor of the NOAA series satellites (Justice, 1985). For example, acting as an important remote sensing parameter of vegetation, NDVI has been used extensively in the fields of global change and land use/land cover change (Eric et al. 1997; Gong et al., 1996; Tucker et al., 1985). Asian monsoon climate has multiple forms of variations such as seasonal variation, intra-seasonal variation and interannual variation, and the interannual variations have both yearly variations and variations among several years. In general, the yearly variations are described with winter temperature and summer precipitation, and the variations among several years are reflected by circulation of ENSO events. Because ENSO events are not only the strong signal of monsoon climate´s several years changes, but also the important driving force of land cover dynamic changes. ENSO events have influence of global scale, and the abnormities of climate elements such as precipitation and temperature of many places are closely related to the ENSO events (Wang et al., 1999a). ENSO events directly influence the vegetation and indirectly influence the land cover dynamics through effecting the key elements of climate such as temperature and precipitation (Kogan, 1998). So far studies of the relationship between land cover and monsoon climate changes in east Asia represented by precipitation variance and ENSO circulation are not available, this kind of research is of great importance to the global change study. In this study, we try to investigate the relationship of land cover and interannual climate change in east Asia using time series 8 km NOAA AVHRR NDVI images, precipitation data and Southern Oscillation Index data. 2 Data source and its processing 2.1 Precipitation data and its processing The basic data sets used in this research are taken from "global long time series weather station´s report data sets for monthly precipitation and monthly mean temperature" complied by Institute of Atmospheric Physics, Chinese Academy of Sciences. At first, by means of data-base management software, we selected the precipitation data from global data sets covering 1982 to 1993 within the spatial scope of 60(E-150(E longitude and 65(N-18(N latitude. Then we used GIS technology to generate the weather stations cover in light of their longitude and latitude, and jointed the precipitation data and attribute data of weather station cover in terms of the weather station sequences. We also used the Inverse Distance Weighted（IDW）interpolation method to interpolate the monthly precipitation data from 1982 to 1993 into grid imageries and calculated the monthly average precipitation in May-September of each year during 1982-1993. In the process of data treatment, the following points are taken into account: 1) east Asian vegetation in summer (May-September) is sensitive to the monsoon climate characterized by synchronous existence of rainy season and thermal climate; and 2) the annual average precipitation during May-September can partially eliminate the seasonal variance of precipitation, so it can soundly reflect the interannual changes of monsoon climate. 2.2 NDVI data and its processing The NDVI data used in this study is provided by the USGS EROS data center for the years 1981-1994. This data set has an 8-km spatial resolution and a 10-day temporal resolution with a spatial scope of 25.6(E-143.7(E and 4.5(S-79(N. In order to match the precipitation data, only the data covering 1982 to 1993 have been used. In addition, supported by GIS technology, the monthly May-September averaged NDVI imageries of each year have been calculated. May-September of each year is regarded as the main factors to be considered: 1) the east Asian summer seasonal vegetation is highly sensitive to the monsoon climate characterized by synchronous existence of rainy season and thermal climate; and 2) monthly average NDVI during May-September of each year can partially eliminate the seasonal changes of vegetation, thus it can fully reflect the interannual variance of vegetation. 2.3 Southern Oscillation Index ENSO is the abbreviation of El Nino and Southern Oscillation. El Nino usually indicates the phenomena of large-scale temperature anomaly increase in the eastern part of the equatorial Pacific Ocean. Southern Oscillation means the air pressure oscillation between the Indian Ocean and southeast tropical Pacific Ocean. In order to show the intensity of Southern Oscillation, many researchers have designed various kinds of indexes, among them a commonly used index named Southern Oscillation Index (SOI), which is the slippage averaged difference of sea level atmospheric pressure between Tahiti Island and Darwin harbor. Before the 1960s, El Nino and Southern Oscillation were studied separately. With the increase of observing materials and in-depth research, people have gradually found out the relationship of these two phenomena since the 1960s. Because the relationship of El Nino and Southern Oscillation has been recognized more and more clearly, the new terminology, called El Nino/Southern Oscillation (ENSO), has been proposed. Usually, because of the interaction of ocean and atmosphere, the El Nino events occur in the negative position of Southern Oscillation, while Southern Oscillation in its positive position, the equatorial Pacific Ocean has a drop in temperature on a large scale. The SOI used in this study can be seen in Table 1. Table 1 The Southern Oscillation Indexes of May-September during 1982-1993 3 Relationship between land cover and interannual variation of precipitation in east Asia 3.1 Singular Value Decomposition (SVD) method In meteorological research, the relationship of deferent elements field is frequently discussed. Especially in the climate change aspect, identification of two deferent fields modality and relationship seems to be very important. We named this kind of important modality as "coupling modality", and there are many kinds of methods to separate the modality of deferent fields. Bretherton´s study has shown that the Singular Value Decomposition (SVD) method is the most compendious one among them (Bretherton et al, 1992). The main connotation of this method is that every SVD modality is described as a couple of spatial mode, in which each mode represents the correlation between one field´s lattice point value and another field´s expansion coefficient. We call this spatial mode as heterogeneous correlation map, and use two parameters such as Explanation Covariance Square Fraction (SCF) and Related Coefficient (R) to measure the coupling intensity reflected by each SVD modality. 3.2 Analysis of the results In this study, we regard the precipitation and land cover as two kinds of spatial fields, and analyze the relationship between land cover and interannual changes of monsoon climate using SVD method based on the spatial-temporal matched NDVI 8km data and precipitation data from 1982 to 1993 in east Asia. The separated coupling modality and the heterogeneous correlation map of the first SVD mode in east Asia during 1982 to 1993 can be seen from Figure 1. Figure 1 shows the dominant modality between land cover filed and precipitation field separated with SVD method, we can see the first couple of heterogeneous vector interprets 86.4(of population variance, and the correlation coefficient between land cover field and time coefficient of precipitation field reaches 91.3(. From the size of the two kinds of indicators, we conclude that the relationship between land cover and precipitation in east Asia is very high. Further analysis of Figure 1a and 1b, we also find that three parts can be manifestly d ifferentiated from the spatial distribution of correlation coefficients of land cover and precipitation, i.e., east Asian monsoon area, central Asian arid area and north Asian area. Furthermore, we find that because the interannual changes of precipitation in the northern and eastern parts of Asia are higher than those of the central part of Asia, the correlation coefficient of these areas has the same distribution model. Figure 1 Heterogeneous correlation map of first SVD mode in east Asia (1982-1989), a. precipitation field; b. land cover field 4 Relationship between land cover and ENSO events in east Asia 4.1 Reclassification of ENSO events With deepening of observations and investigations, the identification criteria of ENSO events have been developed constantly. In its early stage, Southern Oscillation Index was commonly used. Subsequently, the sea surface temperature of east equatorial Pacific Ocean became main criteria, and recently a trend of using many kinds of indexes to confirm ENSO events occurred. Different criteria identify different ENSO events, which are mainly shown by the starting time, ending time, lasting time and intensity. Using 4 kinds of arrays (Nino 3 SST arrays, Nino C SST arrays, and two kinds of SOI arrays) data of SST and SOI, Wang Shaowu (Wang et al., 1999b) established a synthetical index of ENSO confirming, and based on this index the ENSO events during 1867-1998 are confirmed. Table 2 is the segment of 1982-1993. ENSO is a circulation with certain "life period", which consists of formation, development and decline process, and in each developing stage its effect on climate is different. According to its developing phases, the ENSO circulation is generally divided into brewing stage, developing stage and declining stage. Regarding this principle as a basic reliance and based on the analysis of Table 2 in detail, we reclassified different ENSO events from the 1980s to the early 1990s. Among them, ENSO developing years include 1982, 1986 and 1991, and decline ENSO years include 1983,1987 and 1992. Table 2 ENSO events during 1982-1993 Figure 2 Image of component 7 of PCA analysis on land cover time series data 4.2 Principal Components Analysis Principal Components Analysis is used as the way of linear transformation to derive the Principal Components, which has the larger variance orderly, so that the substantial portion of the original information is concentrated in the first four or five new principal components. However, this does not rule out the importance of lower order components since they may contain localized information (Anyamba et al., 1996). Therefore this technique is very useful for analyzing spatial time series data. A Anyamba´s study, using Principal Components Analysis method based on the NDVI time series data, has shown that the higher order components from the first to the eighth have different meanings of its own (Townshend, 1984). That is, component 1 represents the characteristic of NDVI over the entire period, components 2-4 represent seasonal trends, components 5 and 6 illustrate the effects related to orbital changes in the satellite platforms and components 7 and 8 represent the interannual changes of NDVI related to climate change. In this study, we analyze the time series averaged NDVI imageries using Principal Components Analysis. Figure 2 shows the image of the 7th component. 4.3 Interpretation of the results As a result of Principal Component Analysis, Figure 2 shows a kind of residual´s spatial distribution pattern, which indicates the interannual changes of land cover in east Asia during 1982-1993. Strong residuals, in other words, the higher land cover indexes, are seen to occur in the northern part of east Asia, Northeast China, Qinling Mountains, Southwest China, southeastern coastal zone of China, Japanese archipelago, and Indo-China Peninsula. What kind of ENSO year counterpart the spatial distribution of land cover mentioned above? In order to explore the corresponding correlation between spatial distribution of land cover and ENSO events, we illustrate (Figure 2) the relationship of spatial distribution of interannual changes of land cover indicated by the eigenvectors of component 7 and ENSO events, which are represented by the Southern Oscillation Indexes (Figure 3). A comparison of component 7 eigenvectors and SOI explains the land cover indexes (which are represented by eigenvectors of component 7) corresponding to the increasing trend of the ENSO events of 1982 and 1991 while the land cover indexes corresponding to the ENSO events of 1983, 1987 and 1992. Furthermore, we analyze Figures 1 and 2 synthetically, and draw a conclusion that the land cover indexes in developing period of the ENSO events are not only higher than that in declining period of the ENSO events, but also the higher indexes of land cover in developing period of the ENSO events are seen to occur in the northern part of east Asia, Northeast China, Qinling Mountains, Southwest China, southeastern coastal zone of China, Japanese archipelago, and Indo-China Peninsula. Figure 3 Time series change of eigenvectors of component 7 and SOI 5 Conclusions Asian monsoon exists in multiple forms of variations, and the interannual variations have yearly variations and variations among several years. In general, the yearly variations are described with winter temperature and summer precipitation, and the variations among several years are reflected by circulation of ENSO events. Taking this objective truth as a starting point, we study the relationship between land cover and monsoon variations using annual precipitation and ENSO circulations of several years as a representation of monsoon variations based on the time series precipitation data, NOAA AVHRR NDVI data and SOI data. The result is meaningful for the global change study, especially the findings of land cover distribution of different development stages of ENSO are very important to researches of land cover and climate change. By means of revealing the distribution regula rity of land cover and precipitation driven by ENSO and vice versa, we could forecast the regional precipitation change, and also forecast regional drought and flood. References

关键词： east Asian land cover; monsoon climate; interannual variations; Singular Value Decomposition; ENSO events; Principle Component Analysis?

