Study on Response of Ecosystem to the East Asian Monsoon in Eastern China Using LAI Data Derived from Remote Sensing Information

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Abstract: Based on the Leaf Area Index (LAI) data derived from remote sensing information and eco-climate data, the responses of regional ecosystem variations in seasonal and interannual scales to the East Asian monsoon are studied in this paper. It is found that the vegetation ecosystems of eastern China are remarkably correlated with the East Asian monsoon in seasonal and interannual scales. In the seasonal timescale, the obvious variations of the vegetation ecosystems occur with the development of the East Asian monsoon from the south in the spring to the north in the autumn. In the interannual scale, high LAI appears in the strong East Asian monsoon year, whereas low LAI is related to the weak East Asian monsoon year. These further lead to the characteristic of "monsoon-driven ecosystem" in the eastern China monsoon region, which can be revealed by LAI.

Key words: The East Asian monsoon, Monsoon ecosystem, LAI, Climate change.

1. Introduction

The Asian monsoon is an important component of the earth's climate system, which closely associated with the global climate and weather. At present, about 60% of the world's population live under the influence of the monsoon, of which the Asian monsoon is the largest [1~4]. The Influence of ENSO on the interannual climate vacillation, to a great extent, represents its effect on the East Asian monsoon region [5]. China is intensely influenced by the Asian monsoon, especially by the East Asian monsoon. Droughts and floods are closely associated with the variability of the East Asian monsoon [6,7]. At onset of the East Asian summer monsoon, the beginning and development of rainy season are crucial to the agriculture over the eastern China monsoon region. Therefore, it is vital to reveal the development process of the East Asian monsoon and its impact on the vegetation ecosystem. Regarding the interaction between vegetation and climate in the monsoon ecosystem of eastern China, on one hand, the structure, dynamic and biomass variations of the vegetation ecosystem are affected by the variabilities of the monsoon climate in various scales, on the other hand, numerical modeling experiments of regional climate indicate that the Asian monsoon system is also affected by the vegetation ecosystem changes.

At present, in the global and regional scales, the relationships between climate and vegetation have been gradually studied using NDVI derived from remote sensing data. The NDVI variations of Africa in association with ENSO have also been examined [8]. China has done it as well [9,10]. However, because China is located in the East Asian monsoon region, the special geographical location and the complicated eco-climate condition makes it complex to study the interaction between climate and vegetation ecosystem in the eastern China monsoon region. Especially, there is some error when using NDVI as a proxy indicator of the vegetation biomass in previous studies. LAI can better reflect the interaction between vegetation and climate, the density and spatial distributions of vegetation, up to now, has served as the most valuable proxy indicator of vegetation biomass. The interaction between vegetation and climate can be further analyzed based on LAI information derived from remote sensing data in various temporal and spatial scales. LAI variations considerably reveal the changes of vegetation structure and quantity characteristics, which can be used to better understand the interaction between vegetation and climate [11,12]. Consequently, the investigation precision tends to be improved.

Since a little effort has been made in previous research on the relationships between vegetation and climate in global scale using LAI data, particularly in the eastern China monsoon region, the emphasis of this study is on seasonal and interannual variability of the eastern China monsoon and its relationship with vegetation.

2. Data characteristic and study method

This study used the newly released GSFC ISLSCP-II / LAI dataset derived from NOAA-AVHRR with monthly,

1^o latitude by 1^o longitude grid in 2000. The time series is from 1982 to 1990. The Leaf Area Index (LAI) is defined as the ratio of unit leave area per unit area of ground shaded by vegetation, in the case of uniform density of plant components for continuous vegetation. The precision of LAI data has been improved through the transfer among relationships of NDVI-FPAR-Vcover-LAI. The bioclimatic datasets include monthly air temperature and monthly precipitation. The monthly precipitation dataset was obtained from CMAP by merging various satellite observations, standard precipitation observation and model output data [13]. The precipitation data in this study was interpolated to 1^o latitude by 1^o longitude in the spatial resolution, the time series is from 1982 to 1990. The monthly temperature was obtained from ECMWF with monthly 1^o latitude by 1^o longitude in the spatial resolution, and time series is from 1982 to 1990.

3. Result and analysis

1) Variation of LAI and its association with the interannual variability of the monsoon climate in China

Firstly, the year is called the strong monsoon year if the rain front moves to the most part of Northern China at that year. Commonly, the strong monsoon brings about the strong rainfall. We analyzed the 9-year precipitation from 1982 to 1990 based on this definition. The result shows that the 1986 year is a weak monsoon year but 1990 strong monsoon year. A weak monsoon case in 1986 and a strong one in 1990 are chosen to compare the interannual LAI and precipitation variations in the monsoon region.

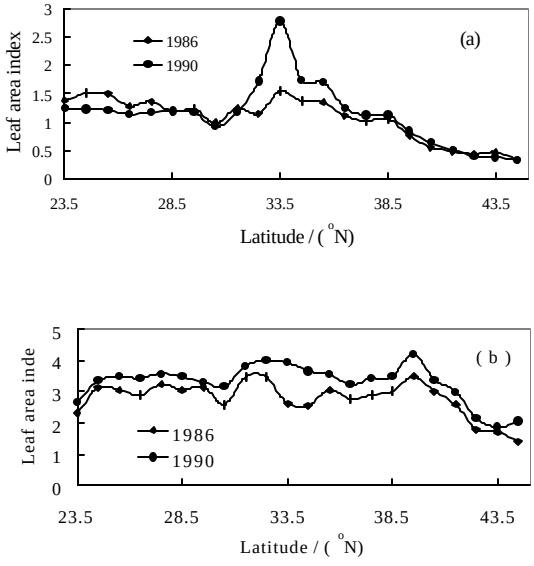

Fig. 2 LAI variations in 1986 and 1990 in study area (a) MAM (b) JJA

Fig.1(a) describes variations of seasonal precipitation in 1986 and 1990 at 26 ~44 N, 111 ~116 E (not shown). The results show that the precipitation intensity in 1986 obviously is lower than that in 1990. The Fig.1(b) indicates that during the growing season, LAI in 1990 is higher than that in 1986(not shown).

Fig. 2(a) and (b) show the LAI variations of MAM and JJA in vegetation growing season in 1986 and 1990. The results present that from March to May and again from June to August in the vegetation growing season, LAI of 1990 is higher than that of 1986, especially in the northern part of the Asian monsoon region (i.e., mid-latitude region). It indicates that high interannual variability is a significant feature of precipitation in the monsoon region, which also serves as a driving force for the ecosystem variations at this time scale.

2) Variation of LAI and its association with seasonal cycle of the monsoon climate in China

Eastern China is characterized by its typical monsoon climate. The precipitation distributions are mainly controlled by the summer monsoon. During the winter, the monsoon climate in Eastern China is dominated by dry and cold north-westly air flow. Whereas, in the summer, warm humid air coming from Pacific & India Oceans brings about a large amount of water vapor [6].

We used the 9-year LAI datasets and climate data to examine the correlations between the precipitation and ecosystem in different seasons. The Fig.3(a) illustrates that in early March to April, at 23 ~29 N of South China, the precipitation of forward flood season starts to reach South China [14, 15], the rainfall appears in this region at the same time. This period can be called the first steady phase, and it lasts about one month. Meanwhile, the vegetation begins growing, and LAI increases rapidly (Fig.3 (b) , not shown). The Fig. 4 (a) shows that, at late May and early June, when the summer monsoon movers over most part of the Yangtze River (29 ~36 N), widespread rainfalls appear in these regions, i.e., the Mei-yu season of the Yangtze River occurs, which is also called the second steady phase, and it lasts about one month (not shown). The Fig.4 (b) shows, here, vegetation grows flourishing and LAI increases rapidly (not shown).

Fig.5 (a) indicates that, up to mid-July, the summer monsoon moves to northern China (36 ~44 N), and controls most part of northern China, widespread rainfalls occur in these regions (not shown). Fig.5 (b) shows that vegetation grows rapidly in this period, LAI also peaks in the whole year, which is called the third steady phase(not shown). This phase lasts till the mid-late term of the August. The precipitation in Northeast China (44 ~47 N) is shown in Fig.6 (not shown). The result shows that LAI also peaks along with the rainfall process development.

From early September, however, when the monsoon rain belt starts to retreat rapidly, the rainfall ends in northern China. Here, the biomass decreases in the northern China ecosystem and LAI declines rapidly, thereafter keeps at a very low value throughout the winter. The figures show that the precipitation arrives at its maximum, but LAI doesn't peak synchronously, which reflect that the response of plants to the seasonal changes of precipitation seems to be lag about 20~30 days.

3. Discussion

It is recognized that there has a significant response of vegetation variations of eastern China ecosystem to the eastern Asian monsoon in the interannual and seasonal timescales. The interannual vegetation growing strongly varies with the precipitation of different years. The interannual precipitation differences have been thought to be caused by many reasons. In general, drought and flood phenomenon occur under the background of abnormal large- scale circumfluence. The persistent droughts and floods of Jianghui regions are closely associated with the 500-mb potential height abnormal and the whole East Asia monsoon activities (i.e., intensity, beginning, and jump dates). The studies in recent years also support that the weak (strong) East Asian monsoon, especially the East Asian summer monsoon, is obviously correlated to the EI Niño (La Niña) event at the interannual scale [16, 17]. Thereby, we may predict the vegetation growing states and crop yields in various years based on climate forecasting, together with the relationship between vegetation and climate in the East Asian monsoon region revealed by remote sensing information.

The seasonal vegetation changes also respond to the seasonal precipitation variations. As for the possible reason of seasonal precipitation differences, the above-mentioned indicated that the strong summer monsoon may bring abundant precipitation. Normally, the rain belt position moves from South China to the Yangtze River, again moves from the Yangtze river to North China, even can reach Northeast China [18]. In the winter, the climate is dominated by dry cold north-westly air flow. From the early flood season of South China to the flood season of Eastern China, the precipitation has three steady phases and two rapid transitions [19], which also can be verified by analyzing LAI datasets. Also, during examine the differences of seasonal LAI and precipitation, it is well shown that the vegetation growing is directly influenced by strong differences of seasonal precipitation. And the characteristics of three phases in respond to precipitation variations are also presented. Thus, the variations of seasonal precipitation also serve as a driving force for vegetation growing. This has further lead to the characteristic of "monsoon-driven ecosystem".

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