ANALYSIS OF SPATIAL AND TEMPORAL CHARACTERISTICS OF DROUGHT AND FLOOD BASED ON PRECIPITATION TEMPERATURE INDEX AT WINTER WHEAT GROWTH STAGES

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ABSTRACT: Drought and flood disasters are the main meteorological disasters in China. Based on vegetation index (VI) and land surface temperature (LST) retrieved by optical remote sensing data for drought and flood disaster monitoring has a lag in time, precipitation data can reflect the surface dry and wet state more timely and intuitively. Current methods to monitoring drought and flood disasters based on precipitation extreme rely primarily on point-based in situ meteorological stations. Tropical Rainfall Measurement Mission (TRMM) microwave remote sensing offers the possibility of quantifying drought and flood conditions over large spatial extents. This research use Precipitation Temperature Index (PTI) retrieved by TRMM precipitation data and LST to explore the spatial and temporal characteristics of flood and drought in Jiangsu Province. PTI is not only related to precipitation changes in a region, but also gives emphasis on LST changes, aiming at integrated monitoring of both drought and flood disasters. We got the 10days-to-10days changes and spatial distributions of PTI from 2000 to 2014 at winter wheat growth stages. Analysis this results we conclude that: The probability of drought and flood disasters happened in Jiangsu Province is 34.08% among 15 years, and the drought (16.74%) close to the flood (17.34%). Jiangsu Province is easily influenced by drought and flood disasters in every season of the year, and drought and flood disasters happened alternately ; Jiangsu Province happened many times extreme drought or flood disasters from 2000 to 2014, such as the 2003 flood year, 2005 autumn drought and 2011 spring drought et al. In addition, central of Jiangsu is easily affected by drought and flood disasters. At the same time, this research shows that the PTI can be used to monitoring the flood and drought disasters in large spatial extents effectively.

1. INTRODUCTION

Increasing temperature and altered precipitation patterns, leads to the extreme weather events like drought and flood which drastically affects the agricultural production. Agricultural drought is nothing but the decline in the productivity of crops due to irregularities in the rainfall as well as decrease in the soil moisture, which in turn affects the economy of the nation. Jiangsu Province in eastern China with its usually plentiful freshwater resources experienced a rare drought from autumn 2010 to summer 2011, and the downstream of the Huaihe River dried up. Further, increase in the frequency and severity of droughts and floods would aggravate the build-up of adversely affect crop productivity and the sustainable development of agriculture.

Drought has a slow onset with systematic progress and flood show sudden occurrence and rapid progress with in a short spell. They are all related to precipitation. Most previous studies applied land surface temperature (LST) and vegetation index (VI) retrieved by optical remote sensing data to drought monitoring. Different kind of vegetation indices are available, but Normalized Difference Vegetation Index (NDVI) is the simplest, efficient and commonly used one. Tucker first suggested NDVI in 1979 as an index of vegetation health and density. Using the NDVI data of the region, the changes in vegetation cover present in the area and the trend in occurrence of agricultural drought can be studied [1]. This index is not free from defects such as data error during rainy season, saturation effect on dense vegetation, etc. Therefore, it is always better to merge it with other parameters to ensure more accuracy. It is seen that there exists a strong correlation between Land Surface Temperature (LST) and NDVI. LST is a good indicator of the energy balance at the Earth’s surface, which can provide important information about the surface physical properties and climate. The reference [2-3] reported that the negative correlation between LST and NDVI, observed at several scales, was largely due to changes in vegetation cover and soil moisture, and indicted that the surface temperature can rise rapidly with water stress. Thus, it can be noticed that the ratio of LST/NDVI increases during times of drought.

This study focus on the drought and flood assessment of the Jiangsu province through the analysis of vegetation stress caused by the lower/higher precipitation and higher/lower temperature. Based on the previous drought monitoring method, a new index called Precipitation - Temperature Index （PTI） was developed based on passive microwave remote sensing of Tropical Rainfall Measurement Mission (TRMM) precipitation products and moderate-resolution imaging spectroradiometer (MODIS) Land Surface Temperature products in this study.

2. DATA SOURCES

TRMM [4-5] was jointly developed by NASA and the Japan National Space Development Agency, its purpose is to understand more about global energy and water cycling by studying the precipitation and latent heat in the tropics. At present, TRMM 3B42 data has been widely verified in many regions. In China, TRMM data correlation with the measured data is better, especially in the eastern plains. The spatial resolution is $0.25^{\circ} \times 0.25^{\circ}$

We used Land Surface Temperature (LST) data from the MODIS instruments onboard NASA's Terra and Aqua satellites, which are publicly available via the USGS Land Processes Distributed Active Archive Center (http://lpdaac.usgs.gov). The LST product is based on 1-2 days of observations and is available in 1000 m spatial resolution. The LST products of the images were downloaded from http://earthexplorer.usgs.gov/.

To produce the drought and flood maps of Jiangsu Province, 15 years of TRMM and MODIS data acquired. Respectively, to use TRMM and MODIS LST products together as on stacked image for producing drought and flood maps, the TRMM layer was resampled to 1000m using nearest neighbor interpolation method.

3. METHOD

We used the precipitation and surface temperature to build the feature space, and developed a new index to monitor drought and flood disasters in the growth stage of winter wheat in Jiangsu Province.

Ten-day land surface temperature and precipitation

The daily precipitation data and Land Surface Temperature data products were synthesized into ten days. The maximum value synthesis method was applied in land surface temperature. The purpose of taking the maximum value is to eliminate the influence of solar elevation angle, satellite angle, orbit drift and cloud. Precipitation data synthesis we use the cumulative method.

The spatial resolution of TRMM precipitation data is $0.25^{\circ} \times 0.25^{\circ}$, and the spatial resolution of MODIS LST data is 1km×1km, the two kinds of data do not match on spatial scale. On the basis of coordinate matching, TRMM precipitation data is processed into 1km×1km scale, the processing method is: each MODIS LST pixels are corresponding to a precipitation value, each precipitation value corresponds to a number of LST value. So we count the number of rows and columns of the MODIS LST image, and the precipitation values corresponding to each LST value are recorded in order to obtain the same TRMM precipitation data as the number of MODIS LST rows.

The multi ten-day accumulation precipitation

The degree of drought and flood, especially drought, were closely related to the precipitation in the previous period, therefore, this study attempts to use the multi ten-day cumulative precipitation to reflect the impact of a period and its previous period precipitation on the drought and flood disasters. We applied the ten-day precipitation data from January to June, 2000-2014. The method of multi ten-day accumulation precipitation was as follows:

$$P_{i_k} = \sum_{1}^{k} p_{i_k} \tag{1}$$

There, i is the year, $i = 2000, 2001, ..., 2014;$ i_k is the k ten-day data of the i year, p is the ten-day precipitation, P is the multi ten-day accumulation precipitation.

PTI

Using the multi-year ten-day accumulation precipitation and this ten-day LST constitute the characteristics of the space, to determine the hot and cold boundaries of this ten-day. The advantage of using the multi-year data to determine the hot and cold boundaries if that there may be extreme weather conditions for drought and floods over many years, and extreme drought and flood can help us to obtain the absolute value of hot and cold borders [6-7]. According to the feature space, we find that the accumulated precipitation and the LST are distributed in the triangular area. With the increase of accumulated precipitation, the pixel gradually decreases. Figure 1 is the cumulative precipitation and LST feature space of last ten days of June, years 2000-2014. According to the feature space, the cold boundary is defined as a straight line with a positive slope: $T_{\min} = 0.070P + 269$ the thermal boundary is a straight line with a negative slope: $T_{\max} = -0.035P + 324$. According to this method, all ten-days of hot and cold boundaries are obtained.

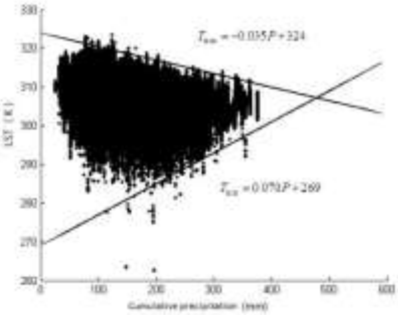


Fig.1 Cumulative precipitation and land surface temperature scatter plot of the June last ten days

The definition of the precipitation and temperature index is:

$$PTI = \frac{T_{P_i \max} - T_{P_i}}{T_{P_i \max} - T_{P_i \min}} \qquad (2)$$

Where:

$$T_{P_i \max} = a + bP_i \qquad (3)$$

$$T_{P_i \min} = a' + b'P_i \qquad (4)$$

Where, P is the multi ten-day accumulation precipitation, $T_{P_i \max}$ and $T_{P_i \min}$ are maximum and minimum LSTs of pixels which have same P value in a study region, respectively, and T_{P_i} denotes LST of one pixel whose P value is P_i. Coefficient a 、 b 、 a' and b' can be estimated from the scatter plot of LST and P in the area.

PTI is not only related to precipitation changes in the region, but also related to LST changes of pixels with a specific precipitation value. The numerator of equation (2) is the difference between maximum LST of the pixels and LST of one pixel, while the denominator of equation (2) is the difference between maximum and minimum LSTs of the pixels.

4. RESULTS AND ANALYSIS

We statistic the frequency of droughts and floods disasters during the growth period of winter wheat pixel-by-pixel. It can be seen from Table 1 that the total frequency of droughts and floods is 46.83% in the past 15 years in Jiangsu Province, of which the drought frequency is 31.31%, and the flood frequency is 15.52, indicating that Jiangsu Province is serious influenced by drought disasters.

Tab.1 frequency of various grade flood and drought disasters happened in Jiangsu Province during 15 years

%

Grade	Drought	Normal	Flood
Frequency	31.31	53.17	15.52

Statistics on the occurrence of droughts and floods each year (Fig.2), The results shown that the frequency of disasters occurred in 2010 was relatively high. The frequency of droughts and floods occurred in 2006 and 2008 was small, which were normal years. The frequency of droughts and floods occurred in 2002, 2003 and 2012 were both serious.

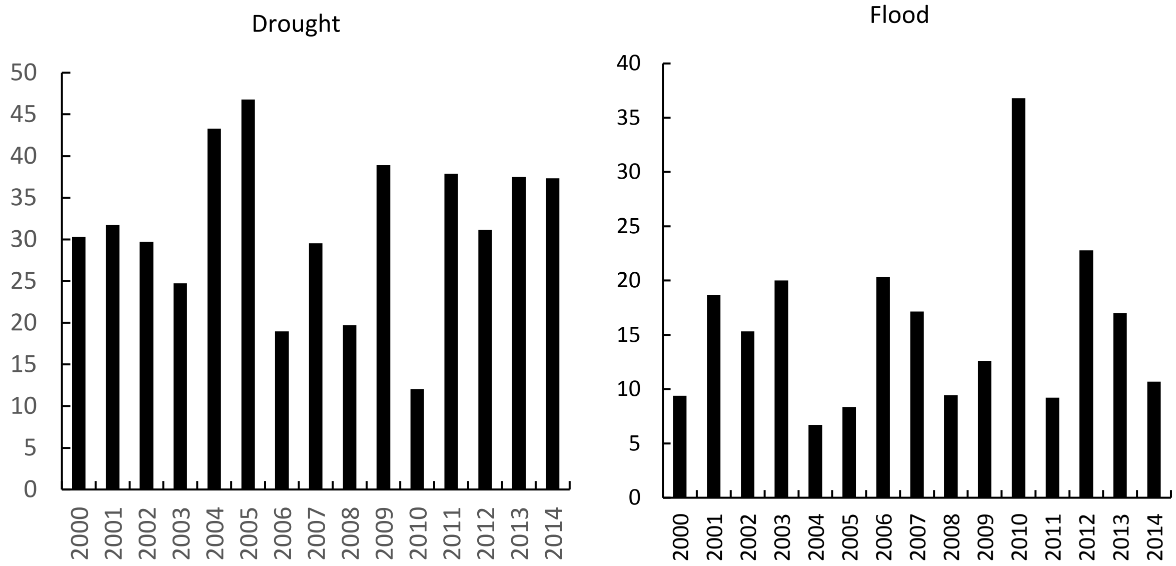


Fig.2 Frequency of drought and flood disaster happened in each year based on PTI of Jiangsu Province in 2000-2014

The frequency of droughts and floods in different growth stages of winter wheat were shown Figure 3, which shows that droughts and floods affect winter wheat throughout the whole growing period in Jiangsu Province. The droughts are mainly concentrated in the regreening stage, milky stage and harvest period. The floods are mainly concentrated in the jointing stage and the heading stage.

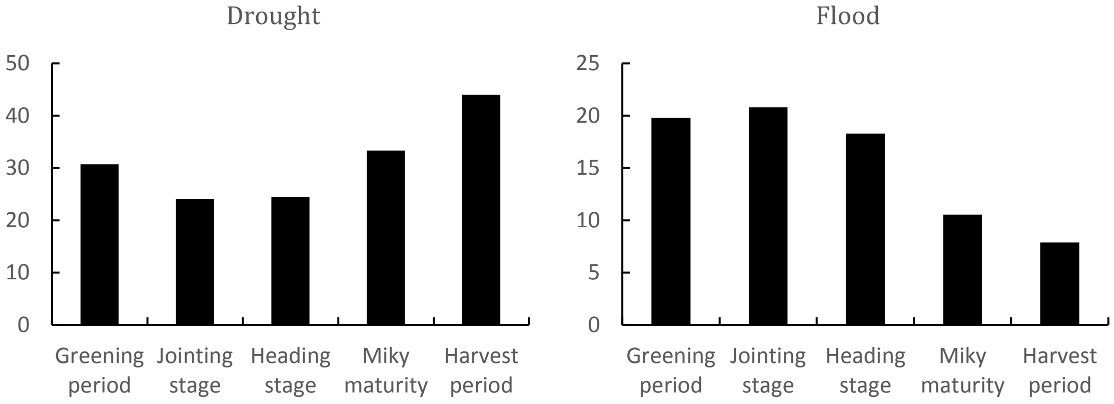
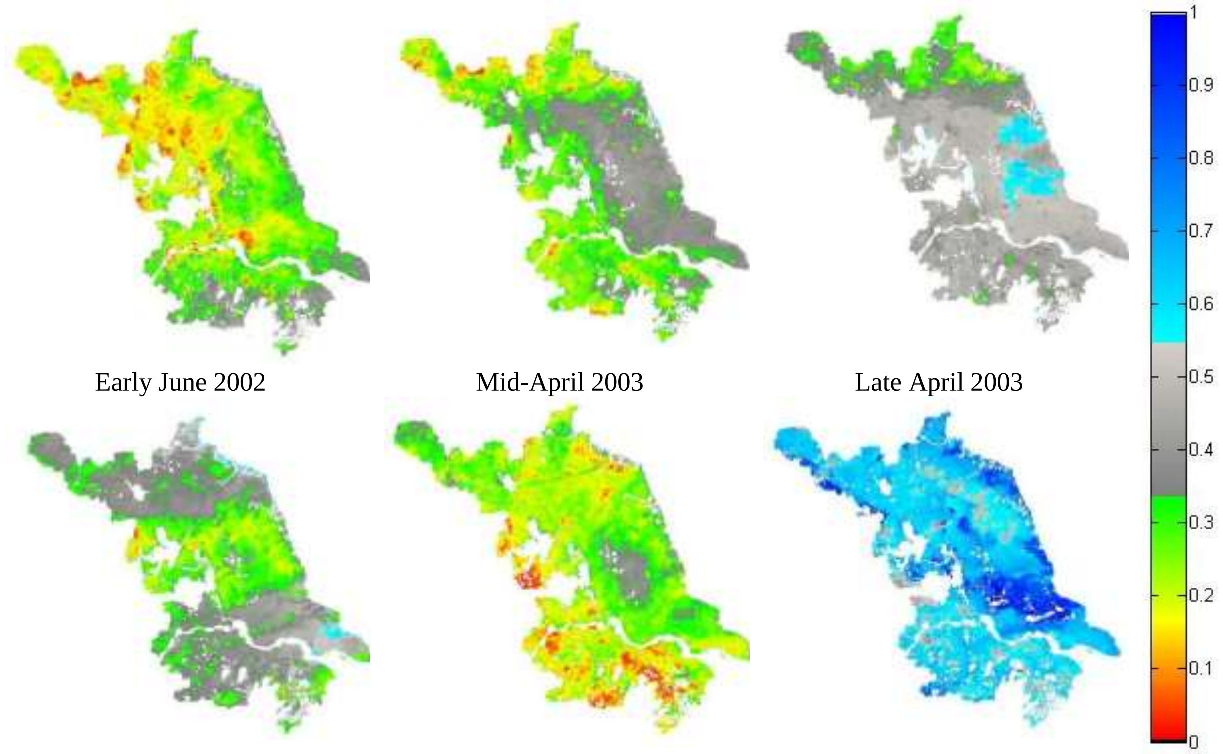


Fig.3 Frequency of drought and flood disasters in different growth periods of winter wheat in Jiangsu province from 2000 to 2014

From the previous analysis, it can be seen that severe drought and flood disasters have occurred for many years. Fig.4 shows the spatial distribution of drought and flood grades in periods when drought and flood disasters are serious in Jiangsu province, from which we can see the regional distribution characteristics of drought and flood disasters in Jiangsu province. In early June 2002, drought occurred in most areas of Jiangsu province, and the northwest area was more serious. In mid-April 2003, drought occurred in the west and north of Jiangsu province. In early March 2005, a large area drought occurred in the central part of Jiangsu province. In 2010, there was a serious flood, and by mid-April the whole province was threatened by flood.



Early June 2002 Mid-April 2003 Late April 2003

Early March 2005 Early April 2005 Mid-April 2010

Fig.4 Spatial distribution of serious drought or flood disaster' period in 2000-2014

5. CONCLUSIONS

Through the analysis of 14 years of drought and flood monitoring results, the following conclusions are drawn:

1. Drought and flood disasters occur frequently in Jiangsu province. Drought has a great influence on the regeneration and harvest stages of winter wheat, while flood has a great influence on the regeneration, jointing and grouting stages of winter wheat;
2. The central part of Jiangsu province is especially affected by drought and flood disasters frequently, and has the characteristics of alternating time;
3. PTI can effectively monitor large-scale drought and flood disasters.

REFERENCES

[1] Tian Miao, Wang Pengxin, Sun Wei. A review of retrieving of land surface parameters using the land surface temperature-vegetation index feature space[J]. Advances in Earth Science, 2010, 25(7): 698-705.

[2] Wan Z, Li Z L. A physics based algorithm for retrieving land-surface emissivity and temperature from Terra Moderate resolution imageing spectroradiometer[J].IEEE Transactions on Geoscience and Remote Sensing, 1997, 35: 980-996.

[3] Wan Z, Zhang Y L, Zhang Q C, et al. Quality assessment and validation of the MODIS global land surface temperature[J]. international journal of remote sensing, 2004, 25(1): 261-274.

[4] Theon J S. The tropical rainfall measuring mission (TRMM)[J]. Remote Sensing of Earths Surface and Atmosphere, 1993, 14(3): 159-165.

[5] Islam M N, Uyeda H. Use of TRMM in determining the climatic characteristics of rainfall over Bangladesh[J]. Remote Sensing of Environment, 2007, 108(3): 264-276.

[6] Wang Pengxin, Gong Jianya, Li Xiaowen. Vegetation temperature condition index and its application for drought monitoring[J]. Geomatics and Information Science of Wuhan University, 2001, 26(5): 412-418.

[7] Sun Wei, Wang Pengxin, Han Lijuan, et al. Further improvement of the approach to monitoring drought using vegetation and temperature condition indexes from multi-years' remotely sensed data[J]. Transactions of the Chinese Society of Agricultural Engineering (Transactions of the CSAE), 2006, 22(2): 22