BUILDING NDVI-PHENOLOGY COMPARISON METHOD TO DETECT GROWING PERIODS DURING 1982~1999A IN NORTHEAST CHINA

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ABSTRACT:

Plant phenology is an integraph of global changes and a comprehensive indicator of landscape and entironment changes, and its responses to global environment changes have become a focus of the field of global changes. Studies on plant phenology by remote sensing technology provide plant phenology data in desolate and uninhabited area, and realize the spatial transition of phenological data from points to coverage. But it is a nut and puzzle for scholars of exploring the relationship between remote sensed data and field eyeballing observation data. NDVI-Phenology Comparison Method was built to solve the puzzling problems and monitor Phenological Key Stages by combining remotely sensed data and phenological observation data. Based on AVHRR/NOAA NDVI data and field data of phenological key stages, adopted by NDVI-Phenology Comparison Method, Growing periods was chosen as a key phenophase to discuss the regional phenology patterns in Northeast China during 1982~1999a. Three indexes, i.e. Green-up date, the end date of growing periods, and the length of growing periods, were adopted to discuss the regional patterns of inter-annual changes in Northeast China.

1. INTRODUCTION

Plant phenology, widely applied to researches on environmental changes all over the world, is an integraph of global changes and a comprehensive indicator of landscape and environment changes (Houghton et al., 1990). New remote sensing technology has recently been involved in phenological observation, which can overcome disadvantages that the located phenological observation based on field stations can only represent certain regions, and can realize the efficient spatial transition of phenological observation from points (phenological observation station) to coverage (macro-region) for better phenological observation across regions, countries, continents, and even in globe easily. However, it is still very immature for the technology and methods of remote sensing using in phenological observation; especially it is very difficult to define the remote sensing data in the phenology. And to solve this problem, the cooperation with methods of surface located phenological observation is needed.

It is very meaningful in ecology to explore methods of Phenological Key Stages by combining remote sensing technology and field phenological observation. Meanwhile, it offers testing data of ecosystem simulation under the circumstances of climate change and develops new concepts in the study of region responses to global change. Studies have suggested (Jeremy et al., 2006) that growing periods based on the mechanism of remote sensing and the system of surface phenological observation , is a link between surface phenological observation and satellite remote sensing, which is rather an ideal index for integrated use of remotely sensed data and surface phenological observation results.
Based on remote sensed data and surface phenological observation data ,this paper constructs the NDVI-Phenology Comparison Method, and applies it to the extraction of Green-up date in Northeast China during 1982~1999a and analyses its space pattern.

2. STUDY AREA

The Northeast China，with the basic characters of moderate temperature zone continental monsoon climate, comes cross cold , warm and warm-tropical temperate regions. The temperature and humidity change much in different seasons; it is long and extremely cold in winter, compared with short-time warm wet summers. The temperature varies from year to year, with an 0～10℃ annual average temperature. Decreased from southeast to northwest area , the annual precipitation amount is 400～1000mm, and it is higher in mountains than plains, and on the winding slopes than wind shielded ones.

According to the division of vegetation region in China, The Northeast China vegetation regions include three types: cold temperate zone covered by coniferous forest, temperate zone covered by mixed forest and tropical temperate zone covered by leaf-fallen broadleaf forest (Chinese vegetation Editorial Board, 2001) .It mainly consists of Korean pine and spruce, fir and mixed pine-leaf and broad-leaf trees. And in the land-use patter of Northeast China, the forest covers the largest proportion ,reaching 44.76％, with cropland 33.03% and residential land 6.64%.

3. MATERIAL AND METHOD

3.1 Acquisition of the Data

At present, studies on monitoring plant phenology by remote sensing technology between foreign and domestic mainly apply NOAA/AVHRR-NDVI dataset. NDVI is an optimal indication factor to vegetation growing status and vegetation fraction, and equals the ratio of the sum between near-infrared band and solar visible band to the difference between them (Equation 1).

$$NDVI = \frac{DN_{NIR} - DN_R}{DN_{NIR} + DN_R} \qquad (1)$$

Where DN_{NIR} = reflectance of near-infrared band

DN_R = reflectance of red band

The advantage of NDVI data is that the data cover the whole world and can analyze the vegetation change of the earth from landscape scale. It also can quantitatively or qualitatively represent vegetation activity, and it is more sensitive to detect green vegetation by single band[2]. NDVI has more advantages in representing surface vegetation coverage statue and revealing vegetation green. Moreover, NDVI is less sensitive to the area with high vegetation fraction index and is propitious to diagnose the dynamic of low covering vegetation. However, studies on phenology analysis by remote sensing adopts NDVI to analyze the beginning of a key phenophase, the ending date of a key phenophase and avoids the bloom stage of vegetation growing, so its analyzed result is comparatively reliable.

Fig.1 introduces the operational flow of distill growing periods with NDVI-Phenology Comparison Method. This method contains three key processes: construction of database, acquisition of NDVI threshold dataset and abstraction of growing periods in similar regions.

3.2 Research Method

3.2.1 Construction of the Database

NDVI-Phenology Comparison Method during growing periods needs three kinds of databases in research area: the database of field plant phenology observation, the database of remote sensing NDVI and the database of surface vegetation. The calculation precision of NDVI-Phenology Comparison Method depends on the precision of classification of surface vegetation, so the effective guarantee to make this method reliably is based upon acquisition the last remote sensing images, images interpretation, ground investigation, classification of real-time interpretation and obtaining graphic library of land use type in a long-time scale.

During constructing the database of field Phenology, the key step is the examination of the field data, it is the garenteen of the reliability of the database. The principles in examining the data are to follow the natural sucession of the phenology: sucession synchroneity and geographical location.

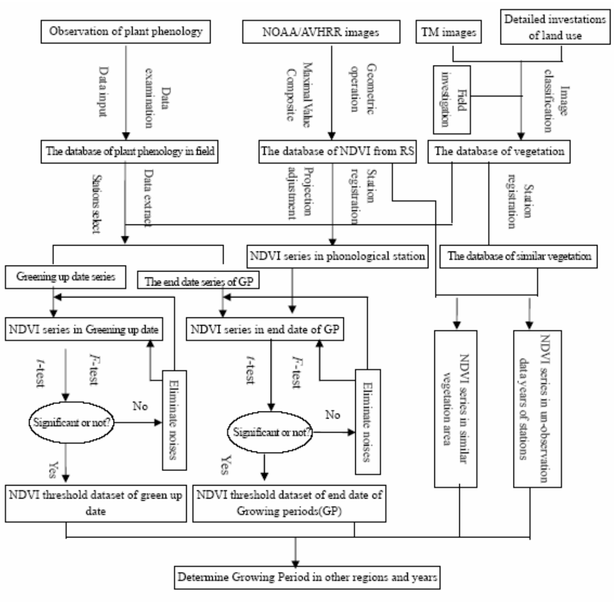

Fig.1 The flow chart of NDVI-phenology comparison method that determines growing periods

3.2.2 Acquisition of NDVI Threshold in Growing Periods

Abstracting series of the beginning and ending date of growing periods in each station among different surface vegetation types from the database of field plant phenology observation and finding values of NDVI which match with the dates from the corresponding remote sensing images construct NDVI threshold dataset in growing periods.

There are two key problems in acquiring NDVI threshold dataset during growing periods.

(1) Testing stability of sequences. Testing stability of sequences can be judged by comparing mean value or variance of sequence variable in different time wheather happen significant change or not. The methods of testing mean value are u-testing and t-testing, and the means of testing variance are x^2-testing and F-testing. For measuring mean value, t-testing is proposed, and for measuring variance, F-testing is proposed. The principle and methods of t-testing and F-testing see interrelated statistic data.

(2) Elimilating singularity of sequence. From fig1, there are fixed NDVI threshold with the same classification of vegetation coverage in the region during the beginning date and the ending date of growing periods.

3.2.3 Abstraction of Growing Periods

Growing periods is confirmed by NDVI threshold dataset of the beginning and ending data of growing periods. After getting the NDVI threshold dataset of the beginning and ending data of growing periods, the beginning and ending data of growing periods in similar classification region of vegetation are abstracted from the NDVI decade sequence of dataset, which is got by programme on the platform of GIS or remote sensing. It should be emphasized that if the date of phenology station in some year was not measured, the unmeasured growing periods also can be confirmed by the NDVI threshold dataset of the beginning and ending data of growing periods.

4. RESULTS

According to flow chart of NDVI-Phenology Comparison Method, the growing periods of Northeast China in 1982~1999a is determined. And observation phonological data in field, AVHRR-NDVI data, land use and plant coverage data were prepared, which is a primary works and the first steps of NDVI-Phenology Comparison Method. The method of data preparing is ordinary and common, so the paper leave out the part of determining the growing periods. According to Fig.1, Green-up date, the end date of Growing Days, the length of Growing Days will be determined, which is the key step of NDVI-Phenology Comparison Method.

4.1 Environmental Analysis

The vegetation change of the earth's surface of ecosystem of land relates to the fact that climatic conditions (Donatella *et al.*, 1999), plant phenology, land use and plant coverage state (Abu-Asab et al., 2001). The previous study shows that there are great changes of environmental background related vegetation in Northeast China during the study period of 1982~1999a, and there are obvious warming up and advance spring phenology after 1980s in Northeast China. Then, how large are the differences of climate, phenology and land use between 1980s and 1990s? And how do the changes of environmental condition influence NDVI threshold value of growing periods? The paper will discuss the above problems in the following text.

4.1.1 Climate Condition

The paper choose climate data of 40 standard meteorological site in Northeast China, and calculate annual average temperature, annual precipitations in 1980s and 1990s of every meteorological site that will be abbreviated as T_{1980s} and T_{1990s}, T_{1980s} and T_{1990s} in the following text respectively. And the paper respectively compute T_{1980s} and T_{1990s}, T_{1980s} and T_{1990s} of every vegetation type zones in Northeast China, and discuss the changes of temperature and precipitation in 1980s and 1990s (Tab.1).

Tab.1 Temperature and precipitation changes of every vegetation type zones in 1980s of 1990s

Unit：℃, mm

vegetation type zone	T_{1980s}	T_{1990s}	P_{1980s}	P_{1990s}	T_{1990s}-T_{1980s}	P_{1990s}-P_{1980s}
Cold temperate zone covered by coniferous forest(abbr. zone1)	-0.6	-0.2	531.6	472.8	0.4	-58.8
Temperate zone covered by mixed forest(abbr. zone 2)	4.4	4.8	615.6	607.2	0.4	-8.4
Tropic temperate zone covered by broad-leaf forest(abbr. zone 3)	11.7	12	619.2	615.6	0.3	-3.6

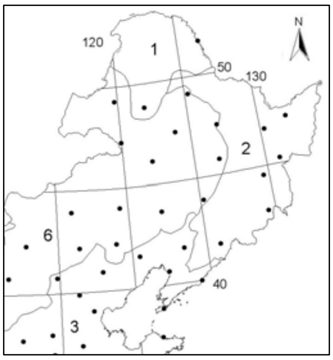

Fig.2 Distribution map of meteorological site in Northeast China (The meanings of 1, 2 and 3 in figure show in Tab.1.)

4.1.2 Phenology Differences

There are different phenological observed stations in 1980s and 1990s, the former is 25, the latter is 16. And the distribution map of the stations is shown in Fig.3. Using phenological observed materials in 1982~1999a, the paper respectively compute growing periods of every observed stations. And according to vegetation type zones, green leaf pheology (green-up date, the end date of Growing Days) will be calculated and prepared, which analysis unit is ten days (about 10 days). Tab.2 shows the analysis results of phenological observed data.

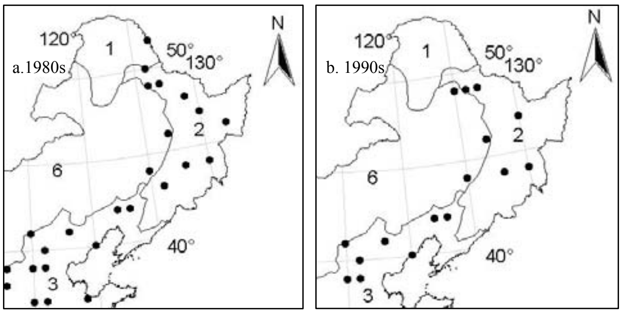

Fig.3 Distribution map of phonological stations in Northeast China of 1980s and 1990s

Tab.2 Growing Periods changes of every vegetation type zones in 1980s of 1990s

Unit: Ten days

vegetation type zone	Green-up date in 1980s	The end date of growing periods in 1980s	Green-up date in 1990s	The end date of growing periods in 1990s
Zone 1	13	27	——	——
Zone 2	13	25	13	25
Zone 3	10	27	10	28

4.1.3 Land Use Differences

Tab.3 Land use changes of every vegetation type zones in 1980s of 1990s

Unit: km^2

vegetation type zone	decade	Wood land	Grass land	Water	Construction land	Waste land	Arable land
Zone 1	1980s	36.26	3.16	0.20	0.04	0.28	0.32
	1990s	14.95	3.11	0.06	0.04	0.36	0.26
Zone 2	1980s	3.17	1.75	0.78	0.71	1.67	12.79
	1990s	3.29	1.85	0.82	0.74	1.88	12.29
Zone 3	1980s	16.71	14.30	2.38	7.92	0.46	49.90
	1990s	30.67	14.50	2.34	7.66	0.64	48.98

There are obvious and prominent changes of land use in Northeast China between 1980s and 1990s, which characters by decreasing area of forest land and grass land.

Tab.4 *t* value and *F* value of NDVI series of growing periods in every vegetation type zones

vegetation type zone	Mean				*t* value	
	1980s/SOS	1980s/EOS	1990s/SOS	1990s/EOS	SOS	EOS
Zone 2	0.24	0.56	0.23	0.53	0.022*	0.092*
Zone 3	0.18	0.34	0.20	0.37	-0.119*	-0.084*

vegetation type zone	Variance				F value	
	1980s/SOS	1980s/EOS	1990s/SOS	1990s/EOS	SOS	EOS
Zone 2	0.0086	0.0083	0.0088	0.0083	0.737*	0.755*
Zone 3	0.0072	0.0103	0.0118	0.0186	0.604*	0.544*

Note: * shows there are not obvious differences of NDVI series between 1980s and 1990s under the test levels of $t_{\alpha=0.01}$ and $F_{\alpha=0.05}$. SOS shows green up date, while EOS shows the end date of growing periods.

4.2 Calculating NDVI Threshold Value of Growing Periods

4.2.1 Measuring Stability of NDVI Series of Growing periods

The key step of determining growing periods by NDVI-phenology Comparison method is calculating NDVI threshold values of green up date and the end date of growing periods. The paper chooses representative phenological stations, according to observation results on the ground, NDVI time series of 1981~1996a at the date of leaf unfold and leaf color (Tab.4). Then, different vegetation zones, how is the stability of NDVI series of growing periods, does NDVI series have a prominent differences at the date of growing periods between 1980s and 1990s? The paper will explain the above problems in terms of statistical analysis.

Accord with the assumption of normal distribution, t-test and F-test of two NDVI series during green-up date and end date of growing periods between 1980s and 1990s will be computed (Tab.4).

From Tab.4, we can see that, mean value of two NDVI series passes the levels of $t_{\alpha=0.01}$, the power variance of the NDVI series passes the test of $F_{\alpha=0.05}$. So there are not prominent differences between two NDVI series during 1980s and 1990s. This is to say, NDVI value during green-up date and the end date of growing periods at different vegetation type zones are relative stability.

4.2.2 Determining NDVI Threshold in Growing Periods

From Tab.1, Tab.2 and Tab.3, we can see that there are great changes of climate, phenology and vegetation coverage from 1980s to 1990s. Tab.4 indicates that NDVI threshold value of various vegetation type zones is relatively stable, which show the starting and close date of growing periods. That is to say, NDVI threshold values have constancy among every vegetation type zone. So, the NDVI averages of 1980s and 1990s can be adopt in Tab.5 as NDVI threshold value, and the changes and distributing pattern of green-up date, the end date and the length of growing periods will be analyzed in Northeast China.

Tab.5 NDVI threshold value in every vegetation type zone between 1980s and 1990s at the date of the beginning and close of growing periods

vegetation type zone	NDVI value of SOS	NDVI value of EOS
Zone 1	0.21	0.34
Zone 2	0.24	0.55
Zone 3	0.19	0.36

4.3 Calculating Growing Periods

After NDVI threshold value of growing periods is ensured, the beginning and close date of growing periods will be calculated. The following two steps must be done. Firstly, the paper chooses the image that NDVI threshold value appears. Secondly, according to acquiring date of the image, the paper determines the appearing date of growing periods. Based on AVHRR-NDVI data in 1982~1999a, The paper adopts the computer programming method in GRID module of ARCINFO platform to calculate the beginning date, the end date, the length of growing periods of every net unit during 1982~1999a in the Northeast China.

The paper adopt NDVI-phenology comparison method by AVHRR/NDVI data and ground observation data to calculate the beginning date, the end date, the length of growing periods of every grid during 1982~1999a in the Northeast China. Through calculating the yearly averages of each grid, the distributing pattern of growing periods during 1982~1999a will be analyzed.

4.3.1 Green-up Date

According to the characteristics of beginning date, the paper chooses threshold value of 3 , 6 , 9 , 12 , 15 ten days and the beginning date is divided into 6 ranks. So the map of green-up date distributing pattern (Fig.4) will be drawn. From Fig.4, we can see that the following phenomenon. The beginning date of growing periods postpones from southeast to northwest of the study area gradually. And green-up date appears in May-June in Northeastern plain generally, while growing periods began in April at Daxinganling Mountains area.

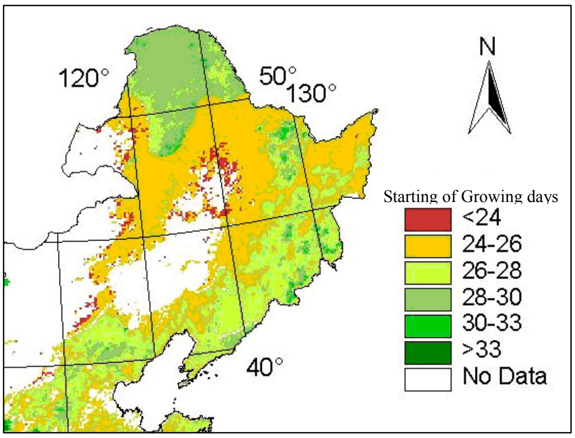

Fig.3 The distributing pattern of the beginning of growing periods in Northeast China during 1982~1999a

4.3.2 The end date of Growing Periods

The distributing map (Fig.5) of the end date of green leave days in Northeast China will be drawn after the average of the end date of growing periods during 1981~1999a is calculated. From Fig.5, we can see the following laws. The end date of growing periods advances from the southeast to the northwest of Northeast China gradually. The end of growing periods appears in August in Songnen plain of Northeast China. The end of growing periods appears at the end of August and the beginning of September in the southeast of Northeast Plain.

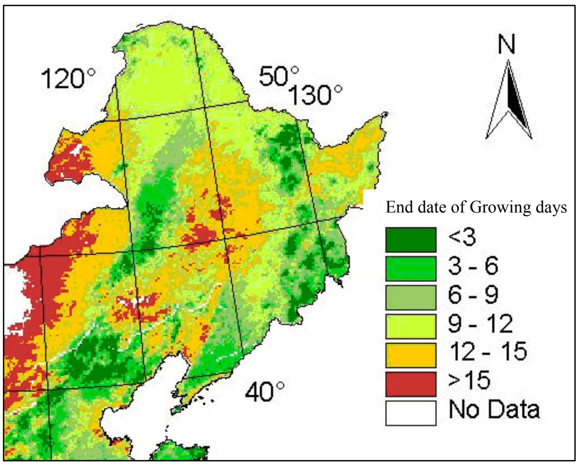

Fig.4 The distributing pattern of the end date of growing days in Northeast China during 1982-1999a

4.3.3 Length of Growing Periods

The length of growing periods becomes shorter gradually from the southeast to the northwest during 1982~1999a, and the length is more than 330d, 300d , 270d , 240d , 210d , 180d, 150d sequentially, under 120d. The length of growing periods is under 120d in the Northeastern plain and Sanjiang plain. While, the lengths are 120-180d in Daxinganling and Changbaishan Mountains region.

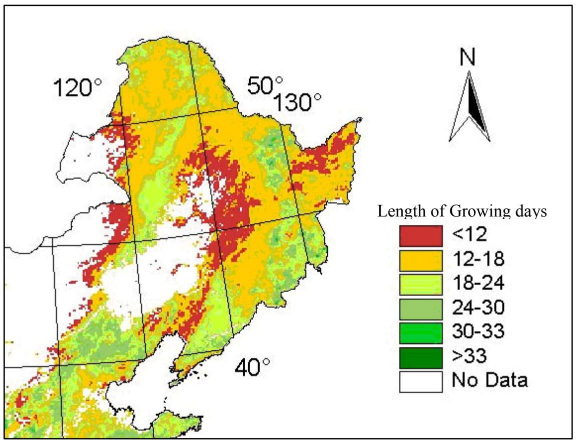

Fig.5 The distributing pattern of length of growing period in Northeast China during 1982-1999a

In conclusion, the changing pattern of the beginning of growing periods is postponing from the southeast to the Northwest of the study area sequentially. While the end date of growing periods is advancing from the southeast to the northwest of the study area sequentially. So, the length of growing periods is shortened from the southeast to the northwest of Northeast China gradually.

5. CONCLUSIONS

NDVI-phenology comparison method to determining growing periods is an effective exploration to organize the remote sensing technology and eye-observation phenology technology, which finish the changes from spot (eye-observation phenology station) to the region (area coverage) and realize the issue of field-to-satellite scaling.

NDVI-phenology comparison method has its limitation and shortcoming, which mainly behave in two aspects. Firstly, the detailed ground observing data will be required. Secondly, precision of result of calculation is limited by the classifying precision of vegetation types to a great extent. For example, there are 25 eye-observation stations when the observing scale is the largest. And the study area is divided three vegetation type zones. If considering the inferior district, the quantity of observing site shows slightly insufficiently.

But, NDVI-phenology comparison method has its obvious advantage that mainly behaves in two aspects. Firstly, once the detailed NDVI threshold value database which includes the beginning and end of growing periods in different land use zones is set up, growing periods can be drawn conveniently and quickly. Secondly, observing results by NDVI-phenology comparison method are same to eye-observe phenology data, which can reflect the growing state of vegetation.

So determining growing periods by NDVI-phenology comparison method is an experimental exploration that combines remote sensing technology and eye-observation phenology data. The method can be popularized and verified in other research region.

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