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Variations in Growing Season NDVI in Northern China (1982-2015) and Its Response to Temperature Extremes (Postprint)

Authors: He Hang

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Abstract

Based on the GIMMS NDVI 3g v1.0 dataset and daily meteorological data, combined with extreme temperature indices, and supplemented by methods such as Extreme-Point Symmetric Mode Decomposition (ESMD), trend analysis, Mann-Kendall trend test, and correlation analysis, this study explores the variation characteristics of vegetation cover and extreme temperature during the growing season in northern China, and investigates the response of vegetation cover to temperature extremes. The results show that: From 1982 to 2015, the growing-season NDVI in northern China increased at a rate of 0.002 · (10a) ¹ ($P<0.05$), and ESMD (Extreme-Point Symmetric Mode Decomposition) revealed a fluctuating upward trend in growing-season NDVI; coniferous forests, shrublands, desert vegetation, grasslands, and cultivated vegetation showed increasing trends, with cultivated vegetation having the fastest growth rate, while mixed coniferous-broadleaf forests, deciduous broadleaf forests, and alpine vegetation exhibited non-significant decreasing trends. Spatially, areas with significantly increasing NDVI accounted for more than 33% of the entire region, mainly distributed in the Tianshan Mountains, northern Tarim Basin, Qilian Mountains, Longnan mountainous area, Loess Plateau, Hetao Plain, Lüliang and Taihang Mountains, Dabie Mountains, and the hilly areas of western Liaoning; significantly decreasing areas comprised only 12%, mainly distributed in the Greater Khingan Range, Lesser Khingan Range, and Changbai Mountains.

Among the extreme temperature indices, except for TNmean (mean daily minimum temperature) and TNn (minimum value of daily minimum temperature) which showed increasing trends, all other cold extreme indices showed decreasing trends; all warm extreme indices showed increasing trends; among other indices, DTR (diurnal temperature range) showed a decreasing trend, and GSL (growing season length) showed an increasing trend. Correlation analysis between NDVI and extreme temperature indices in northern China

indicated that, among the cold extreme indices, NDVI was significantly negatively correlated with FD0 (number of frost days), TN10p (number of cold nights), and TX10p (number of cold days) ($P<0.05$), and significantly positively correlated with TNmean ($P<0.01$); NDVI was positively correlated with all warm extreme indices, and showed significant correlations with TR20 (number of tropical nights), TXmean (mean daily maximum temperature), TX90p (number of warm days), and TN90p (number of warm nights) ($P<0.05$); NDVI was significantly positively correlated with GSL ($P<0.05$). Areas with significantly increasing NDVI, such as the Tianshan Mountains, northern margin of the Tarim Basin, Qilian Mountains, Hetao Plain, Loess Plateau, Taihang and Lüliang Mountains, showed strong responses to extreme temperature indices. Areas with significantly increasing NDVI responded strongly mainly to indices such as FD0, TNmean, TN90p, and GSL. Areas with significantly decreasing NDVI showed varied responses to the indices, being mainly significantly negatively correlated with SU25 (number of summer days) ($P<0.05$).

Full Text

Preamble

Spatiotemporal Change of NDVI and Its Response to Extreme Temperature Indices in North China from 1982 to 2015

HE Hang, ZHANG Bo, HOU Qi, LI Shuai, MA Bin, MA Shang-qian
(College of Geographical and Environmental Sciences, Northwest Normal University, Lanzhou 730070, Gansu, China)

Abstract: Climate warming is conducive to enhancing vegetation activities. Here, the interannual and spatial variations of vegetation cover in north China in growing season were analyzed based on the satellite-derived normalized difference vegetation index (NDVI), and its responses to the change of extreme temperature indices were studied by using GIMMS NDVI3g V1.0 datasets, daily temperature and precipitation data. Across the whole study area, the trends calculated by linear regression showed that the NDVI value in growing season increased at a rate of $0.002 \cdot (10a)^{1}$ from 1982 to 2015. The results of extreme-point symmetric mode decomposition showed that the NDVI increased gradually until 1992, decreased slightly until 2005, and then increased gradually. The NDVI values of coniferous forest, shrubbery, desert vegetation, grassland and cultivated vegetation were all in an increase trend, and those of mixed forest, broadleaved deciduous forest and alpine vegetation were in a decrease trend. Spatially, the NDVI was in a decrease trend from the southeast to the northwest, and the area of the regions where the vegetation was significantly improved accounted for 33% of north China. The regions where the NDVI increased significantly were mainly distributed in the Tianshan Mountains and north Tarim Basin in north Xinjiang, Qilian Mountains, mountainous area in south Gansu Province, Loess Plateau, Hetao Plain, Lvliang Mountain, Taihang Mountain, and hilly region in west Liaoning Province. The area of the regions where the NDVI decreased significantly were mainly distributed in the Great Khingan Range, Lesser Khingan Mountains and Changbai Mountain. Among the 18 extreme temperature indices, except the mean daily minimum air temperature and the lowest minimum air temperature were in an increase trend, all others of cold extreme temperature indices were in a decreased trend; the warm extreme temperature indices were all in an increase trend. The NDVI was negatively correlated with FD0, TN10p and TX10p ($P<0.05$), but positively correlated with TNmean ($P<0.01$). The NDVI was positively correlated with all warm extreme temperature indices, and was significantly correlated with TR20, TXmean, TX90p and TN90p ($P<0.05$). There was also a significant positive correlation between NDVI and GSL ($P<0.05$).

Keywords: growing season; GIMMS NDVI3g V1.0; spatiotemporal variation; extreme temperature index; response; North China

1 Introduction

1.1 Study Area

The study area of north China (31°23 ∼53°31 N, 73°40 ∼135°5 E) spans from the temperate zone to the cold temperate zone, covering an area of 5.78×10 km². The main vegetation types include coniferous forest, shrubbery, desert vegetation, grassland, cultivated vegetation, mixed forest, broadleaved deciduous forest, and alpine vegetation. The regional climate varies from humid and semi-humid in the east to arid and semi-arid in the west, with significant topographic variations.

1.2 Data

The study utilized GIMMS NDVI3g v1.0 data spanning from 1981 to 2015, with a temporal resolution of 12 months per year. The dataset was obtained from NASA's Ecocast website (https://ecocast.arc.nasa.gov/data/pub/gimms/3g.v1/). Data preprocessing was conducted using MATLAB, including format conversion from netCDF to TIFF and extraction of NDVI values for the study area. The Maximum Value Composite (MVC) method was applied to generate monthly NDVI data. Pixels with NDVI<0.1 were classified as non-vegetated areas and excluded from the analysis. The growing season was defined as the period from May to September, consistent with previous studies in the region.

Daily temperature and precipitation data were obtained from the China Meteorological Data Service Center (http://www.resdc.cn). Based on data quality and length of record, 15 meteorological stations within the study area were selected for analysis. These stations provided continuous observations from 1982-2015, which were used to calculate various extreme temperature indices.

1.3 Methods

1.3.1 Trend Analysis The Mann-Kendall test and linear regression were employed to detect trends in NDVI and extreme temperature indices. The extreme-point symmetric mode decomposition (ESMD) method was used to analyze temporal variation characteristics of NDVI. Correlation analysis was performed to examine relationships between NDVI and temperature indices.

The study examined 18 extreme temperature indices, including cold extremes (FD0, TN10p, TX10p, TNn, TNmean) and warm extremes (TR20, TXmean, TX90p, TN90p). Growing season length (GSL) was also calculated. Statistical significance was assessed at $P<0.05$ and $P<0.01$ levels.

3 Results

3.1 Main Findings

(1) The linear trend analysis revealed that NDVI in north China increased significantly at a rate of $0.002 \cdot (10a)^{1}$ ($P<0.05$) during the 1982–2015 period. The ESMD method showed that NDVI increased gradually until 1992, decreased slightly until 2005, and then increased again. Coniferous forest, shrubbery, desert vegetation, grassland, and cultivated vegetation all exhibited increasing NDVI trends, while mixed forest, broadleaved deciduous forest, and alpine vegetation showed decreasing trends.

(2) Spatially, NDVI exhibited a decreasing gradient from southeast to northwest across the study area. Regions with statistically significant NDVI improvement accounted for 33% of north China' s total area. These significant increase areas were primarily located in the Tianshan Mountains and northern Tarim Basin of Xinjiang, the Qilian Mountains, mountainous regions of southern Gansu, the Loess Plateau, Hetao Plain, Lvliang Mountain, Taihang Mountain, and hilly areas of western Liaoning Province. Significant NDVI decreases were mainly observed in the Great Khingan Range, Lesser Khingan Mountains, and Changbai Mountain region.

(3) Among the extreme temperature indices, all cold extreme indices except TNmean and TNn showed decreasing trends, while all warm extreme indices exhibited increasing trends. NDVI was significantly negatively correlated with FD0, TN10p, and TX10p ($P<0.05$), and significantly positively correlated with TNmean ($P<0.01$). Positive correlations were found between NDVI and all warm extreme indices, with particularly significant relationships for TR20, TXmean, TX90p, and TN90p ($P<0.05$). A significant positive correlation was also identified between NDVI and growing season length (GSL) ($P<0.05$).

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