Early vegetation growth onset reduced temperature contrls on summer vegetation growth in temperate China

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1. Introduction

Climate warming has substantially advanced spring phenological development and increased productivity of terrestrial ecosystems. However, the impact of spring phenology on vegetation growth has not yet been thoroughly investigated.

Our study aims to investigate the relative importance of SOS date and climatic factors on the vegetation growth, and we focused on grassland in China to study if the trend of SOS date on grassland vegetation types changes in different time periods.

2. Study area and dataset

Our study focuses on five vegetation types in temperate areas of China, where includes Cold-temperate Needleleaf Forest (CNF), Mixed Needle-leaf and Broadleaf Forests (MF, later also Mixed forests), Deciduous Broadleaf Forests (DBF), Grassland, and Deserts (Figure.1). Croplands were not included in the study, because phenology of crops is mainly affected by human activities. We used GIMMS 8km NDVI data ($NDVI_{3g}$) from Very High Resolution Radiometer (AVHRR) to extracted spring phenology and represent vegetation growth during 1982-2015. In order to reduce the influence of bare soil signals on the NDVI time series, we extracted pixels with mean annual NDVI greater than 0.1. Surface daily meteorological data was extracted from a dataset created by the Cold and Arid Regions Science Data Center at Lanzhou (He and Yang, 2011).

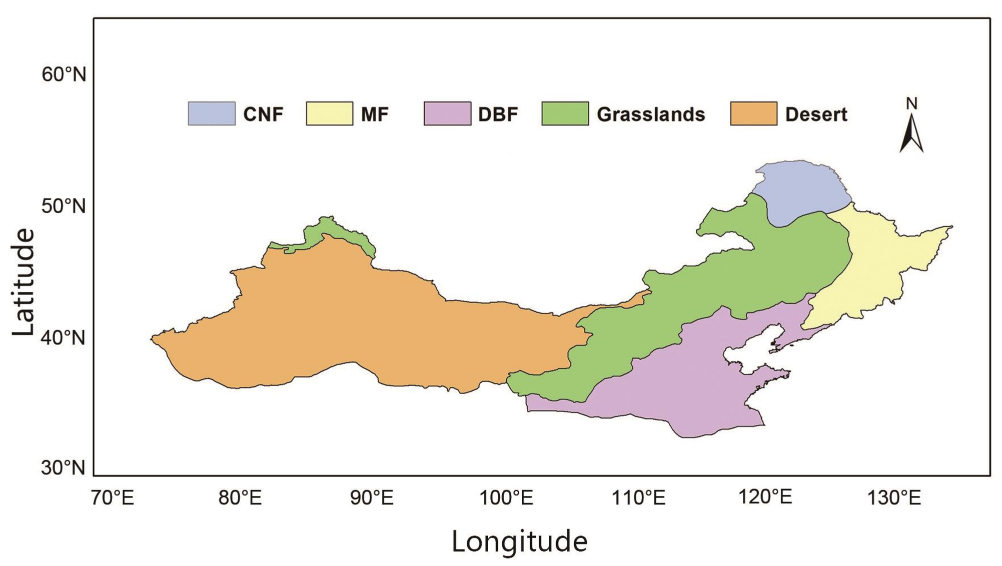

Figure.1 Five vegetation types addressed in the study in temperate areas of China: Cold-temperate Needleleaf Forests (CNF), Deciduous Broadleaf Forests (DBF), Mixed Needle-leaf and Broadleaf Forests (MF), Grassland and Deserts.

3. Methods

We extracted Start of Season (SOS) dates using five standard methods (Table.1) from satellite-derived Normalized Difference Vegetation Index (NDVI) data and explored the spatio-temporal variation in vegetation growth and its linkages to spring phenology and climatic factors using partial correlation analysis.

Method	Data filter function	Threshold determination
Gaussian	NDVI(t) = a+b $\times e^{-((t-c)/d)^2}$	NDVI ratio exceeded 0.5
Spline	NDVI(t) = $a_t t^3 + b_t t^2 + c_t t + d_t$	NDVI ration exceed 0.5
Polyfit	NDVI(t) = $a_0 + a_1 t + a_2 t^2 + a_3 t^3 + \cdots a_n t^n$	Maximum variation
HANTS	NDVI(t) = $a_0 + \sum_{i=1}^{n} a_i \cos(w_i t -$	Maximum variation
Timesat-SG	NDVI(t) = $\frac{\sum_{i=-m}^{i=m} C_i NDVI_{j+i}}{N}$	20% of NDVI amplitude

Table.1 Summary of five methods in determining the date of SOS from satellite-derived NDVI data

4. Results

4.1 Spatial differences and temporal trends of spring phenology

The start of Season (SOS) days mean values estimated by the five methods and the mean standard deviation value of different methods are shown in fig 2.

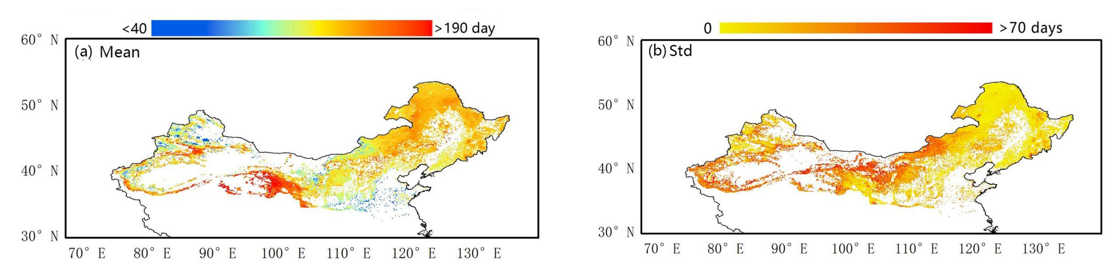

Figure.2 The mean Start of Season (SOS) dates in temperate China during 1982–2015, as estimated by analyzing NDVI data with five methods (a). And (b) its standard deviation of the SOS estimates obtained with the five methods.

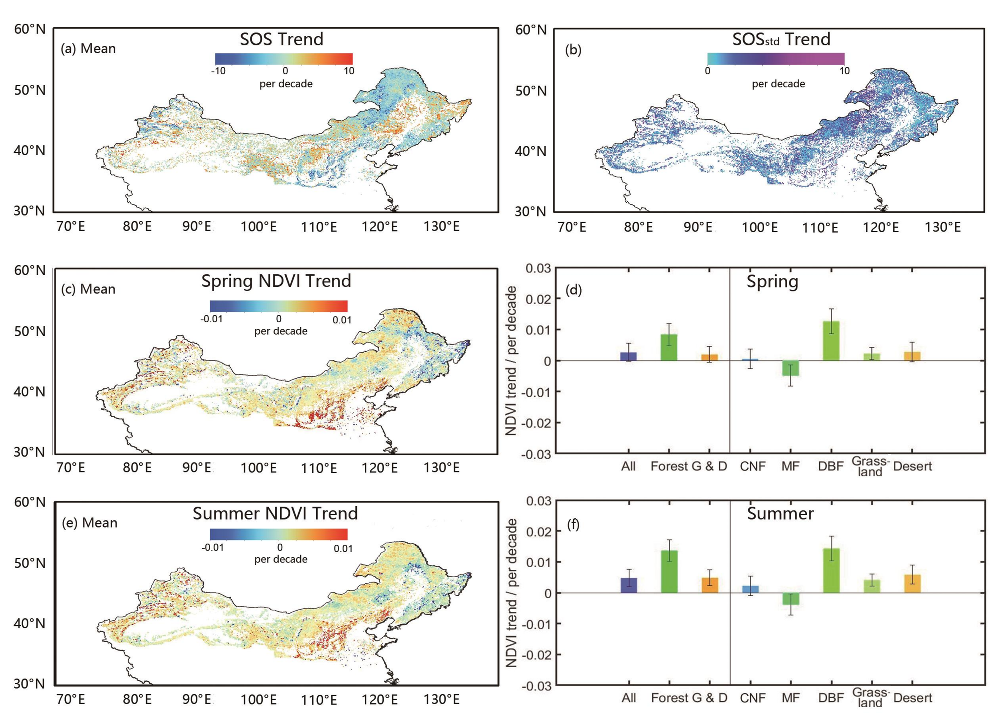

Figure.3 Trends during 1982-2015 in spring phenology and spring and summer vegetation growth in temperate China.

We found that in more than 60% of study area the SOS dates advanced, with a mean rate of -1.16 ± 0.25 d per decade. And Both spring (Fig. 3c,d) and summer vegetation growth (Fig. 3e,f) showed an increasing trend during 1982 – 2015.

4.2 Drivers of vegetation growth in spring and summer

The partial correlation coefficients quantifying the effects of spring phenology (SOS days) and the climatic factors on spring and summer growth are displayed in Figs. 4 and 5. SOS day was found as dominant factor in both spring and summer vegetation growth in the three forested vegetation types (Figs. 4b, c, d, 5b, c, d,) but the dominant factor varied between spring and summer in grassland and deserts (Figs. 4e, f, 5e, f,).

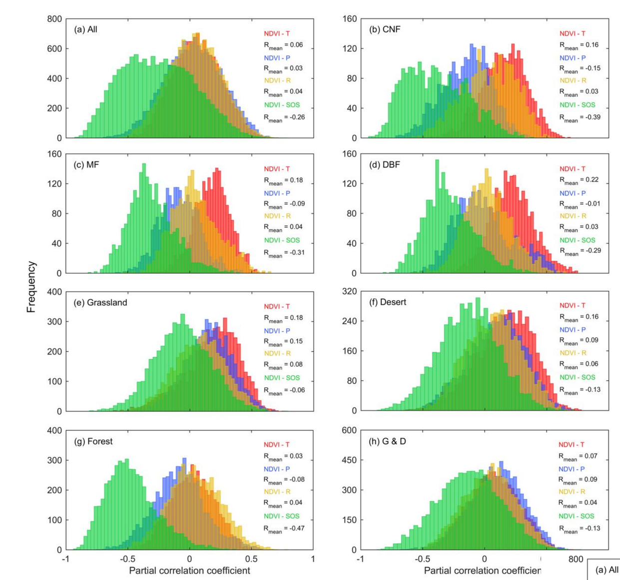

Figure.4 Partial correlation coefficients between spring growth, as estimated by the average monthly composite NDVI during March – May, and air temperature (red), precipitation (green), radiation (yellow), and spring phenology as quantified by the Start of Season (SOS) days (orange).

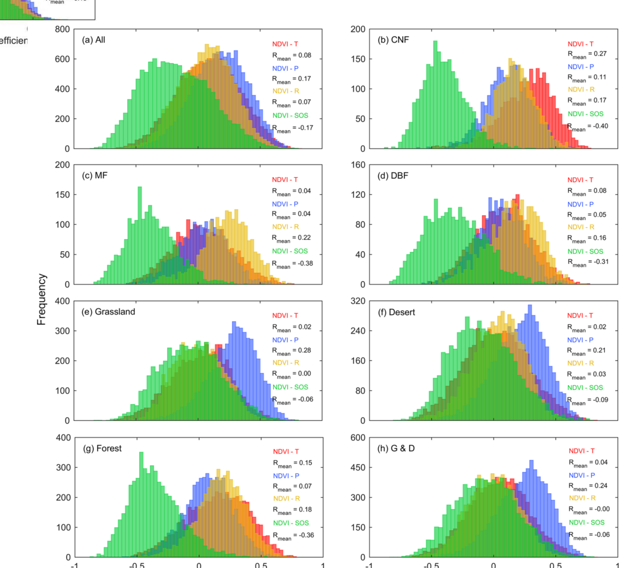

Figure.5 Partial correlation coefficients between summer growth, as estimated by the average monthly composite NDVI during June – August, and air temperature (red), precipitation (green), radiation (yellow), and spring phenology as quantified by the Start of Season (SOS) days (orange).

4.3 Differences in spring phenology between 1982-1998 and 1999-2015 in Grassland

Then we focused on the spring phenology in grassland, the mean date of the start of the season (SOS) was day of year (DOY) 116 over 1982-2015. The SOS date displayed a notable spatial variability,with a generally decreasing trend from northeast to southwest. And the standard deviation (Std) of the SOS displayed a significant increasing trend from northeast to southwest. The pheonology trend over the whole study area was a slight delay in SOS (+0.02 days/year), with this trend being significant for 29.8% of the area (fig. 6).

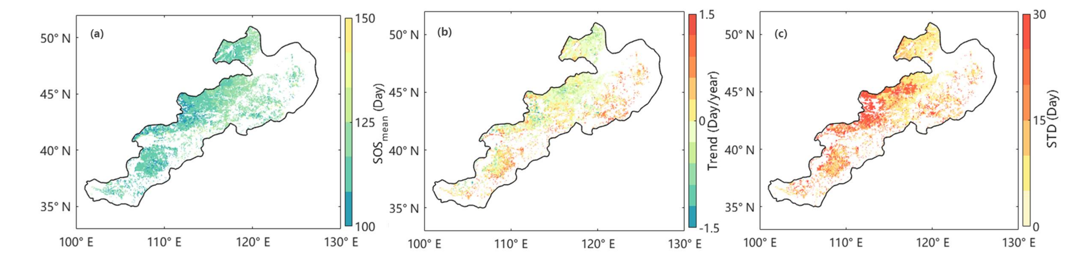

Fig 6 (a) Spatial distribution of mean SOS date, and temporal trends during the entire study period 1982-2015 of (b) SOS dates, and (c) the standard deviation of SOS dates.

we divided the entire study period into two sub-periods: 1982-1998 and 1999-2015. We found the average SOS dates slightly advanced by about two days from the first (DOY 119.6±18.4) to the second sub-period (DOY 117.5±13.3). Interestingly, the inter-annual variability of SOS dates between these two periods did differ significantly, with less SOS date fluctuations during the first (mean Std = 8.8±1.1 days) than during the second sub-period (mean Std = 10.3±1.1 days) (Fig. 7).

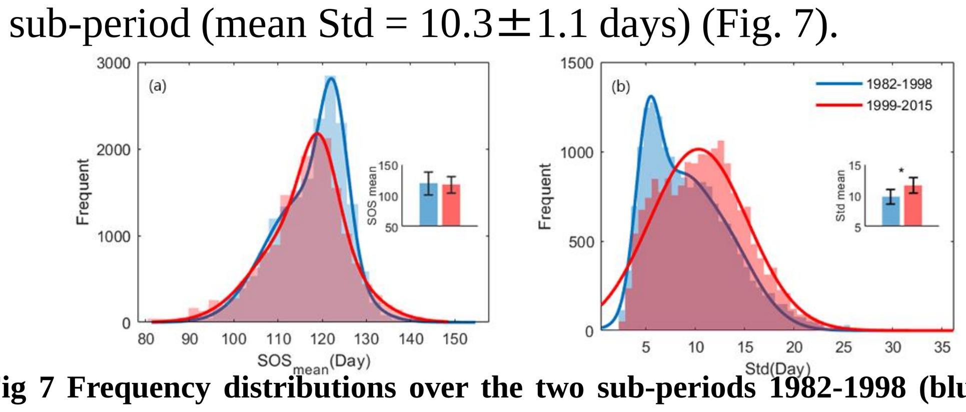

Fig 7 Frequency distributions over the two sub-periods 1982-1998 (blue) and 1999-2015 (red) of the mean SOS date over the whole study area and (b) its standard deviation. The symbol * indicates a significant difference between 1982-1998 and 1999-2015.

5. Conclusion

We found that SOS was the main determinant of spring vegetation growth across the forests and grassland , rather than climatic factors. And its effect on summer vegetation growth was weaker in all vegetation types, and in grassland precipitation was the main determinant of summer growth. Besides, our study found that spring phenology in grassland was different in two time periods, which means climate factors control on spring phenology may have changed in grassland.

References

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