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Short communication

Effect of grassland vegetation on diurnal temperature range in China's temperate grassland region

Xiangjin Shen[a,*], Binhui Liu[b], Daowei Zhou[a], Xianguo Lu[a]

[a] Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun 130102, China
[b] College of Forestry, Northeast Forestry University, Harbin 150040, China

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ABSTRACT

Based on the observation minus reanalysis (OMR) method, this study explored the impacts of grassland vegetation on diurnal temperature range (DTR) in China's temperate grassland region from 1982 to 2005. Results showed that temperate grassland vegetation generally tended to decrease growing-season DTR, but the degree of influence of vegetation on DTR was different among different grassland types. From 1982 to 2005, the decline of OMR trend in growing-season DTR was the largest for temperate meadow (−0.191 °C/decade), moderate for temperate steppe (−0.093 °C/decade) and the smallest for temperate desert steppe (−0.022 °C/decade). During the whole growing season, grassland vegetation has a similar warming effect on minimum air temperature (T_{min}), and the differences in monthly OMR trends of DTR are mainly determined by the effects of vegetation on maximum air temperature (T_{max}). For temperate meadow and temperate steppe, there were obvious cooling effects of vegetation on T_{max} from July to September due to evaporative cooling feedback, and these cooling effects intensified with the increase of surface vegetation greenness. For temperate desert steppe, due to low vegetation cover and weak cooling feedback, it exerted comparable warming effects on T_{max} and T_{min}, thus having no significant impact on DTR change in any month.

1. Introduction

Vegetation activity is not only affected by climate change, but also plays an important role in the change of regional climate (Woodward et al., 1998). Investigating the impact of vegetation on climate change is becoming an important aspect of climate change studies (Betts, 2001; Fearnside, 2000; Shen et al., 2015a; Xia et al., 2015). Because it is difficult to separate the local change signal from global change, most previous studies used numerical simulation to analyze the influence of vegetation on local climate (Henderson-Sellers et al., 1993; Xue, 1996). Kalnay and Cai (2003) proposed an Observation minus Reanalysis (OMR) method to investigate the influence of land use and land cover change on regional or global climate change. The basis of OMR method is that the surface observations data included all the climate functions, whereas the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis (hereafter NNR) data are insensitive to land properties as they do not assimilate surface observations over land (Kalnay and Cai, 2003; Lim et al., 2005). Therefore, the differences between the observations and reanalysis can be attributed to the effects of land surface (Kalnay and Cai, 2003). During the past few years, the OMR method has been wildly used to examine the effects of vegetation on regional or global climate change (Lim et al., 2008; Fall et al., 2010; Yang et al., 2010; Wang et al., 2014).

As an important climate change index, diurnal temperature range (DTR) is thought to provide more information about climate change than the average temperature (Liu et al., 2004). Many studies have found that vegetation can have significant impacts on local and global DTR change (e.g. Collatz et al., 2000; Zhou et al., 2007; Wi et al., 2011). Given the complexity of the climatology (Liu et al., 2004), further investigations on the mechanisms of DTR changes are still needed.

As a widespread vegetation type in the world, grassland vegetation is reported to play an important role in regulating regional climate (Piao et al., 2006). China's temperate grassland region is regarded as the third largest grassland area of the world (Lee et al., 2002). Some studies have investigated the response of average air temperatures to grassland vegetation in China's temperate grassland region (Chen et al., 2009; Shen et al., 2015b, 2016), but the impacts of grassland vegetation on DTR in this region have not been reported so far. If we only focus on the changes of average

* Corresponding author.
E-mail address: shenxiangjin@iga.ac.cn (X. Shen)

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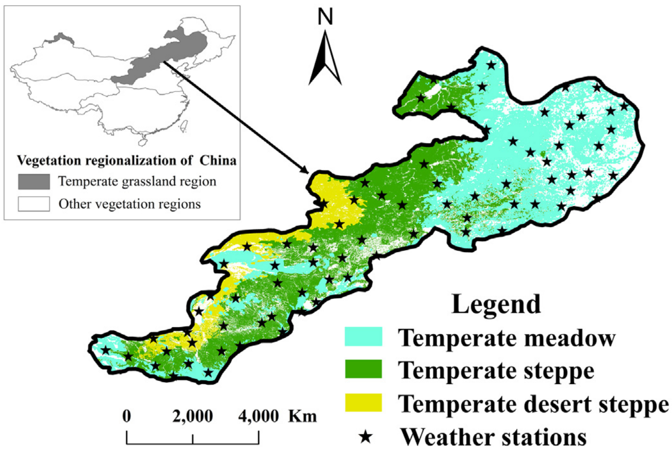

Fig. 1. The locations of 77 weather stations and distribution of unchanged temperate grasslands in China's temperate grassland region from the 1980s–2005.

air temperature, a lot of information about the possible impacts of vegetation on surface air temperature will be ignored. Understanding the impact of grassland vegetation on DTR change in this region will contribute to understand the mechanism of regional DTR change, and to project further climate change in China's temperate grassland region.

Based on the OMR method, this study investigated the impacts of grassland vegetation on DTR during the growing season in China's temperate grassland region. Following many previous studies (Piao et al., 2006; Shen et al., 2015b), the growing season was defined as April–October for temperature grasslands of China. Considering the possible different responses of surface air temperature to different grassland types (Shen et al., 2015b), we examined the OMR trends in DTR for different grassland types respectively.

2. Data and methodology

Data used in this study include monthly maximum air temperature (T_{max}) and minimum air temperature (T_{min}) from both NCEP-NCAR reanalysis (NNR) and observation, Normalized Difference Vegetation Index (NDVI) during the growing seasons of 1982–2005. The NNR temperature data were available on each Gaussian grid, and they were obtained from the Physical Sciences Division of NOAA/Earth System Research Laboratory. The observation data were from 77 weather stations of the study area (Fig. 1), provided by the China Meteorological Administration. The initial quality control of these observation data has been performed by the China Meteorological Administration, and we further homogenized these data as described in our previous study (Shen et al., 2014). With the vigorous data assurance policy, the quality and consistency of these data have been guaranteed (Shen et al., 2014). NDVI has been widely used as indicators of vegetation growth. The NDVI data in this study were derived from Global Inventory Modeling and Mapping Studies (GIMMS) NDVI dataset (GIMMS NDVI1 g), with a temporal resolution of 15 day and a spatial resolution of 8 km (Tucker et al., 2005). These NDVI data had been processed with geometric, radiometric and atmospheric corrections (Tucker et al., 2005). In this study, the NDVI data were used to investigate the relationships between grassland vegetation change and surface air temperatures. Data used in this study also included two land-use maps covering the study area in the 1980s and 2005, which were obtained from National Earth System Science Data Sharing Platform. These two maps have a spatial resolution of 100 m, with 6 first levels of land-use categories and 25 s levels of land-use categories (Shen et al., 2015b).

This study was investigated in China's temperate grassland region, which is distributed in northern China and dominated by arid and semi-arid climate (Shen et al., 2015b). Temperate grassland vegetation in the study area can be divided into three types: temperate meadow, temperate steppe and temperate desert steppe (Shen et al., 2015b). By using the OMR method (Kalnay and Cai 2003), this study investigated the OMR trend (difference between the observations and NNR trend) of DTR for different grassland types. In order to exclude the impact of land-use change on OMR tends, we extracted unchanged (the land use type belongs to grassland from the 1980s to 2005) patches of temperate grasslands (Fig. 1) by comparing two land use maps in the 1980s and 2005. First, we extracted the grassland vegetation patches from two land use maps by setting other land use categories invalid; then we made raster subtraction calculation (image subtraction) and got the unchanged patches from the resulting raster (Shen et al., 2015b). Following the procedures which were described in detail in our previous paper (Shen et al., 2015b), we processed the temperature and NDVI data, and calculated the OMR trend for each grassland type.

3. Results and discussion

3.1. Time series of growing season surface air temperature

We compared the growing-season temperature (including T_{max} and T_{min}) anomalies from observations and NNR averaged grassland vegetation covered regions during 1982–2005. Results showed a good agreement between observed and reanalyzed temperature anomalies (Fig. 2(a), (b)), confirming that NNR temperature captures the inter-annual variability of observed temperature very well (Kalnay and Cai, 2003; Kalnay et al., 2006; Lim et al., 2008; Fall et al., 2010). During 1982–2005, the observed and reanalyzed growing-season T_{max} showed a warming trend of 0.528 and 0.291 °C/decade; and growing-season T_{min} of observations and reanalysis increased at a rate of 0.581 and 0.261 °C/decade respectively. For both T_{max} and T_{min}, the increasing rate of observations was larger than that of reanalysis, which may be attributed to the poor reproduction of temperature change signal related to land effects in the reanalysis data (Lim et al., 2008). Because of this, the OMR time series of T_{max} and T_{min} obtained by subtracting reanalysis from the observations show a positive trend (0.237 and 0.320 °C/decade, respectively). During 1982–2005, the OMR trend in growing-season DTR was −0.083 °C/decade. It indicates that grassland vegetation in the study area generally tend to decrease growing-season DTR due to asymmetric warming effects on T_{max} and T_{min}.

3.2. Comparison of the OMR temperature trends with different vegetation types

Fig. 2(c) shows the decadal OMR trends in growing-season T_{max}, T_{min} and DTR for different temperate grassland types during 1982–2005. The results showed that the OMR trends in growing-season T_{max} and T_{min} were positive for all the grassland types (Fig. 2(c)). The increasing OMR trends of both T_{max} and T_{min} were the largest for temperate desert steppe, moderate for temperate steppe and the smallest for temperate meadow (Fig. 2(c)). The different vegetation properties and growth environments of three types of grassland may contribute to this difference. It is well known that the evaporative cooling feedback could damp the warming of surface air temperature, especially during the daytime (Yang et al., 2010). For temperate meadow which is dominated under conditions of abundant precipitation, high soil moisture and strong evaporation feedback could damp the surface warming (Shen et al.,