Responses and Changes to Reviewers' Comments

Dear Reviewers,

We really appreciate your helpful suggestions and comments. We have carefully revised the manuscript and addressed all comments. In terms of content, we mainly increased the experimentation of CRU and ERA5 meteorological data to enhance the reliability of the article results. We also conducted a mechanism analysis to investigate how drought regulates the relationship between vegetation and precipitation (temperature). As for the methodology, we detrended all variables before studying the vegetation-climate relationship to prevent statistical analysis independence. Instead of comparing the NDVI and climate relationship between pre- and post-2000, we used multiple sliding windows to emphasize the inter-annual variability of this relationship. In writing, we improved the language use throughout the entire article, made significant changes to the introduction to highlight the innovation of this study, and added descriptions of the interpretation of the results, as well as discussions of the results.

Referee: 2

Introduction

(1) The first paragraph is too short to introduce the background and I find a weak linkage between the two sentences?

Response:

Thank you very much for your comments. We have made significant modifications to the introduction section, not only adding background information but also highlighting the innovation of this study.

We have added a detailed description of previous studies and pointed out the uncertainties: "The changing correlation between climate and vegetation has recently gained some attention. For example, Wang and Yan (2021) found that the correlation between vegetation and temperature has weakened throughout China over the past 34 years. The precipitation threshold required for vegetation growth in Australia had been found to decrease from 1982 to 2010 (Ukkola et al., 2016). Keenan and Riley (2018) measured how vegetation cover responded to temperature changes and found that the limitations imposed by temperature had decreased over time. Zhao and Yu (2021) found an increased association between climate change and vegetation index variation in Northwest China over the past 34 years. However, most of these studies have solely identified the occurrence of the changes in the relationship between precipitation (or temperature) and vegetation. Uncertainties remain regarding the drivers and how they regulate the changes in the relationship"

The diverse response of vegetation growth to climate variables across land surfaces has indeed always been a hot topic. However, variations may also exist in the patterns of changes in the relationship between climate and vegetation across distinct types of land cover, and the mechanisms behind them are also different, which has been confirmed by our results, but this area of research has not received enough attention yet. Therefore, we provided a detailed description in the introduction: " Vegetation greenness patterns display high spatial heterogeneity across different land surfaces (Gao et al., 2017; Wang et al., 2021), and it's response to climate also varies greatly among different terrestrial ecosystems (Yuan et al., 2019a). The influencing mechanisms of vegetation dynamics in diverse vegetation types have been well documented (Cai et al., 2021; Li et al., 2019; Luo and Chen, 2013; Tao et al., 2015; Upgupta et al., 2015; van Oijen et al., 2018; Wu et al., 2021). Based on previous research, it can be easily inferred that variations may also exist in the patterns of changes in the relationship between climate and vegetation across distinct types of land cover, and the mechanisms behind them are also different, but this area of research has not received enough attention yet"

In addition, we added an explanation in the introduction about why Northwest China was selected as the study region: "Northwest China is characterized by vast areas with different land cover types, including grasslands, forests, and barren lands with sparse vegetation. Since the early 1980s, several studies have indicated warmer and more humid conditions in this area (Liu et al., 2013; Shi et al., 2002; Shi et al., 2007; Wang et al., 2020; Wang et al., 2007; Zhang et al., 2021; Zheng et al., 2021). Recent decades have also seen significant changes in the growth of vegetation in this region (Chen et al., 2019; Niu et al., 2019). As a result, Northwest China presents an ideal opportunity for examining the changes in relationship between climate and vegetation across a variety of vegetation types"

（2）Line 60 It's difficult to know what is the "relationship between vegetation and climate" represents here. The long-term trend or the interannual variability of climate? for vegetation greenness? Productivity? Growth? Or others? Also, ' As climate varies with climate ', it's not clear "climate" for what

Response:

Thank you very much for your comments. We have made revisions to all these uncertain parts in the introduction.

（3）The previous efforts on the study topic, the knowledge gap as well as the aim of this study are very ambiguous in Line 60-69. The authors highlight the potential problems in time scales, different time periods and vegetation types, but it's confusing these problems for what? For example, I don't know what are the "different periods", what are the "different vegetation types", and what is the "study period"

Response:

Thank you very much for your comments. We have added a detailed description of previous efforts and removed all of ambiguous statements. We have summarized the deficiencies of previous research: (1). Although the changes in the correlation between climate (precipitation or temperature) and vegetation greenness has recently gained some attention, uncertainties remain regarding the drivers and how they regulate the changes in the relationship. (2). The diverse response of vegetation growth to climate variables across land surfaces has indeed always been a hot topic. However, variations may also exist in the patterns of changes in the relationship between climate and vegetation across distinct types of land cover, and the mechanisms behind them are also different, but this area of research has not received enough attention yet

（4） Given that this research topic is not new, they didn't clarify their improvements or their novelty in this study.

Response:

We are sorry for not adequately describing the background and innovation in the introduction earlier. Now we have made significant modifications to the introduction section, not only adding background information but also clarifying our novelty of this study.

Methods

（5） I can't understand why they use the combined NDVI from GIMMS and MODIS datasets because as far as I know, the GIMMS NDVI has released data at least to the end of 2018.

（6） It's not clear how to combine the two NDVI datasets. The authors only say that they used the pixel-wise linear regression but how to realize it in detail? They need to provide more details to show how they cope with the trend and variability of the newly combined NDVI time series. From Fig. 2, I can only see they compare the pixels of expanded NDVI with the GIMMS NDVI and MODIS NDVI for the overlapped years but this figure can't verify the time series of the expanded NDVI are credible for their long-term trend and variability.

Response:

Thank you very much for your comments. To avoid errors caused by combining different datasets, we are currently only using the GIMMS NDVI for our research

（7） As the previous study (Frankenberg et al., 2020, science) points out, there are systematic biases in the AVHRR for the pre-2000 time series, the authors should take caution with the interpretation of potential change before and after 2000 when using GIMMS NDVI

Response:

Thank you very much for your comments. Instead of comparing the NDVI and climate relationship between pre- and post-2000, we now use multiple sliding windows to emphasize the inter-annual variability of this relationship.

（8） The authors didn't state if the climate and vegetation data were detrended

prior to calculating the correlations to avoid the issues like independence of the statistical analysis. If not, I think their results are not credible

Response:

Thank you very much for your comments. We have detrended all variables before studying the vegetation-climate relationship to prevent statistical analysis independence, and the description was stated in Methodology.

Results

(9) The authors completely fail to interpret their results because they didn't provide any data to support what they claimed in the result section. For example, the values of the temporal trend, the values of the correlation, etc

Response:

Thank you very much for your comments. We have added description that interpret our results, for example, this paragraph for the results below: "The statistics categorized by vegetation types show that, $R_{NDVI-GP}$ and $R_{NDVI-GT}$ have shown a declining trend in approximately 81% and 71% of the entire forest area in northwest China, respectively. In the grassland, $R_{NDVI-GP}$ exhibits almost an equal distribution area between positive and negative trends in terms of area, whereas $R_{NDVI-GT}$ displays an upward trend in the majority of the area, accounting for approximately 56%. As for the barren land, the areas occupied by the positive and negative trends of $R_{NDVI-GP}$ or $R_{NDVI-GT}$ are roughly equal."

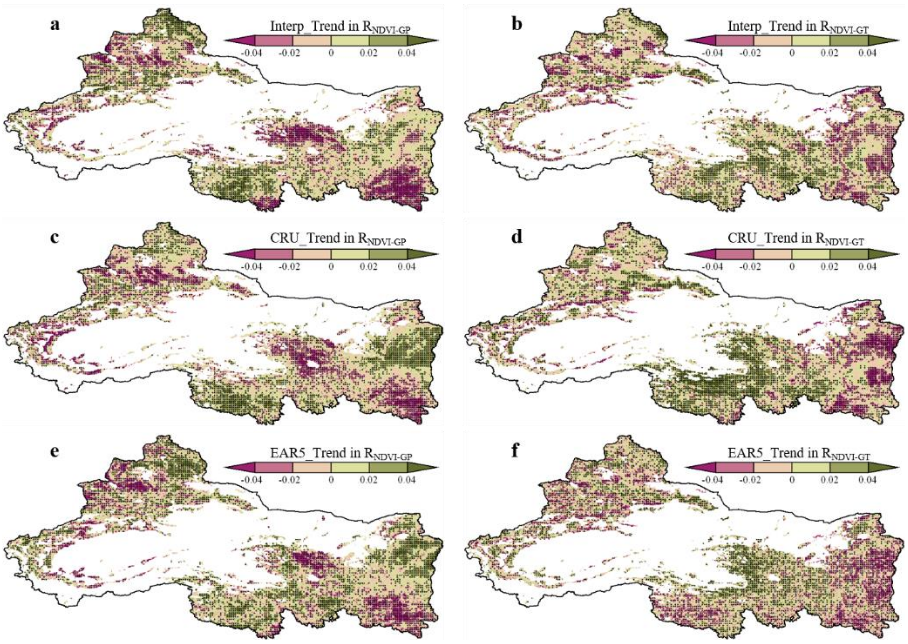

Figure 5. Spatial distribution of trends in $R_{NDVI-GP}$ and $R_{NDVI-GT}$ at a 13-year sliding window. Here, $R_{NDVI-GP}$ is the partial correlation coefficient between GS NDVI and GS precipitation from Interp (**a**), CRU (**c**), and ERA5 (**e**); $R_{NDVI-GT}$ is the partial correlation coefficient between GS NDVI and GS temperature from Interp (**b**), CRU (**d**), and ERA5 (**f**). They are calculated using a 13-year sliding window during 1982-2015. All variables are detrended. The

dots indicates the regions with significant trend in $R_{NDVI-GP}$ (or $R_{NDVI-GT}$) ($P < 0.05$)

（10）They only show the results from their figures but they never explain why those findings they got, what is mechanisms underlying their findings, and any literature to support their findings. Therefore, I don't know if their findings are robust and reliable. I think they need to discuss their results by comparing with previous studies

Response:

Thank you very much for your comments. We have added sentences for supporting our findings by literature for example, this paragraph for the results below: "The relationship between temperature, precipitation, and NDVI has a close connection with their spatial distribution in the northwest region of China. Generally, when precipitation is low, there is a strong correlation between NDVI and precipitation. However, as precipitation increases, the correlation between NDVI and precipitation gradually weakens, and even becomes negative (Figure 3a, b, c). This is because in areas with water shortages, vegetation growth is highly dependent on precipitation, whereas in relatively humid areas, vegetation growth is less dependent on precipitation (Huxman et al., 2004; Maurer et al., 2020). This also makes the correlation between NDVI and precipitation stronger in areas with sparse vegetation and bare ground compared to grassland and forest. When the temperature is low, the correlation between NDVI and temperature increases as temperature increases. However, when the temperature reaches a certain value, the correlation between NDVI and temperature decreases as the temperature continues to increase (Figure 3d, e, f), indicating that current enhanced greening trend will decline or even disappear (Piao et al., 2006). Previous studies have shown that vegetation growth usually has an optimal temperature, which is the temperature at which vegetation growth is most favorable (Huang et al., 2019; Xu et al., 2013). In areas with low temperatures, vegetation growth is highly dependent on temperature, while in areas with high temperatures, temperature increase can hinder vegetation growth. Therefore, grassland in high-altitude areas is positively correlated with temperature, while sparse vegetation on bare ground in areas with high temperatures is negatively correlated with temperature"

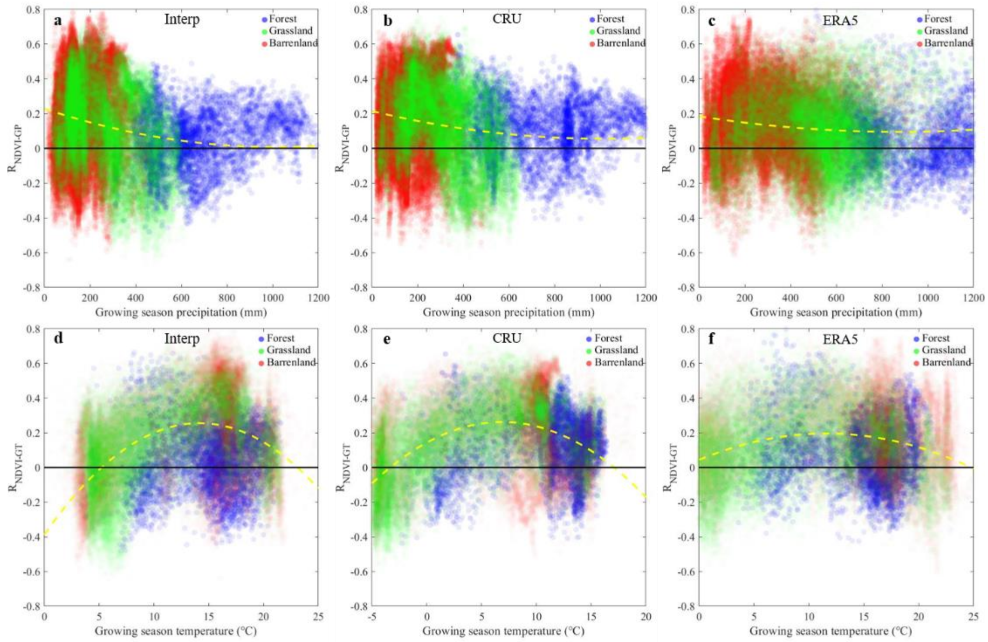

Figure 3. Scatter plots between $R_{NDVI-GP}$ and precipitation from Interp (a), CRU (b) and ERA5 (c), and scatter plots between $R_{NDVI-GT}$ and temperature from Interp (d), CRU (e) and ERA5 (f). Here, $R_{NDVI-GP}$ is the partial correlation coefficient between GS NDVI and GS precipitation, and $R_{NDVI-GT}$ is the partial correlation coefficient between GS NDVI and GS temperature (All variables are detrended). The yellow dashed line is the quadratic fit for all the scatters.

In addition, we also conducted a mechanism analysis to investigate how drought regulates the relationship between vegetation and precipitation (temperature) in Discussion. Considering that the decreased temperature sensitivity of tree growth may be attributed to the potential impact of increased drought stress, which can alter the response of plant growth to temperature change (D'Arrigo et al., 2004; Piao et al., 2006) . Reduce in soil water and increase in atmospheric aridity caused by drought will constrain vegetation growth by affecting plant photosynthesis (Piao et al., 2014; Yuan et al., 2019b). Hence, we focus on two mechanisms of vapor pressure deficit (VPD) and soil water volume (SWV), as we examine how their trends regulate the relationship between NDVI and temperature or precipitation. The results are shown below.

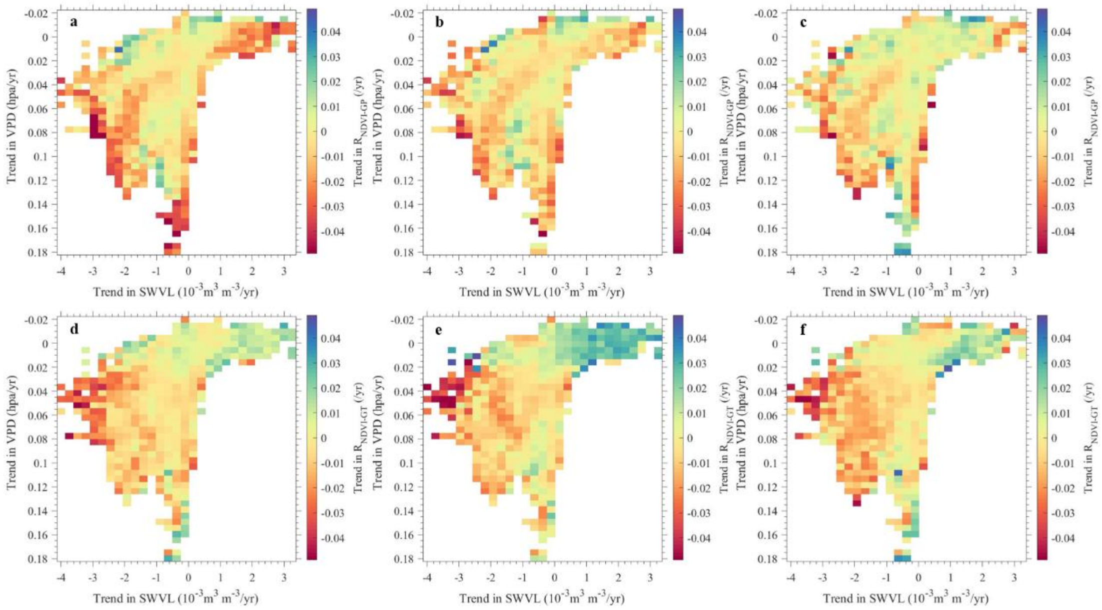

Figure 6. Average trend of $R_{NDVI-GP}$ and $R_{NDVI-GT}$ at a 13-year sliding window in a climate phrase space. Here, $R_{NDVI-GP}$ is the partial correlation coefficient between GS NDVI and GS precipitation from Interp (**a**), CRU (**b**), and ERA5 (**c**); $R_{NDVI-GT}$ is the partial correlation coefficient between GS NDVI and GS temperature from Interp (**d**), CRU (**e**), and ERA5 (**f**). They are calculated using a 13-year sliding window during 1982-2015. All variables are detrended. The climate space is delineated by changes in GS soil water volume (SWV) and changes in vapor pressure deficit (VPD).