

The impact of global warming on the ecological environment of the Tibetan Plateau

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Abstract. The Qinghai-Tibet Plateau is an important climate change indicator in China, and with the rapid development of China's industrialization and population increase in recent decades, the greenhouse gas emitted by humans has greatly strengthened the greenhouse effect, resulting in an increase in temperature, and the overall heat income is greater than the expenditure, resulting in changes in the climate and environment of the Qinghai-Tibet Plateau. Based on the CMIP5 multi-model simulation prediction results, the response of plateau vegetation to 2 °C temperature rise was studied, and the sensitivity of plateau vegetation to climate factor changes was discussed. Leaf Area Index (LAI) increased significantly compared with the historical period, and the plateau turned greener, among which the LAI and vegetation carbon storage in the central part of the plateau increased most significantly, and the Sanjiangyuan area was the area with the fastest vegetation increase. After warming, the area of bare land decreased rapidly, the vegetation coverage rate increased overall, the grassland showed an increasing trend in most areas, and the decreasing trend of forest slowed down. However, if the temperature increases too much, it will lead to the shrinking of the living space of some cherished alpine organisms, the melting of large areas of glaciers, and the increase of the height of the snow line, which will have a great impact on the stability of the ecological environment and the conservation of species diversity in China.

Keywords: warming of the Tibetan Plateau, greenhouse effect, temperature, ecological environment.

1. Introduction

The Qinghai-Tibet Plateau, known as the "third pole of the earth", is located in the middle of the troposphere of the mid-latitude westerly wind belt, with obvious vertical and horizontal zonal characteristics and complex climate zones. Because the Tibetan Plateau is located at high latitudes and altitudes, it is more susceptible to global warming factors and more sensitive to global warming[1]. The results show that under the background of 2 °C, there is a high-value region with a temperature rise of 3.0 °C or more in the Tibetan Plateau, which is larger than that of regional climate temperature rise in China (2.7~2.9 °C), and may be the most sensitive region in China to global warming. In the case of continuous global warming in the future, the Qinghai-Tibet Plateau will continue to warm, and the compound risk of climate and ecological environmental disasters will increase. The results of the CMIP5 study show that the Tibetan Plateau will warm by about 2°C by about 15 years and by 3°C by nearly 20 years compared to the global average, and even warmed by up to 8.5°C in 2100 compared with the climate state in 1850–1900 under the RCP7.5 emission pathway [2]. With the increasing radiative

forcing (mainly greenhouse gas emissions), the amplification effect of warming over the Tibetan Plateau will be further intensified in the future, which will lead to faster changes in the intensity, duration and frequency of extreme weather in the region. Therefore, it is of great significance to study the warming of the Tibetan Plateau for the changes of the ecological environment in the region, which is conducive to the management of the plateau ecosystem, and can provide a scientific basis and direction for the conservation of plateau ecological diversity.

The Qinghai-Tibet Plateau is also an important ecological security barrier in China, and due to the relatively fragile ecological environment[3], it is difficult to recover in a short period of time after being damaged, so the response of the climate and environment in this region to global warming is first reflected in the vegetation change. Based on the importance of vegetation on the Tibetan Plateau for the protection of the plateau ecological environment, national biosecurity and regional economic development, scholars at home and abroad have carried out a lot of work on the vegetation change of the plateau in recent decades, and some studies have shown that with the warming of the climate, the vegetation of the plateau shows regional changes, and the normalized difference vegetation index (NDVI) is indicated in the growing season (May-September) and LAI in Tibet. The increase in the southeast was dominated and the plateau as a whole showed a trend of "greening", the plateau vegetation regreening period generally showed an early trend, the plateau tree line showed an upward trend, the alpine steppe plant species richness and diversity decreased, the plateau vegetation productivity generally showed an increasing trend, and the carbon storage of the plateau ecosystem increased[4,5]. Due to environmental and environmental constraints, the lack of comprehensive observation of multi-circle layers on the Qinghai-Tibet Plateau in China is the biggest obstacle to the study of the response of plateau vegetation to climate change.

This paper studies the changes of ecological environment under the influence of warming on the Tibetan Plateau, so as to provide a reference for the maintenance of ecological security of plateau vegetation and the formulation of relevant environmental protection policies.

2. Data Sources

2.1. Data Sources

The data used are derived from the 8 models of CMIP5 in RCP8.5. The simulation results under the concentration emission pathway include four variables: precipitation rate, air temperature, vegetation leaf area index (LAI), and vegetation cover. Previous studies have shown that these eight models can well reproduce the spatial and temporal distribution characteristics of plateau vegetation LAI in the historical period, so these eight models were selected as the basis for this study[4].

3. The impact of global warming on the Tibetan Plateau and its ecological environment

3.1. Amplification effect of warming on the Tibetan Plateau

Over the past half-century, as the greenhouse effect has intensified in China, the average temperature in China has increased, and the Tibetan Plateau has warmed more significantly. The results show that there are complex regional differences and seasonal variations in the warming of the Tibetan Plateau, which is highly dependent on altitude[6,7]. The warming of the Tibetan Plateau is largely caused by the increase in greenhouse gas emissions caused by human activities, which changes the local radiative forcing of the plateau caused warming[8]. According to the experimental data, winter is the season with the most significant amplification effect of warming on the Tibetan Plateau, which is about 1.4 times that of the global average. The important physical processes responsible for the warming of the Tibetan Plateau are roughly as follows: (1) snow cover albedo feedback. The results show that: (2) The impact of cloud cover changes. The increase of low cloud cover at night will enhance the atmospheric inverse radiation, while the decrease of cloud cover during the day will weaken the ability of clouds to reflect solar shortwave radiation, thereby promoting the near-surface warming of the Tibetan Plateau. (3) With global warming and evaporation, the increase of water vapor content over the Tibetan Plateau will also

strengthen the downward reflected long-wave radiation of the atmosphere, which will promote the increase of near-surface temperature over the Tibetan Plateau. (4) Effects of aerosol particles. It can affect the temperature change of the plateau by directly affecting the radiation, as well as by affecting the macro and micro characteristics of clouds over the plateau. (5) Atmospheric circulation anomalies caused by air-sea interactions also play a significant role in warming the Tibetan Plateau[7,9-12]. Among them, the enhanced evaporation of the Tibetan Plateau leads to an increase in the water vapor content in the air, which in turn increases the cloud cover and air humidity, which increases the forest vegetation coverage of the underlying surface of the Tibetan Plateau, and promotes the development of the ecosystem of the Tibetan Plateau to a certain extent. However, for permanent glacier areas above 6000m above sea level, the amplification effect of warming leads to the rise of the snow line height and the melting of large areas of glaciers, which will lead to the loss of a large amount of solid water resources, and due to the undulating terrain of the Qinghai-Tibet Plateau, a large amount of glacial meltwater flows downstream between the valleys, which will lead to the increase of natural disasters such as flash floods in the Qinghai-Tibet Plateau, and the degree of harm will be aggravated. At the same time, many ancient viruses contained in glaciers will be released at the same time, causing immeasurable and devastating damage to the local and global biosphere.

Therefore, the warming of the Qinghai-Tibet Plateau, although to a certain extent, has promoted the expansion of the ecological environment area such as forests and grasslands on the Qinghai-Tibet Plateau, so that it can promote the water conservation capacity, the production and maintenance of oxygen, and the regulation of climate warming and humidification. However, the loss of permanent glaciers is still unpredictable and destructive to the overall ecological environment of the Qinghai-Tibet Plateau.

3.2. *Changes in grassland and vegetation coverage on the underlying surface of the plateau*

The underlying surface types of the plateau are mainly bare soil and grassland, among which grassland is the most important vegetation cover type, and the proportion of forest is relatively low.

Figure 1 shows the spatial distribution, trend and temporal variation of bare soil coverage. Fig. 1(a) shows that the bare land coverage area of the plateau during the historical reference period is extensive, and the bare soil coverage rate is between 20%~30% in the Qaidam area of Qinghai, the western and northern parts of the northern Tibetan plateau, and the southwestern part of Tibet. Compared with the historical reference period, the area covered by the bare soil on the plateau was significantly reduced during the 2 °C warming period, and the reduction area mainly occurred in the area where the bare soil coverage rate was relatively concentrated (the bare soil coverage rate was higher than 20%), and the regional average bare soil coverage rate decreased by 5%~10% compared with the historical reference period (Fig. 1(b)). In different periods of climate warming, the area of bare soil on the plateau decreased significantly at different rates: in the historical reference period, except for the middle and upper reaches of the Sanjiangyuan region, which showed a relatively slow decreasing trend (the reduction rate was $5\% \cdot (100a)^{-1}$ in most areas, which did not pass the 95% reliability test), the northern and western parts of the northern Tibetan Plateau decreased rapidly at a rate of $20\% \cdot (100a)^{-1} \sim 30\% \cdot (100a)^{-1}$, and the bare soil decreased mainly in the 2 °C warming period Distributed in the southern part of the northern Tibetan plateau and the lower reaches of the Sanjiangyuan region, the bare soil in these areas decreased at a rate of more than $20\% \cdot (100a)^{-1}$, almost twice that of the historical reference period [$-10\% \cdot (100a)^{-1}$] [Fig. 1(c), (d)]. From Fig. 1(d), it can also be found that the areas with little bare soil change in the middle and upper reaches of the Sanjiangyuan and Qaidam Basin corresponding to the historical reference period showed a slight increase trend during the 2 °C warming period, but most of the increase areas did not pass the 95% reliability test, which inferred that the increase in bare soil in these areas may be related to the uncertainty of the simulation results caused by the inconsistency of multi-model results. The increase in bare soil seen in Figure 1(d) may be related to the uncertainty of the multimodal results.

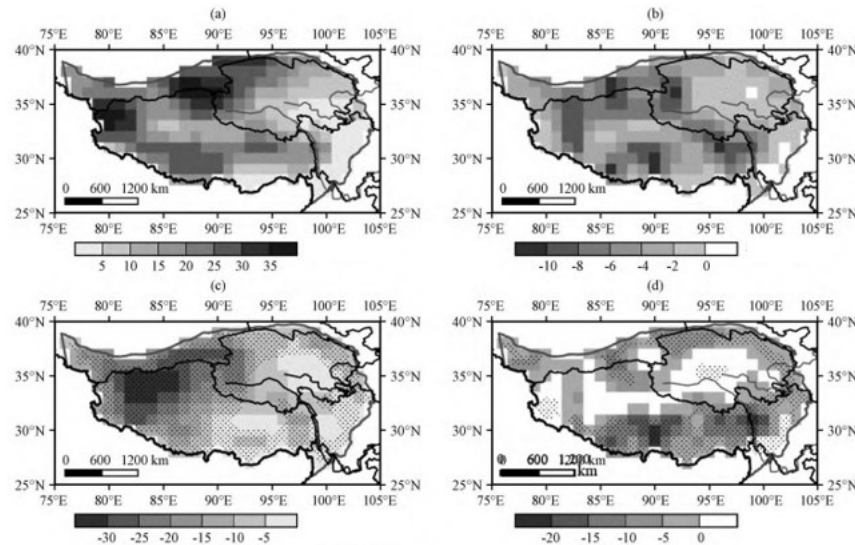


Figure 1. Spatial distribution of bare ground coverage fraction during historical period (a) and its changes [(2026 -2055) minus (1971 -2000)](b), and distribution of fraction variability (linear trend)[unit: $\% \cdot (100a) - 1$] during historical period (c) and 2 °C global warming (d)

The rapid decrease of bare land cover in the plateau under the background of warming is related to the change of vegetation cover. Grassland is the most important, most widely distributed and most representative vegetation cover type on the Qinghai-Tibet Plateau, and the grassland resources of the Qinghai-Tibet Plateau account for 1/3 of the total grassland resources in China, which is the largest natural grassland in China. The study of the change of plateau grassland cover under the background of global warming is of extensive significance for the study of the response characteristics of plateau alpine vegetation to climate change, and also has important practical significance for the protection of grassland resources in China.

3.3. Changes in forest cover on plateaus

Although the area covered by forests on the plateau is relatively small, the distribution of the response of alpine vegetation to alpine vegetation is also very representative of the changes in forest cover on the plateau under the condition of continuous warming in the future, due to the problems of "upgrading" and "transitioning" vegetation types in warm environments. Previous studies have shown that the forest cover simulated by CMIP5 multi-model ensemble reaches half of the total area of the plateau, mainly distributed in the southeastern edge of the plateau, the Sichuan-Tibet Gorge and the southern Tibetan valley, the Qaidam Basin, and parts of the Qinghai Plateau. The results show that plateau forests are only distributed in a small number of areas such as the southern and southeastern margins of the plateau, and the simulation error of the CMIP5 multi-model is mainly caused by the bias of the vegetation model in the coupled model[4,13]. In view of this, this paper only examines the trend change of forest distribution in the southeast edge of the plateau during the historical reference period and the temperature rise period to study the response of forest distribution on the plateau to warming. Compared with the historical reference period, the forests in the southern and southeastern margins of the plateau decreased slightly during the 2 °C warming period, and on the whole, the forest coverage in the southern and southeastern margins of the plateau showed a significant decreasing trend (through the 95% reliability test) during the historical reference period, especially in the 80~90s of the 20th century (after 1992), the interannual variability slowed down, and the forest decline trend slowed down during the 2 °C warming period [Fig. 2], and the coverage rate increased in the middle and late 21st century.

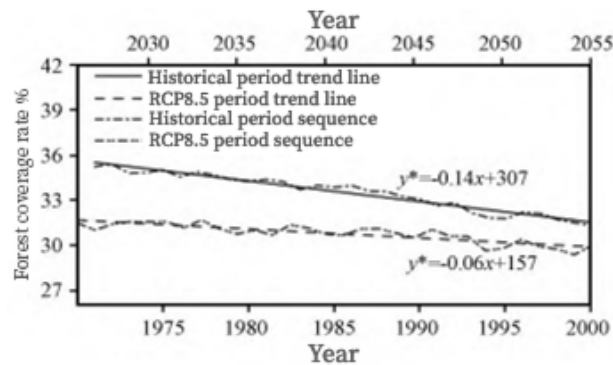


Figure 2. Region-averaged fraction time series over the forest-covered area over the QXP. The square at the bottom right corner is real forest-covered area[13]

4. Conclusion

Based on CMIP5 multi-model simulations, this paper explores the response of plateau vegetation to climate change based on the LAI, NPP, main underlying surface types and main vegetation types of the plateau from 2026 to 2055 using correlation analysis and other methods using correlation analysis and other methods, taking 1971-2000 as the historical reference period, based on the LAI, NPP, main underlying surface types and main vegetation types of the plateau from 2026 to 2055, and draws the following conclusions

After the increase of temperature, the area of bare land decreases rapidly, the overall vegetation coverage rate of the plateau increases, the vegetation coverage area increases, the grassland in most areas of the plateau shows an increasing trend, and the forest reduction trend in the historical reference period tends to be flat, indicating that the temperature rise caused by global warming can promote the growth of plateau vegetation to a certain extent.

If the global warming continues, the warming of the Tibetan Plateau will be infinitely amplified, and the glaciers in most areas of the plateau will melt and the height of the snow line will rise. In the short term, the liquid water resources of the Qinghai-Tibet Plateau will increase, which is conducive to the growth of a variety of organisms and the increase of biological species. However, from a long-term perspective, the ancient viruses released by the melting of glaciers will continue to spread among biological groups, resulting in some rare disease symptoms in the ecosystem, coupled with the evaporation and runoff of liquid water resources, the total water resources of the Qinghai-Tibet Plateau can no longer meet the needs of a large number of increased organisms, and the number of biological species will fluctuate and decline along with both viruses and water sources, and even some rare biological species will become extinct, bringing a devastating blow to the entire ecological environment of the Qinghai-Tibet Plateau.

Based on the analysis of the CMIP5 experimental data, we conclude that under the background of global temperature rise of 2 °C, the plateau climate is warmer and wetter, the vegetation state is better, the temperature and precipitation rate are positively correlated with vegetation growth, the temperature is the main controlling factor affecting vegetation, and vegetation is more sensitive to climate change. Due to the performance errors of model simulation, data processing errors, the complexity of the terrain, and the diversity of climatic factors affecting vegetation, the results of this analysis are not comprehensive and in-depth.

The future study can take the current results as a reference to further deepen the research.

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