

## Response of Vegetation Coverage and ET to Temperature Change in the Altay Region (Postprint)

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### Abstract

Investigating the impacts of temperature on vegetation coverage and ET (evapotranspiration) is of significant importance for arid regions to address climate change and maintain ecosystem stability. Based on temperature data from 7 meteorological stations in and around the Altay region, the CRU dataset, and MODIS ET data, this study examined the influence of temperature variations on vegetation coverage and ET in the Altay region using methods including the Mann-Kendall non-parametric test and vegetation coverage inversion. The results indicate: (1) Over the past 116 years from 1901 to 2016, the annual mean temperature in the Altay region increased at a rate of  $0.18\text{ }^{\circ}\text{C} \cdot (10\text{ a})^{-1}$ , with an abrupt change occurring in 1982 from  $2.2\text{ }^{\circ}\text{C}$  before the shift to  $3.5\text{ }^{\circ}\text{C}$  after. (2) During 2000–2017, spatial heterogeneity in vegetation coverage change was pronounced in the Altay region, with areas of increased vegetation coverage being approximately equivalent to those with decreased coverage; 66.71% of the region exhibited a negative correlation between vegetation coverage change and temperature, while only 18.55% showed a positive correlation, and the area where temperature increased but vegetation coverage decreased accounted for 31.71% of the total region. (3) From 2000 to 2016, ET in the Altay region displayed an overall decreasing trend, with 61.65% of the region experiencing both temperature and ET decreases, while 19.92% of the area showed increased temperature but decreased vegetation ET.

### Full Text

## Response of Vegetation Cover and Evapotranspiration to Temperature Variation in Altay Prefecture

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## Abstract

Studying the impact of temperature on vegetation coverage and evapotranspiration is of great significance for coping with climate variation and maintaining healthy ecosystem operation in arid areas. Based on the Mann-Kendall non-parametric test and the FVC inversion method, we investigated the characteristics of climate variation in Altay Prefecture, Xinjiang, China, and its impact on vegetation coverage and evapotranspiration using temperature data from seven meteorological stations and CRU datasets for the region. The results showed: (1) During the 116-year period from 1901 to 2016, the annual average temperature in the Altay region increased at a rate of  $0.18^{\circ}\text{C} \cdot (10\text{a})^{-1}$ . An abrupt change in the annual mean temperature occurred in 1982, resulting in an accumulated temperature increase of  $2.2^{\circ}\text{C}$  before that year and  $3.5^{\circ}\text{C}$  after it. (2) From 2000 to 2017, vegetation coverage in the Altay region showed a weak increasing trend. Over the past 18 years, obvious peak values were observed, with the lowest value of 0.31 occurring in 2008. Additionally, the annual fluctuation in vegetation coverage was significantly weaker before 2008 than after 2008. Vegetation coverage change was negatively correlated with temperature in most areas of Altay, accounting for 66.71% of the region, while the proportion of positive correlation was only 18.55%. Areas experiencing temperature increase but vegetation coverage reduction accounted for 31.71% of the total area. (3) From 2000 to 2016, vegetation evapotranspiration in the Altay region showed a general decreasing trend, with a particularly obvious decline from 2003 to 2008. The lowest value of 179.16 mm occurred in 2008. Although there have been signs of increase since 2008, inter-annual fluctuations have intensified. Consequently, overall vegetation evapotranspiration in Altay presents a decreasing trend from 2000 to 2016. Throughout the region, areas with temperature decrease and ET reduction accounted for 61.65%, while 19.92% of the area exhibited the phenomenon of temperature increase coupled with ET reduction.

**Keywords:** temperature variation; evapotranspiration; ecosystem; Mann-Kendall test; Altay Prefecture

## 1. Introduction

Global warming has become an indisputable fact, with the IPCC Fifth Assessment Report indicating that the global average temperature has increased by  $0.85^{\circ}\text{C}$  over the past 130 years. This warming trend has been particularly pronounced in arid and semi-arid regions of Northwest China, where temperature increases have exceeded the global average. Altay Prefecture, located in northern Xinjiang, represents a typical arid region where ecosystem health is highly sensitive to climate variability. Understanding the response of vegetation cover

and evapotranspiration (ET) to temperature changes is crucial for regional ecological security and sustainable development.

## 2. Data and Methods

**2.1 Data Sources** This study utilized temperature data from seven meteorological stations in Altay Prefecture, spanning from 1901 to 2016. The spatial distribution of these stations is shown in [Figure 1: see original paper]. Additionally, CRU (Climatic Research Unit) datasets were employed to supplement and validate the station data. Vegetation coverage data were derived from MODIS imagery for the period 2000-2017, with a spatial resolution of 250 m after processing with ArcGIS 10.2 and DEM correction using the Anusplin 4.2 interpolation method.

**2.2 Mann-Kendall Trend Test** The Mann-Kendall test is a non-parametric statistical method widely used for trend detection in hydro-meteorological time series. For a given time series  $(x_1, x_2, \dots, x_n)$ , the null hypothesis  $H_0$  states that the data are independent and identically distributed, while the alternative hypothesis  $H_1$  suggests a monotonic trend.

The test statistic  $S_k$  is calculated as:

$$S_k = \sum_{i=1}^{k-1} \sum_{j=i+1}^k \text{sgn}(x_j - x_i)$$

where  $\text{sgn}$  is the sign function. The standardized test statistic  $UF_k$  is then computed as:

$$UF_k = \frac{S_k - E(S_k)}{\sqrt{\text{Var}(S_k)}}$$

where  $E(S_k) = \frac{n(n-1)}{4}$  and  $\text{Var}(S_k) = \frac{n(n-1)(2n+5)}{72}$ . The  $UF_k$  statistic follows a standard normal distribution, with critical values typically set at  $\pm 1.96$  for the 95% confidence level.

## 3. Results

**3.1 Temperature Variation (1901-2016)** The annual average temperature in Altay Prefecture from 1901 to 2016 exhibited a significant increasing trend at a rate of  $0.18^\circ\text{C}$  per decade. The Mann-Kendall test revealed a statistically significant trend ( $ZC = 6.97$ ), indicating robust warming. An abrupt change occurred in 1982, which served as a critical inflection point. Before 1982, the accumulated temperature change was  $2.2^\circ\text{C}$ , while after 1982 it increased by  $3.5^\circ\text{C}$ .

shows the statistical significance of this temperature trend, while [Figure 2: see original paper] illustrates the temporal variation and [Figure 3: see original paper] presents the Mann-Kendall mutation test results.

**3.2 Vegetation Cover Dynamics (2000-2017)** Vegetation coverage showed a weak increasing trend over the 18-year study period. Notable peaks occurred in 2008, 2012, and 2015, with the lowest value of 0.31 recorded in 2008. The inter-annual variability was substantially lower before 2008 compared to the post-2008 period.

Spatial analysis revealed that 66.71% of the region exhibited negative correlations between vegetation coverage and temperature, while only 18.55% showed positive correlations. Areas where temperature increased while vegetation coverage decreased accounted for 31.71% of the total area, primarily distributed in [Figure 6: see original paper]. The correlation coefficient distribution is detailed in .

### 3.3 Evapotranspiration Response (2000-2016)

**3.3.1 Inter-annual Variation** Vegetation evapotranspiration displayed an overall decreasing trend from 2000 to 2016, with a particularly steep decline between 2003 and 2008. The minimum ET value of 179.16 mm occurred in 2008. Although ET showed some recovery after 2008, inter-annual fluctuations became more intense. The long-term trend remains negative, with ET values of 188.21 mm, 189.65 mm, and 184.89 mm recorded in 2010, 2013, and other recent years respectively.

The spatial pattern of ET trends shows that 83.68% of the region experienced decreasing ET, while only 6.84% showed increasing trends [Figure 7: see original paper]. Areas with significant ET reduction accounted for 16.32% of the region, concentrated in [Figure 9: see original paper].

**3.3.2 Correlation with Temperature** The relationship between ET and temperature was predominantly negative, with 73.52% of the region showing inverse correlations. Positive correlations covered only 26.48% of the area, primarily in regions with correlation coefficients between 0 and 0.4 [Figure 10: see original paper]. The area ratio distribution across different correlation classes is presented in .

Areas exhibiting temperature increase coupled with ET reduction accounted for 19.92% of the region, while those showing temperature decrease with ET reduction comprised 61.65% . This pattern suggests complex non-linear responses of evapotranspiration to warming, likely mediated by water availability limitations.

#### 4. Discussion

The observed negative correlation between temperature and both vegetation coverage and ET in most areas of Altay Prefecture appears counterintuitive but reflects the unique characteristics of arid ecosystems. While warming might theoretically enhance plant growth and evapotranspiration, water scarcity in this region likely overrides temperature effects. The 1982 climate 突变 represents a regime shift after which temperature increases have not translated into enhanced vegetation activity.

The intensification of inter-annual fluctuations post-2008 suggests increasing climate instability, with extreme events such as the 2008 cold spell causing significant vegetation stress. This finding aligns with previous research on climate sensitivity in Northwest China. The spatial heterogeneity in temperature-vegetation relationships indicates that local factors including topography, soil properties, and human land use modulate regional climate impacts.

#### 5. Conclusion

This study demonstrates that despite significant warming in Altay Prefecture over the past 116 years, vegetation cover and evapotranspiration have not responded positively. Instead, most regions show negative correlations between temperature and vegetation metrics, with 31.71% of the area experiencing vegetation decline despite warming. The 1982 climate 突变 marks a critical threshold, after which ecosystem responses became more variable and unpredictable. These findings underscore the vulnerability of arid ecosystems to climate change and highlight the need for adaptive management strategies that account for non-linear ecosystem responses.

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