Variation Characteristics of Ground Temperature and Air Temperature in the Southern Mountainous Region of Sichuan, 1981–2011 (Postprint)

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Abstract

Using daily 0 cm soil temperature and air temperature data from meteorological stations during 1981-2011, this study analyzed the spatial distribution, variation trends, and abrupt change characteristics of ground temperature and air temperature in six subregions of the southern mountainous area of Sichuan, employing basic statistics, linear regression, cumulative anomaly, and signal-to-noise ratio, and analyzed and compared the relationship between ground temperature and air temperature. The results show that the annual mean ground temperature and air temperature in the southern mountainous area of Sichuan ranged from 15.6-20.5 °C and 12.2-17.2 °C, respectively, exhibiting a spatial distribution pattern of lower in the north and higher in the south, and lower in high mountains and higher in valleys. Over the 31-year period, the annual mean ground temperature and air temperature in all six subregions showed significant increasing trends, but seasonal variation differences were pronounced, with warming rates in winter higher than those in summer. From a regional perspective, the alpine zone (Region VI) exhibited the most significant annual and seasonal warming trends, 2–6 times those of other regions, and both ground temperature and air temperature experienced an abrupt change around 1990; the valley zone (Region II) showed minimal annual and seasonal temperature variation with no abrupt change. Ground temperature and air temperature in all subregions showed an extremely significant positive correlation ($P<0.01$) with high consistency, but an asymmetric warming phenomenon also existed. The annual and seasonal mean ground temperature in mountainous areas (Regions III, V, and VI) and spring ground temperature in the valley (Region I) warmed more intensely than air temperature, resulting in a significant increasing trend in the ground-air temperature difference, which even experienced an abrupt change.

Full Text

Preamble

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Journal: Arid Land Geography (ChinaXiv Partner Journal)

Study Period: 1981-2011

Research Focus: Variation characteristics of soil surface temperature and air temperature in the mountainous region of southern Sichuan.

Temperature Range: The mean annual soil surface temperature and air temperature in the study area ranged from 15.6-20.5°C and 12.2–17.2°C, respectively.

Study Area Location: 100°15 -103°53 E, 26°3 -29°27 N

Regional Division: The study area was divided into six regions (I–VI) based on landform, soil type, and main land use, with elevation ranges as follows: - Region I: 305–1300 m - Region II: 1300–1800 m - Region III: 1800–2500 m - Region IV: 1800–2400 m - Region V: 2500–3000 m - Region VI: >3000 m

Annual Precipitation: Approximately 800 mm

Data Sources: Meteorological data from eight local weather stations including eastern Panzhihua district, Huili County, Leibo County, Muli County, Xichang City, Yanyuan County, Yuexi County, and Zhaojue County of Liangshan Yi Autonomous Prefecture, Sichuan Province.

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1. Introduction

1.1 Regionalization Basis

The study employed a linear regression model to analyze temperature trends: $Y = a + bt$, where Y represents soil or air temperature, a is the intercept, b is the trend coefficient, and t is time. The temperature trend rate was calculated as $b \times 10$ (°C/10a). The significance of trends was tested using the Mann-Kendall method and signal-to-noise ratio analysis.

1.3.2 Data Analysis Methods

The temperature data series were analyzed using cumulative sum anomaly detection and signal-to-noise ratio methods to identify abrupt changes. The relationship between soil surface temperature and air temperature was examined through correlation analysis.

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2. Results

2.2.2 Temperature Trends

Significant warming trends were observed for both soil surface temperature and air temperature across all regions. Region VI (high mountainous area) exhibited the most pronounced warming trend, with rates 2-6 times higher than other regions. The warming trend for soil surface temperature in Region VI reached 1.15°C・(10a) ^{1}, while air temperature warming was 0.69°C・(10a) ^{1}. In contrast, Region II (Anning River valley) showed the lowest temperature change with no significant abrupt changes.

2.2.3 Seasonal Variations

Seasonal analysis revealed that warming rates were higher in winter than in summer across most regions, indicating distinct seasonal variation patterns. The temperature trends varied significantly among the six regional types, with mountainous regions (III, V, VI) showing stronger soil surface temperature warming compared to air temperature warming.

2.3 Abrupt Changes

2.3.1 Abrupt Change Detection Abrupt changes in temperature occurred primarily around 1990. Region VI experienced the most significant abrupt changes, with soil surface temperature and air temperature shifts detected in 1998 and the early 1990s, respectively. The signal-to-noise ratio analysis confirmed these changes were statistically significant ($P < 0.01$).

2.3.2 Asymmetric Warming Phenomenon The difference between soil surface temperature and air temperature (Ts-Ta) showed a significant increasing trend in mountainous regions (III, V, VI) and in the Jinsha River valley (Region I) during spring. This asymmetric warming phenomenon was particularly evident in Region VI, where the Ts-Ta difference increased at a rate of 0.45°C・(10a) ^{1}. The phenomenon indicates that soil surface temperature is warming faster than air temperature in these regions.

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3. Discussion

The study reveals several key findings: (1) Both soil surface temperature and air temperature showed significant increasing trends from 1981-2011, with more pronounced warming in winter than summer. (2) Region VI exhibited the highest warming rates, 2-6 times greater than other regions, with abrupt changes occurring around 1990. (3) A significant asymmetric warming phenomenon exists, where soil surface temperature warming exceeds air temperature warming in mountainous regions and the Jinsha River valley during spring. (4) The Ts-Ta difference showed significant increasing trends and abrupt changes, particularly in Region VI.

The results demonstrate extremely significant positive correlations between soil surface temperature and air temperature ($P < 0.01$), indicating high consistency between the two temperature indices. However, the asymmetric warming phenomenon suggests that changes in the Ts–Ta relationship may have important implications for the climate system, particularly for predicting drought and flood disasters and building climate models.

The study' s findings differ from previous research by simultaneously analyzing both temperature indices and revealing the significant asymmetric warming phenomenon ($P < 0.05$). This highlights the need to consider not only individual temperature variations but also the impacts of changing Ts–Ta relationships on the climate system.

Figures and Tables

[Figure 2: see original paper] Spatial distribution of mean soil surface temperature and air temperature in the mountainous region of southern Sichuan

[Figure 3: see original paper] Variation trend of mean annual soil surface temperature and air temperature during 1981–2011 in the mountainous region of southern Sichuan

[Figure 4: see original paper] Accumulated anomaly of mean annual soil surface temperature and air temperature in the mountainous region of southern Sichuan

Regionalization basis

Climatic tendency rates of seasonal soil surface temperature and air temperature in the mountainous region of southern Sichuan

Seasonal abrupt change of soil surface temperature and air temperature in the mountainous region of southern Sichuan

Correlative relationships between soil surface temperature and air temperature in each regionalization

Variation of the difference between soil surface temperature and air temperature (Ts–Ta) in the mountainous region of southern Sichuan

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Note: Figure translations are in progress. See original paper for figures.