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Research Article

Evaluation and Analysis of Soil Temperature Data over Poyang Lake Basin, China

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Soil temperature reflects the impact of local factors, such as the vegetation, soil, and atmosphere of a region. Therefore, it is important to understand the regional variation of soil temperature. However, given the lack of observations with adequate spatial and/or temporal coverage, it is often difficult to use observational data to study the regional variation. Based on the observational data from Nanchang and Ganzhou stations and ERA-Interim/Land reanalysis data, this study analyzed the spatiotemporal distribution characteristics of soil temperature over Poyang Lake Basin. Four soil depths were examined, 0–7, 7–28, 28–100, and 100–289 cm, recorded as ST1, ST2, ST3, and ST4, respectively. The results showed close correlations between observation data and reanalysis data at different depths. Reanalysis data could reproduce the main spatiotemporal distributions of soil temperature over the Poyang Lake Basin but generally underestimated their magnitudes. Temporally, there was a clear warming trend in the basin. Seasonally, the temperature increase was the most rapid in spring and the slowest in summer, except for ST4, which increased the fastest in spring and the slowest in winter. The temperature increase was faster for ST1 than the other depths. The warming trend was almost the same for ST2, ST3, and ST4. An abrupt change of annual soil temperature at all depths occurred in 1997, and annual soil temperatures at all depths were abnormally low in 1984. Spatially, annual soil temperature decreased with latitude, except for the summer ST1. Because of the high temperature and precipitation in summer, the ST1 values were higher around the lake and the river. The climatic trend of soil temperature generally increased from south to north, which was opposite to the distribution of soil temperature. These findings provide a basis for understanding and assessing the variation of soil temperature in the Poyang Lake Basin.

1. Introduction

Soil temperature, an important parameter to characterize the thermal properties of soil, plays a key role in the land surface processes [1]. It can also affect climate change by affecting the energy distribution, exchange, and water budget on the surface. Moreover, it gradually acts on the upper atmosphere through its influence on the surface boundary layer [2–5]. Therefore, soil temperature plays an important role in the interaction between land and air [1, 2]. Soil temperature also plays an important role in climate change [3–5]. Changes in soil temperature associated with climate warming could result in variation of terrain and hydrological conditions, alteration of the distribution and growth rate of vegetation, enhancement of soil organic carbon decomposition, and increased CO2 emissions from the soil to the atmosphere [6–11]. These effects could have major consequences both locally and globally.

Under the influence of global warming, the mean surface temperature around the world increased by an average of 0.85°C (0.65–1.06°C) from 1880 to 2012 [12]. Between 1961 and 2011, the mean temperature of China increased by 1.1°C, which is greater than the global and the Northern Hemisphere values [13]. Driven by the air temperature, the soil temperature in China has also shown a warming trend. Since the 1990s, based on the monthly soil temperature data of 532 stations in China, the annual mean soil temperature has remarkably increased. Regionally, the soil temperatures in northeastern China have increased most significantly, whereas, in the eastern part of southwestern China, soil temperature has tended to decrease [14]. In Lhasa (Tibet), from 1961 to 2005, the annual mean soil temperatures at shallow layers (0–40 cm) showed increasing trends, with increase rates of (0.45–0.66°C)/10a, which was greater than the increase trend of air temperature in the same period [15]. In Alxa Left Banner (Inner Mongolia Autonomous region, northwestern China), from 1961 to 2005, the increase rates of annual soil temperatures at 0–80 cm soil depths were (0.28–0.46°C)/10a, which was lower than that of the air temperature (0.46°C/10a). Seasonally, the responses of summer, autumn, and winter air temperature to climate change are more substantial than soil temperatures, while the responses of soil temperatures to climate change are more significant than air temperature in spring [16]. Based on the analysis of the long-term changes (1961–2018) in soil temperature at Nanchang (the middle–lower reaches of the Yangtze River, southern China), Zhan (2019) found that the annual variation of air temperature correlated very well with soil temperatures at 0–320 cm soil depth [11]. The increase rates of soil temperature were reported as 0.074–0.186°C/10a, lower than those of annual air temperature, 0.255°C/10a.

To date, many studies have investigated the variations of soil temperatures at specific research stations, but examinations of the spatiotemporal variations of soil temperature remain largely comparative. However, given the lack of observations with adequate spatial and/or temporal coverage, it is difficult to use the observation data of stations to study the regional variation. Because of the continuity and adequate spatial and temporal coverage, reanalysis data plays an important role in soil temperature regional study. Yang and Zhang (2017) evaluated four reanalysis datasets of soil temperature, the land surface reanalysis of the European Centre for Medium-Range Weather Forecasts (ERA-Interim/Land), the second modern-era retrospective analysis for research and applications (MERRA-2), the National Centre for Environmental Prediction Climate Forecast System Reanalysis (NCEP-CFSR), and version 2 of the Global Land Data Assimilation System (GLDAS-2.0) [17]. They found that reanalysis data could reproduce the main spatial distribution of soil temperature in summer and winter, especially over the east of China but generally underestimated their magnitudes. Moreover, four reanalysis products (the ERA-Interim reanalysis, ERA-Interim/Land, MERRA-Land, and NOAA-CIRES 20CR) were used to analyze the soil temperature variation over middle and high latitudes of East Asia [18]. In addition, the ERA-Interim land surface temperature dataset has also been used in mapping the permafrost distribution over the Tibetan Plateau [19].

In this study, soil temperatures at different depths were examined in the Poyang Lake Basin, located in the subtropical monsoon region of China, a region sensitive to climate change. However, owing to the lack of sufficient observation stations, it was not realistic to use observation data to study regional soil temperature variation. Therefore, we first evaluated the reanalysis data based on the observation data. Subsequently, we used the reanalysis data to study the temporal and spatial variation characteristics of soil temperature in the Poyang Lake Basin. The findings of this study will provide a scientific basis for improved understanding and assessment of the impact of climate change on terrestrial ecosystems.

2. Data

2.1. Study Area. The Poyang Lake Basin (28°22′–29°45′N, 115°47′–116°45′E, area of $1.62 \times 10^5\,km^2$) is located in the middle–lower reaches of the Yangtze River, within the sphere of the East Asian monsoon, and has a typical monsoon climate (Figure 1). From 1961 to 2018, the annual temperature is 18.1°C and annual precipitation is approximately 1650 mm. The region has four distinct seasons: spring (March–May), summer (June–August), autumn (September–November), and winter (December–February). It plays an important ecological and hydrological role in the middle and lower Yangtze River Region [20].

The Nanchang (28°36′N, 115°55′E; elevation: 46.9 m) and Ganzhou (28°52′N, 115°; elevation: 58.6 m) weather station were selected for this study because they had remained at the same location since 1960. Nanchang station is located in the northern part of the basin and Ganzhou is located in the southern, thus Nanchang and Ganzhou could reflect the overall climate characteristics of the basin. Moreover, the time series data of soil temperatures (depths of 0, 20, 80, and 320 cm) recorded at the two stations are long term, and the data integrity is considered satisfactory (i.e., the amount of missing data annually is <5%).

2.2. Observed Data. The soil temperature date (0, 20, 80, and 320 cm soil depth) from Nanchang and Ganzhou National Weather stations span from 1961 to the present (black circles in Figure 1). Prior to further analysis, these data were tested for homogeneity. The missing data, less than 1%, have little or no effect on the research results.

2.3. ERA-Interim/Land Reanalysis Data. ERA-Interim/Land is a global land surface reanalysis dataset covering the period 1979 to the present. It describes the evolution of soil moisture, soil temperature, and snowpack. ERA-Interim/Land is the result of a single 32-year simulation with the latest ECMWF (European Centre for Medium-Range Weather Forecasts) land surface model driven by meteorological forcing from the ERA-Interim atmospheric reanalysis and precipitation adjustments based on the monthly GPCP v2.1 (Global Precipitation Climatology Project) [21, 22]. There are four soil depths 0–7, 7–28, 28–100, and 100–289 cm, written as ST1, ST2, ST3, and ST4, respectively. The horizontal resolution is about $1^\circ \times 1^\circ$ and the time frequency is monthly (grid in Figure 1), from January 1979 to December 2018.

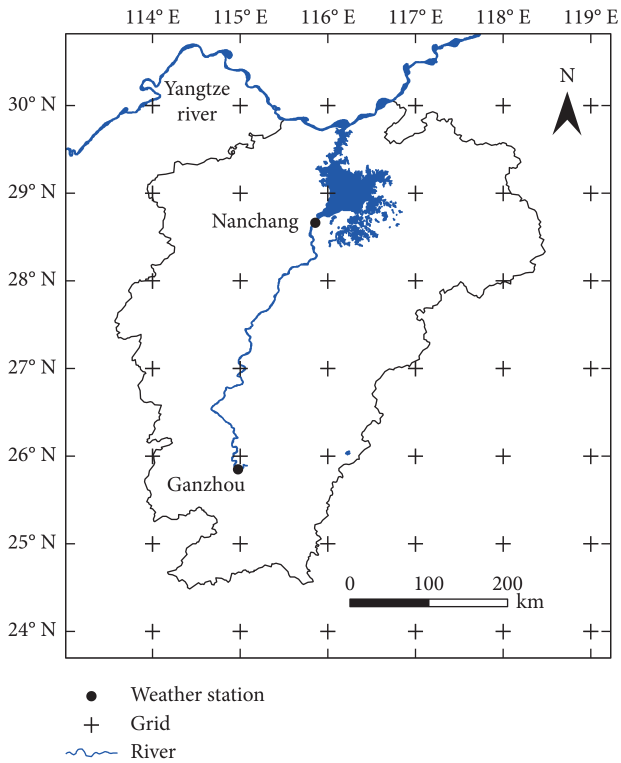


FIGURE 1: Location of the Nanchang and Guangzhou National Weather stations, China.

2.4. Method

2.4.1. Applicability Evaluation of ERA-Interim/Land Reanalysis Data. The evaluation of the ERA-Interim/Land reanalysis data using the observed data focused on monthly variations. The correlation coefficients, mean error (ME), mean absolute error (MAE), and root mean square error (RMSE) between ERA soil temperature and observational soil temperature were calculated to investigate their agreement at monthly time scales. The two observed time series are from Nanchang and Ganzhou stations. Their counterparts, the ERA-Interim/Land reanalysis data, are the average values of the two grid cells closest to the weather stations (red grid cells in Figure 1). STERA represented the soil temperature series of the ERA-Interim/Land reanalysis data, while STobs represented the soil temperature series of the observational data:

$$\mathrm{ME} = \sum_{i=1}^{n}\left(\left(\mathrm{ST}_{\mathrm{ERA}} - \mathrm{ST}_{\mathrm{obs.}}\right)/n\right),$$
$$\mathrm{MAE} = \sum_{i=1}^{n}\left(\left(\left|\mathrm{ST}_{\mathrm{ERA}} - \mathrm{ST}_{\mathrm{obs.}}\right|\right)/n\right), \quad (1)$$
$$\mathrm{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\mathrm{ST}_{\mathrm{ERA}} - \mathrm{ST}_{\mathrm{obs.}}\right)^2}.$$

2.4.2. Sen's Slope Estimator. Sen (1968) developed the nonparametric procedure for estimating the long-term trend [23]. Compared with the least squares linear regression, Sen's slope estimator is not sensitive to outliers and thus the estimated linear trend is significantly more accurate and robust for skewed data. The slope of N pairs of data points can be estimated by the following relation:

$$\beta = \mathrm{median}\left(\frac{x_j - x_l}{j - l}\right), \quad (j > l > 1), \quad (2)$$

where x_l and x_j are data values at time l and time j, respectively. This method is widely applied to hydrological and climatic time series because of its robustness for estimating the magnitude of a trend [24–28].

2.4.3. Test of Abrupt Change. The Mann–Kendall test was developed by Mann and Kendall [29, 30] and was originally used to detect trend changes in the sequence. Goossens and Berger (1986) improved and further developed the test, allowing it to determine the year of the abrupt change in the trend [31].

For time series x with n sample sizes, a rank series S_k is constructed:

$$S_k = \sum_{i=1}^{k} r_i, \quad r_i = \begin{cases} 1 & x_i > x_j \\ 0 & \text{else} \end{cases}, \; j = 1, 2, \ldots, i, \quad (3)$$

$$\mathrm{UF}_k = \frac{S_k - E(S_k)}{\sqrt{\mathrm{Var}(S_k)}}, \quad k = 1, 2, \ldots, n. \quad (4)$$

In equation (4), $\mathrm{UF}_1 = 0$ and $E(S_k)$ and $\mathrm{Var}(S_k)$ are the mean and variance of the S_k:

$$E(S_k) = \frac{n(n+1)}{4},$$
$$\mathrm{Var}(S_k) = \frac{n(n-1)(2n+5)}{72}. \quad (5)$$

Arrange x in reverse chronological order, $x_n, x_{n-1}, \ldots, x_1$. Repeat the process again to obtain UB:

$$\mathrm{UB}_k = -\mathrm{UF}_k, \quad k = n, n-1, \ldots, 1. \quad (6)$$

UF is a standard normal distribution, which is in the time series x order $x_1, x_2, \ldots, x_n$. Look up the normal distribution table at the given significance level α. If $|\mathrm{UF}_i| > U_\alpha$, it indicates that there is an obvious trend change in the sequence. If $\alpha = 0.05$, $U_{0.05} = \pm 1.96$.

If the UF and UB intersect and $|\mathrm{UF}_i| > 1.96$, x would change abruptly at the intersection. The Mann–Kendall test has been frequently used to quantify the abrupt changes in hydrometeorological time series [32, 33].

2.4.4. Anomaly and Standard Deviation. Climate anomalies are considered conditions in which anomalies of climatic elements reach a certain magnitude. The World Meteorological Organization has stated that when an anomaly of a climatic element is more than double the standard deviation, the climatic element should be considered abnormal [11].

3. Results

3.1. Validation of ERA-Interim/Land Reanalysis Data for Applicability. In this study, the observational soil temperatures of the Nanchang and Ganzhou stations were used to evaluate the ERA-Interim/Land reanalysis data at its nearby grid points (Figure 1). There were four soil depths in the observational (obs.) data (0, 20, 80, and 320 cm, given as obs. ST1, obs. ST2, obs. ST3, and obs. ST 4, resp.).

Comparing the month-by-month average data from January 1979 to December 2018, we found a very strong correlation between ERA and obs. soil temperature data (Figure 2 and Table 1). Taking the obs. ST1 of Nanchang and ST1 of ERA as an example, the correlation coefficient is 0.99, and the averages of obs. and the ERA are 20.2 (3.2, 38.0) and 19.1 (4.9, 32.1), respectively. The ME, MAE, and RMSE are −1.1°C, 1.7°C, and 2.2°C. This shows that there is a high degree of consistency between ERA and obs. at the ST1. At the same depth, the ERA-Interim/Land reanalysis data are in good agreement with the observed data (Figure 2 and Table 1). The ERA-Interim/Land reanalysis data are shown to be reliable for regional soil temperature research in the Poyang Lake Basin.

3.2. Monthly, Seasonal, and Yearly Changes of Soil Temperatures. The mean temperatures from 1979 to 2018 in Poyang Lake Basin, were 19.8, 19.0, 19.1, and 19.1°C for ST1–4, respectively. In ST1 (0–7 cm), the temperature reaches a peak in July (28.8°C) and a minimum in January (9.6°C). The temperature rises from January, peaks in July, and then gradually decreases. In ST2 (7–28 cm) and ST3 (28–100 cm), the temperature changes are very similar to those for ST1, except for the temperature peaks in August rather than July. Unlike other depths, in ST4 (100–289 cm), the temperature starts increasing in March (12.6°C), peaks in September (25.4°C), and then declines to February of the following year (Figure 3). From March to September, the temperature of ST1 is higher than the temperature of ST4. Therefore, the heat travels from the surface to depth and the soil is in a state of energy absorption. From October to February of the following year, the temperature of ST4 is higher than that of ST1. The energy path thus reverses, from the deep soil to the surface, and the soil becomes a source of heat energy.

Monthly values are averaged to obtain the seasonal temperature. Seasons are defined as follows: winter = December, January, and February; spring = March, April, and May; summer = June, July, and August; and autumn = September, October, and November. In general, the temperature at each depth and each season increases year by year. In terms of seasons, the temperature increases the fastest in spring and the slowest in summer, except for the ST4, which increases the fastest in spring and the slowest in winter. In terms of depth, the temperature of ST1 rises the fastest, but the warming trend is similar among the other layers (Figure 4).

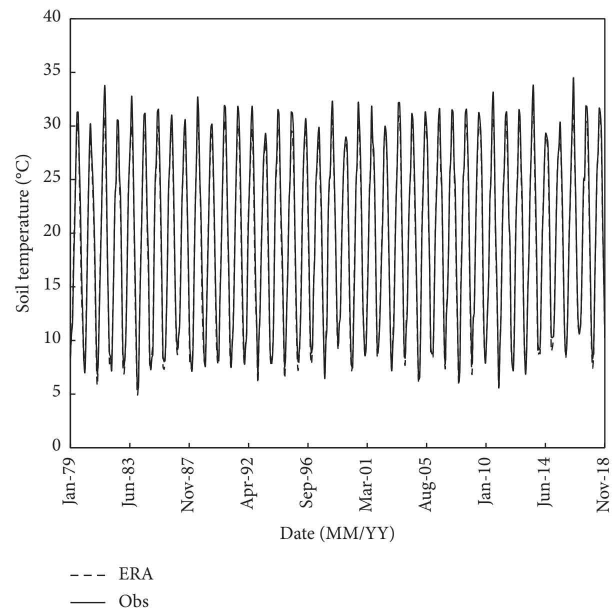


Figure 2: Monthly variations in ERA ST1 and obs. ST1 at Nanchang station.

3.3. Abrupt Change of Soil Temperatures. Based on equations (3)–(6), the years of abrupt change in soil temperatures were then calculated. Most of the annual and seasonal soil temperatures show abrupt changes; in general, the soil temperatures changed from a relatively cold period to a comparatively warm period (Figure 5 and Table 2). An abrupt change of annual soil temperature occurred at all depths in 1997 (Figure 5), while an abrupt change of spring soil temperature occurred in 1996. Abrupt changes in summer soil temperatures of ST1, ST2, and ST3 occurred in 2002, but the summer soil temperature of ST4 had its abrupt change in 1999. In autumn, the abrupt changes of ST2, ST3, and ST4 occurred in 2000, while the abrupt change of ST1 occurred in 1997. In winter, ST2 and ST3 showed no abrupt changes, whereas ST1 and ST4 showed an abrupt change in 1992.

3.4. Anomalous Characteristics of Soil Temperatures. In spring, the soil temperatures at depths of ST1, ST2, and ST3 were abnormally low in 1996 and abnormally high in 2018. In 1984, the soil temperature of ST4 was abnormally low. In summer, the soil temperature of ST1 was abnormally low in 1982. The soil temperatures of ST1, ST2, and ST3 were abnormally high in 2013, whereas that of ST4 was abnormally high in both 2007 and 2018. In autumn, the soil temperature of ST1 was abnormally low in 1979 and that of ST2 was also abnormally low in 1981. The soil temperature of ST4 was abnormally high in 2009. In winter, soil temperatures at all depths were abnormally high in 1999 and 2017 and low in 1984. In terms of the annual mean, soil temperatures at all depths were abnormally low in 1984 (Table 3).

3.5. Spatial Variations of Soil Temperatures. In the Poyang Lake Basin, annual mean ST1 decreases with latitude. There are two low-value areas in the northeast and northwest of the

Table 1: The monthly variations of ERA and obs. soil temperature data.

		Correlation coefficients	ME (°C)	MAE (°C)	RMSE (°C)
ERA versus Nanchang	ST1	0.99	−1.1	1.7	2.2
	ST2	0.99	−1.3	1.3	1.5
	ST3	0.99	−1.1	1.2	3.7
	ST4	0.94	−1.2	2.7	3.2
ERA versus Ganzhou	ST1	0.99	−2.5	2.6	3.2
	ST2	0.99	−2.6	2.6	2.7
	ST3	0.99	−2.5	2.5	2.6
	ST4	0.87	−2.6	3.1	4

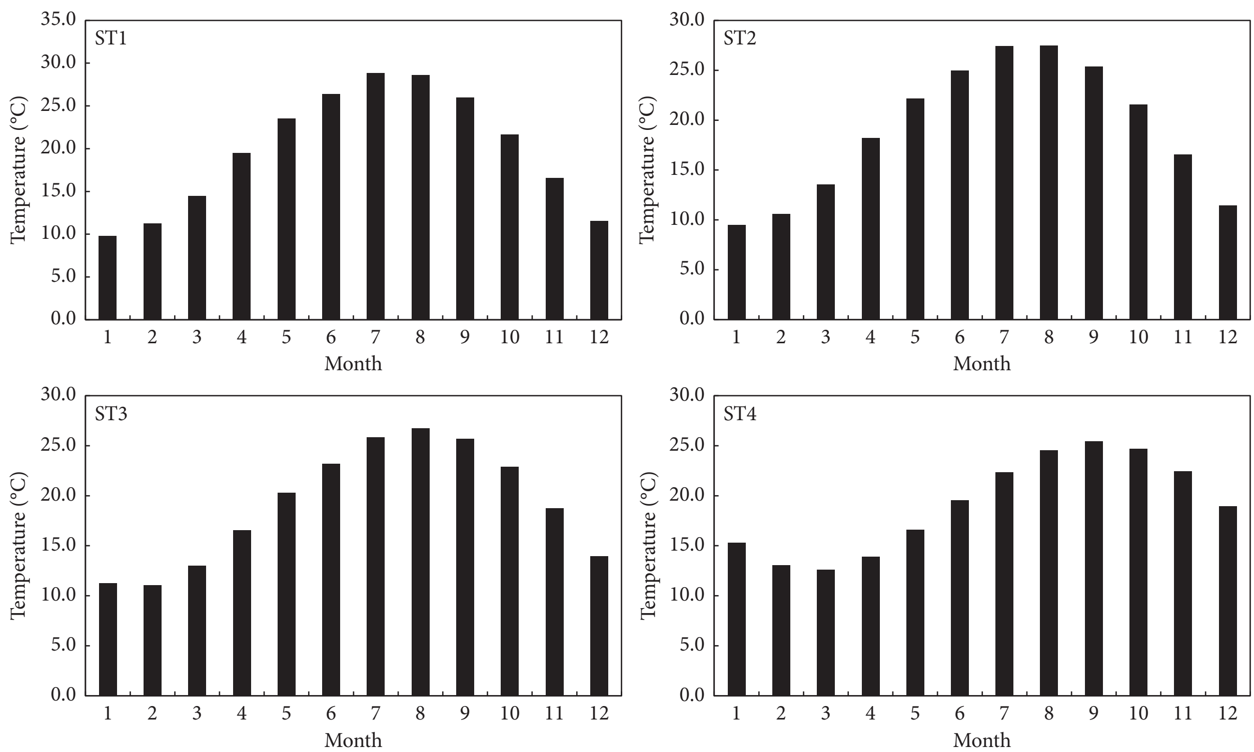


Figure 3: Monthly change of the soil temperature at the four soil depths.

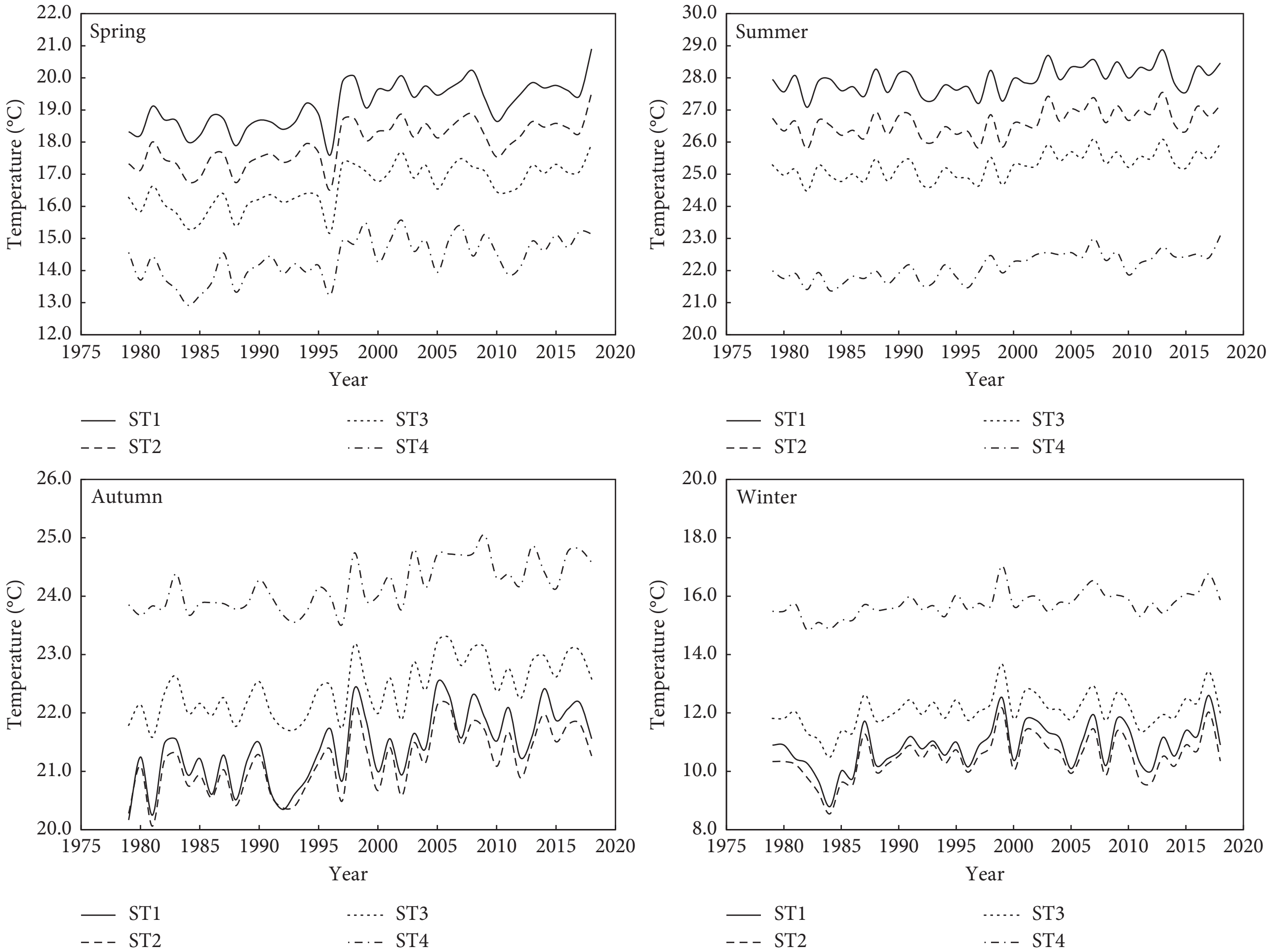
Poyang Lake Basin (Figure 6(a)). The spatial distributions of almost all soil temperatures are very similar to the annual ST1 soil temperature; the spatial correlation coefficients are over 0.9, except for the summer soil temperatures of ST1 and ST2 (Table 4). The spatial correlation coefficient between summer soil temperatures ST1 and ST2 is 0.860. Unlike the annual soil temperature ST1, the summer soil temperature ST1 values are higher around the lake and the river (Figure 6(b)).

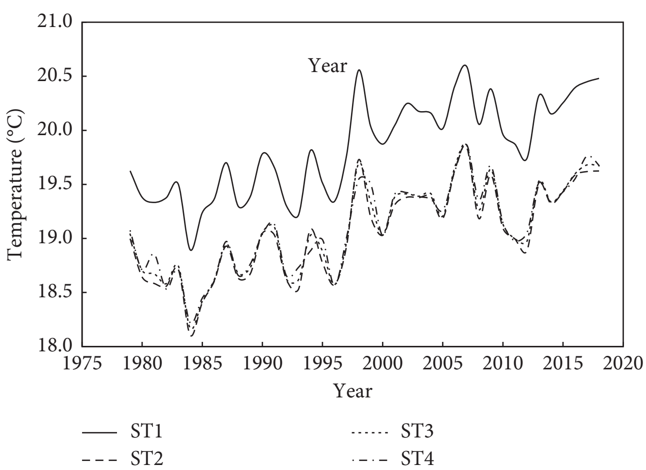
Summer air temperature and summer precipitation may be the main factors influencing the spatial distribution of the summer ST1. In terms of high temperature regions, the spatial distribution of summer air temperature and ST1 are basically the same, except for the northeast part of the basin. Heavy precipitation in the northeast part may cause the soil temperature to fail to increase (Figure 7).

In general, the climatic trend of soil temperature presents a generally increasing trend from the south area to the north in the Poyang Lake Basin, opposite to the distribution of soil temperature. There are high-value areas in the northeast region of the Poyang Lake Basin (Figure 8). We plotted a distribution map of soil temperature for the four depths at different scales (data not presented), the correlation coefficients of which with annual ST1 are around 0.9, except for the trends of ST1 and ST2 in summer (Table 5). The only difference is that the low-value area of the trend of summer ST1 is more northward. Annual ST1 shows a clear upward trend; in most areas, it can reach 0.3°C/10a (Figure 8(a)). Summer ST1 also shows a clear upward trend in the whole area, but the increase rate is lower than that of annual ST1.

4. Discussion

Over the past century, the effects of global warming have affected not only the air temperature but also precipitation patterns and soil temperatures [34]. Soil temperature is the main factor affecting the length of the growing season, rates





Climatic trend rate (°C/decade)	Spring	Summer	Autumn	Winter	Year
ST1	0.43	0.19	0.33	0.29	0.31
ST2	0.41	0.19	0.26	0.20	0.29
ST3	0.42	0.22	0.27	0.19	0.29
ST4	0.37	0.29	0.25	0.20	0.30

Figure 4: Changes in seasonal and annual soil temperatures over the Poyang Lake Basin.

of mineralization and nutrient assimilation, and plant productivity [35–37]. It is therefore very important to determine the variation of soil temperature. Based on the observation and reanalysis data from 1979 to 2018, this study analyzed the variation of seasonal and annual soil temperature, abrupt changes and abnormal years, and the spatial distribution of the soil temperature and its trends. In fact, the Poyang Lake Basin includes plains, basins, and mountains; we need further to detect if the reanalysis data perform well in complex terrain. Poyang Lake Basin locates in the middle and lower Yangtze river and South China. We also need further to investigate the differences between soil temperature in Poyang Lake Basin and that in the big area. In context, we have found an abrupt change of soil temperature: we also need to know why it happened and what is the subsequent impact. Another important issue is how regional

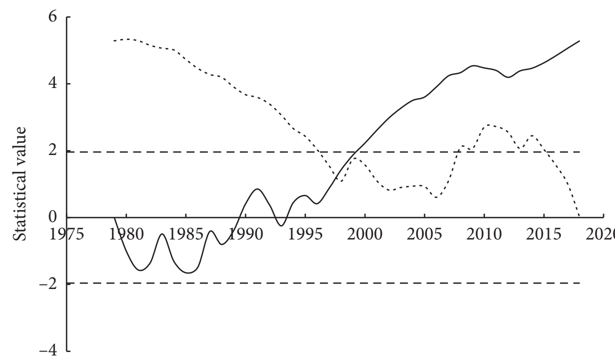


FIGURE 5: Years of abrupt change in annual ST1.

TABLE 2: Abrupt change years of annual and seasonal soil temperatures over the Poyang Lake Basin.

Index	Spring	Summer	Autumn	Winter	Annual
ST1	1996	2002	1997	1992	1997
ST2	1996	2002	2000	—	1997
ST3	1996	2002	2000	—	1997
ST4	1996	1999	2000	1992	1997

Note. "—"indicates no abrupt change.

TABLE 3: Years of anomalous annual and seasonal mean soil temperatures over the Poyang Lake Basin.

Index	Spring	Summer	Autumn	Winter	Annual
ST1	1996 (-), 2018 (+)	1982 (-), 2013 (+)	1979 (-)	1984 (-), 1999, 2017 (+)	1984 (-),
ST2	1996 (-), 2018 (+)	2013 (+)	1981 (-)	1984 (-), 1999, 2017 (+)	1984 (-),
ST3	1996 (-), 2018 (+)	2007, 2013 (+)	—	1984 (-), 1999, 2017 (+)	1984 (-),
ST4	1984 (-)	2007, 2018 (+)	2009 (+)	1984 (-), 1999, 2017 (+)	1984 (-),

Note. (+) abnormally high, (–) abnormally low.

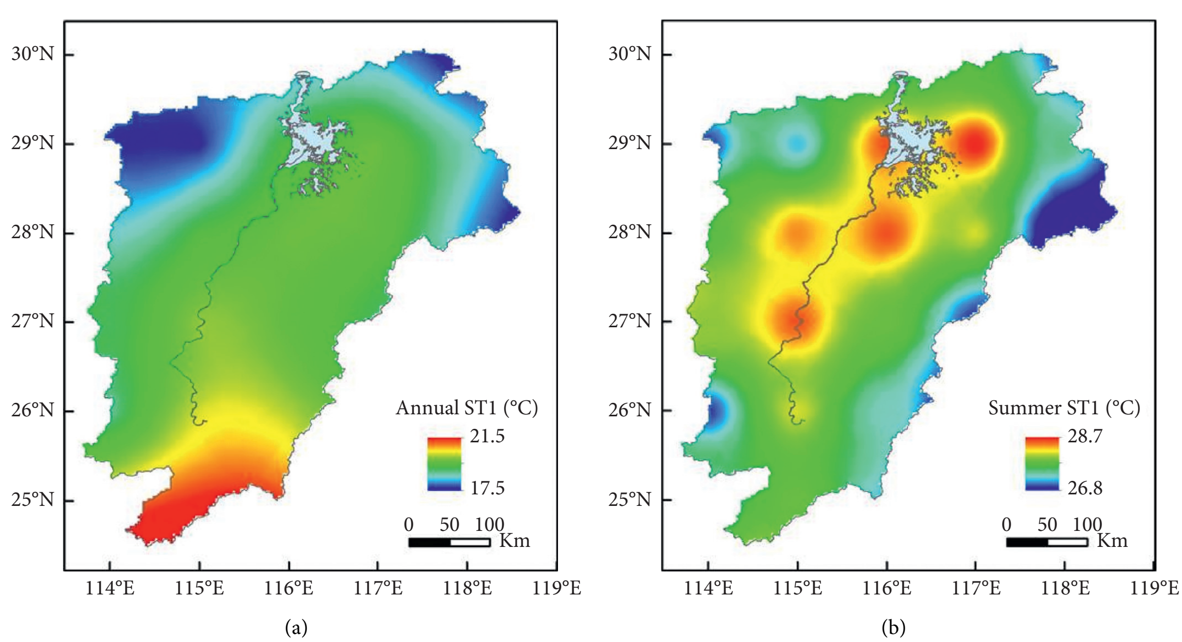


FIGURE 6: Spatial distribution of annual soil temperature (a) and summer soil temperature (b) of ST1 over the Poyang Lake Basin.

Table 4: Spatial correlation coefficient between annual ST1 and soil temperatures for other depths and time periods.

Correlation coefficient		Annual ST1
ST1	Annual	—
	Spring	0.992
	Summer	0.497
	Autumn	0.997
	Winter	0.986
ST2	Annual	0.995
	Spring	0.996
	Summer	0.642
	Autumn	0.996
	Winter	0.984
ST3	Annual	0.995
	Spring	0.993
	Summer	0.872
	Autumn	0.991
	Winter	0.991
ST4	Annual	0.995
	Spring	0.992
	Summer	0.975
	Autumn	0.926
	Winter	0.978

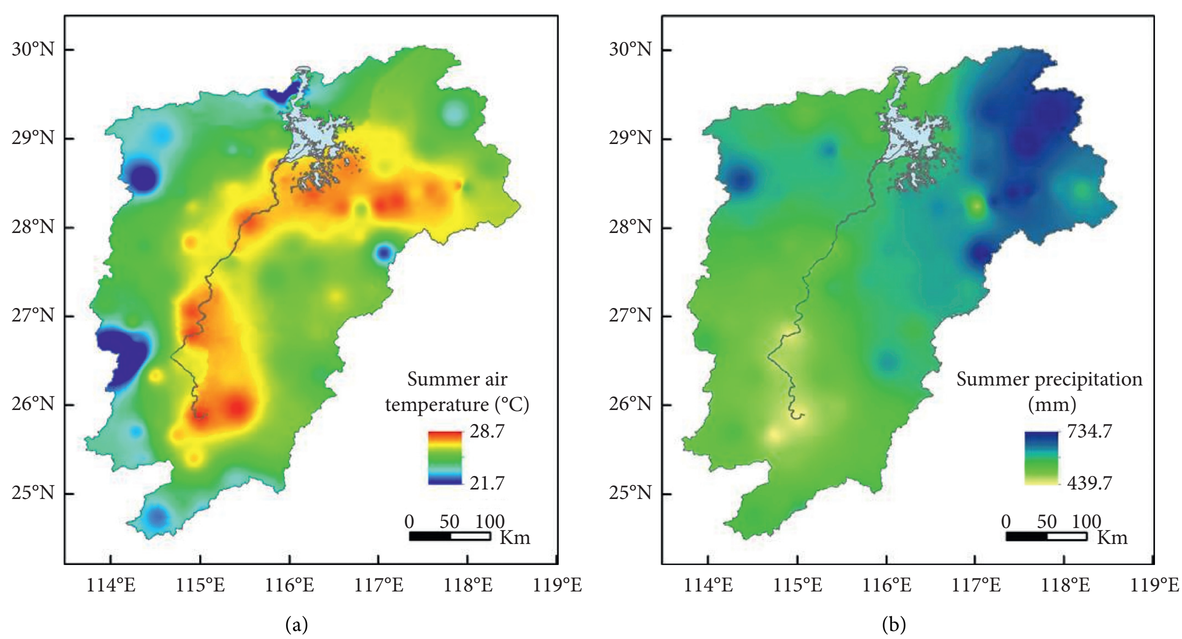


Figure 7: Spatial distribution of summer air temperature (a) and summer precipitation (b) over the Poyang Lake Basin.

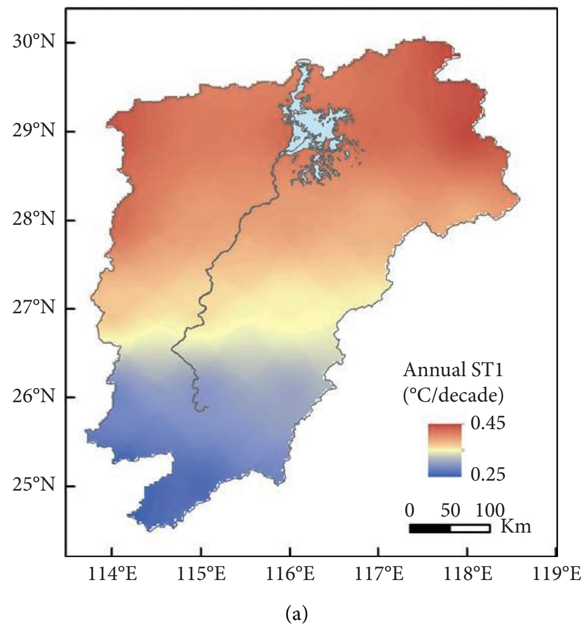


Figure 8: Spatial distribution of the climatic trend of annual soil temperature (a) and summer soil temperature (b) of ST1 over the Poyang Lake Basin.

Table 5: Spatial correlation coefficient between the climatic trend of annual ST1 and soil temperatures for other depths and time periods.

Correlation coefficient	Annual ST1	
ST1	Annual	—
	Spring	0.951
	Summer	0.768
	Autumn	0.933
	Winter	0.886
ST2	Annual	0.989
	Spring	0.933
	Summer	0.790
	Autumn	0.952
	Winter	0.900
ST3	Annual	0.989
	Spring	0.946
	Summer	0.862
	Autumn	0.943
	Winter	0.921
ST4	Annual	0.987
	Spring	0.946
	Summer	0.938
	Autumn	0.908
	Winter	0.946

climate change and soil temperature interact. What role does soil temperature play in the monsoon climate is also a question worth studying.

5. Conclusions

The main conclusions of this study are as follows:

(1) The relationships between the observation data and reanalysis data all showed good correlation at each of the studied depths over the past 40 years (correlation coefficients ≥0.87) and a significant upward trend. Compared with the observation data, the reanalysis data generally underestimates their magnitudes. Compared with Nanchang (Ganzhou), the ME is −1.1 to −1.2 (−2.5 to −2.6). The ERA-Interim/Land reanalysis data are reliable for regional soil temperature research in the Poyang Lake basin.

(2) Monthly, from March to September, the temperature of ST1 is higher than the temperature of ST4. This indicates that the heat travels from the surface to depth. From October to February of the following year, the temperature of ST4 is higher than the temperature of ST1, indicating that the energy path had reversed, now traveling from the deep soil to the surface. Seasonally and annually, the soil temperatures mostly increased during the study period. In terms of seasons, the temperature increase was the fastest in spring (0.37–0.43°C/10a) and the slowest in summer (0.19–0.29°C/10a), except for ST4, increasing the fastest in spring (0.37°C/10a) and the slowest in winter (0.20°C/10a). Annually, the temperature increased the fastest for ST1 (0.31°C/10a). For the other layers, the warming trend is almost the same.

(3) In general, the soil temperatures changed from a relatively cold period to a comparatively warm period. Abrupt changes of the annual soil temperature at all depths occurred in 1997, while the abrupt change of spring soil temperature occurred in 1996. Abrupt changes in summer soil temperatures of ST1, ST2, and ST3 occurred in 2002, except for ST4, which showed an abrupt change in 1999. In autumn, the abrupt changes of ST2, ST3, and ST4 occurred in

2000, whereas the ST1 had its abrupt change in 1997. In winter, the ST2 and ST3 showed no abrupt change, whereas ST1 and ST4 showed abrupt changes in 1992.

(4) Annually, the years of anomalous soil temperatures at all depths were consistent and were anomalously low in 1984. Seasonally, the years of anomalous soil temperatures of ST1, ST2, and ST3 cm were consistent, but they were inconsistent with the soil temperature of ST4.

(5) Spatially, in the Poyang Lake Basin, the soil temperature decreases with latitude, except for ST1 in summer. The high air temperature and heavy precipitation in summer may be the main causes of the spatial distribution of the summer ST1. Unlike the other soil temperatures, the summer soil temperature of ST1 is higher around the lake and the river. The climatic trend of soil temperature presents a general increasing trend from the south to the north in Poyang Lake Basin, opposite to the distribution of soil temperature.

Data Availability

The observed data at depths of 0, 20, 80, and 320 cm (1979–2018) used to support the findings of this study were accessed from http://data.cma.cn/under account and therefore they cannot be made freely available. The ERA-Interim/Land reanalysis data can be downloaded from http://apps.ecmwf.int/datasets/.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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