

Analysis on Spatial and Temporal Distribution of 0-20cm Soil Temperature in Henan Province for the Last 30 Years

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Abstract: Based on the available observation data from meteorological stations in Henan Province from 1981 to 2010, annual and seasonal average soil temperature of each station during the past 30 years was calculated, monthly, seasonal and annual sequence of average temperature of each layer was generated, climate trend rate of annual and seasonal average soil temperature was calculated as well as spatial distribution characteristics of average soil temperature of Henan Province and vertical change, monthly change, seasonal change, annual change and other temporal change characteristics.

Introduction

Mutual effect between underlying surface and atmosphere affects weather and climate change in various scales, while in the mutual effect between land and atmosphere, surface albedo, soil temperature and moisture have a major impact on the atmospheric circulation and climate change[1]. In the context of global warming, what kind of change does the temperature of soil, as the underlying surface of atmosphere has. Henan Province is the largest province of agricultural production in China. Agricultural production is closely linked to soil temperature. Previously, study on soil temperature of Henan Province only focused on a particular year or a part of observation stations. As a result, it is lack of systematic analysis to long-term evolvement rule of soil temperature of Henan as well as features of change within a year and annual change characteristic. In this paper, detailed discussion was given to spacial distribution, vertical change, as well as annual and inter-decadal change characteristics of average temperature of 0-20cm soil based on soil temperature data of meteorological observation stations of Henan Province from 1981 to 2010. The writer hopes that this study can provide reference for agricultural production, such as determining crop sowing time and adjusting planting structure.

Information and analysis methods

Source of observational data

The data comes from Henan Climate Center. Quality control was first carried out to observation data before study on data of soil temperature, to ensure the reliability and accuracy. Missing, invalid and wrong records were canceled and stations with incomplete data were canceled as well. For a more comprehensive analysis on change characteristics of 0-20cm soil temperature in Henan, regular meteorological observation data of daily temperature of 0cm, 5cm, 10cm, 15cm and 20cm soil collected by these observation stations in Henan was used.

Information analysis methods

Statistics was carried out to 0-20cm soil temperature data collected by these stations during the past 30 years layer by layer (December to February is winter, March-May is spring, June-August is summer and September-November is autumn), and annual and seasonal average soil temperature of each station during the past 30 years was worked out, to make analysis to temporal and spacial distribution characteristics and vertical change of soil temperature. In addition, arithmetic average of soil temperature data of the five layers of 0-20cm soil collected by these stations was worked out

layer by layer, monthly, seasonal and annual sequence of average temperature of each layer was generated as well as climate trend rate of annual and seasonal average soil temperature was calculated so that a further analysis could be made to monthly, seasonal, annual change and other temporal change characteristics of average soil temperature of Henan.

Spatial distribution of average soil temperature

Temporal and spacial distribution characteristics and vertical change of average soil temperature of the past 30 years

Annual and seasonal average soil temperature collected by these stations during the past 30 years was used to make analysis to temporal, spacial and seasonal change of soil temperature of Henan Province. In order to reveal temporal and spacial change characteristics of soil temperature in an even better way, spatial analysis features of ArcGIS was used for interpolation to generate isosurface. It can be seen from the average temperature distribution diagram of 0-20cm soil of Henan during 1981-2010 that spacial distribution of average soil temperature basically increases with increasing of latitude. Meanwhile, the average soil temperature gradually reduces from south to north and it is lower in mountains than that of plains at the same latitude. As for the spacial distribution of soil temperature of Henan, average soil temperature of each layer is comparatively higher in southern Henan Province, high in central Henan Province and low in northern Henan Province. In addition, it is the lowest in western Henan Province, which is mountain area, and some areas of east part of northern Henan. The average soil temperature of western mountain areas of Henan and Songshan, which is located in central Henan, is significantly lower than other regions at the same latitude.

In Henan Province, the average temperature of 0cm soil is 14.6°C - 18.2°C; 5cm soil is 14.1°C - 17.2°C; 10cm soil is 14.0°C - 17.3°C; 15cm soil is 14.4°C - 17.5°C; 20cm soil is 14.3°C - 17.4°C. The average soil temperature of each layer is basically between 14°C - 18.2°C and difference value between the highest soil temperature and the lowest soil temperature is between 3.1°C - 3.6°C. The average soil temperature of Xichuan, Xinyang and Gushi is the highest. Mianchi Station is the lowest one in average temperature of 5cm, 10cm, 15cm and 20cm and the average temperature of the past 30 years is 14.1°C, 14°C, 14.4°C and 14.3°C respectively. Luanchuan Station, which is also located in western Henan, is close behind. The difference value between average temperature of 5cm soil and 10cm soil is small enough to be negligible. The average temperature of 10cm soil is 0.3°C lower than that of 15cm soil. The average temperature of 15cm soil is 0.1°C higher than that of 20cm soil. The sequence of the average soil temperature is 0cm>15cm>20 cm> 5cm=10cm.

Temporal and spacial distribution characteristics and vertical change of average soil temperature in different seasons

Seasonal average value describes temporal and spacial distribution characteristics of soil temperature in different seasons and seasonal change of soil temperature[3, 4] . In spring, the average soil temperature from north to south is 17.1°C - 18.4°C, the difference is very small and there is no significant change for soil temperature with change of latitude. Except western mountain areas of Henan, the average soil temperature of other areas in summer is 29.1°C - 30.4°C. The average soil temperature of autumn and winter gradually reduces from south to north with change of latitude. The average soil temperature is 14.3°C - 18.2°C in autumn and is 0°C - 4.6°C in winter. Spacial soil temperature difference change is bigger than that in spring and summer. Analysis was also made to seasonal spacial distribution characteristics of average temperature of 5cm soil, 10cm soil, 15cm soil and 20cm soil and the results were consistent with that of 0cm soil.

From the vertical change of the average soil temperature of these five layers in four seasons, it can be seen that with warming up in the spring, heat transfers from the upper layer to the lower layer, the surface temperature increases fast and the characteristics of the average soil temperature is 0cm>5cm>10cm=15cm>20cm. In summer, with increasing of temperature, the vertical change of the average soil temperature is similar to the spring, which is 0cm>5cm>10cm=15cm>20cm. In autumn, with reducing of the temperature, the surface temperature reduces fast, the heat transfers

from the lower layer to the upper layer and the average soil temperature is 20cm>15cm>10cm>0cm>5cm. In winter, with reducing of temperature, the average soil temperature is 20cm>15cm>10cm>5cm>0cm. As for seasonal and annual average soil temperature of each layer of soil from 1981 to 2010, please refer to Table 1.

Table 1: Seasonal and annual average temperature of 0-20cm soil of Henan from 1981 to

layer//cm	spring	summer	autumn	winter	annual	2010 °C
0	17.8	29.6	16.4	2.4	16.6	
5	16.2	27.9	16.2	2.9	15.8	
10	15.8	27.4	16.6	3.4	15.8	
15	15.8	27.4	17.2	4.0	16.1	
20	15.4	26.9	17.4	4.4	16.0	

Temporal change characteristics of average soil temperature

Monthly change of average soil temperature

It can be seen from Fig. 1 that, during 1981 to 2010, the average temperature of 0-20cm soil of Henan Province gradually increases from January to July, the highest value is in July, and the warming trend reduces with increasing of the depth. From August to December, the average soil temperature gradually reduces and the cooling trend increases with increasing of depth. It suggested that under the influence of external factors, there is hysteresis in soil temperature change with increasing of depth.

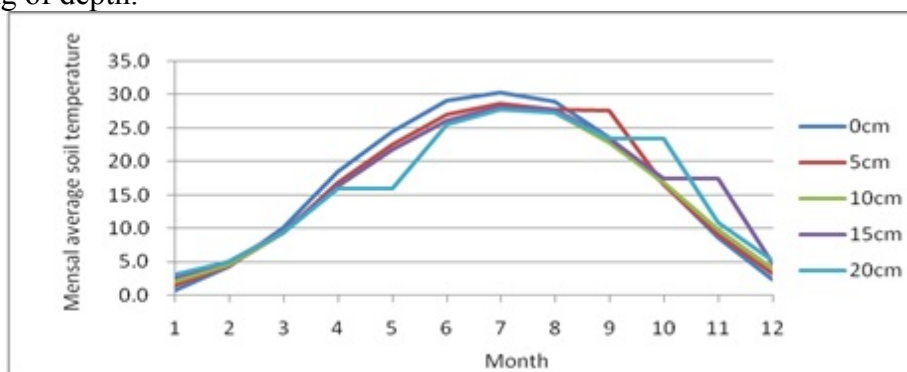


Fig. 1: Monthly curve of average soil temperature of Henan from 1981 to 2010

Annual change of average soil temperature

Fig. 2 to Fig.3 shows annual and seasonal curve of average temperature of 0-20cm soil in Henan Province. It can be seen from these figures that, during 1981 to 2010, average soil temperature of 0cm soil is obviously higher than those of other layers, and the difference of the average temperature of 5cm soil, 10cm soil, 15cm soil and 20cm soil is very small. During these 30 years, annual change trend of each layer of soil is consistent in soil temperature. It can be seen from the curve of annual average soil temperature that, from 1980s to mid-1990s, the soil temperature is comparatively low, and from mid-1990s to the beginning of the 21st Century, the soil temperature is comparatively high[5, 6].

From the seasonal curve of average temperature of 0-20cm soil, it can be seen that, the average soil temperature gradually reduces with increasing of depth from 0cm to 20cm soil in spring and summer and it gradually increases with increasing of depth in autumn and winter.

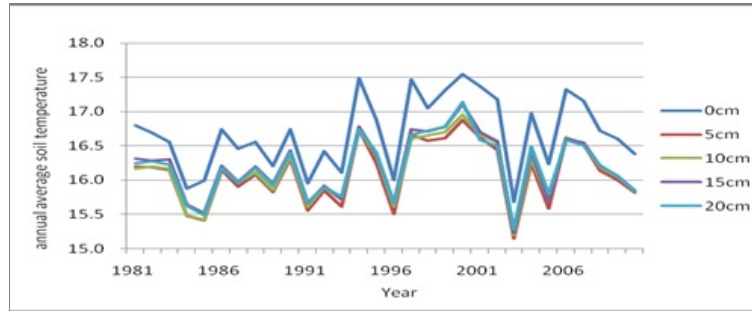


Fig. 2: Annual curve of average soil temperature of Henan from 1981 to 2010

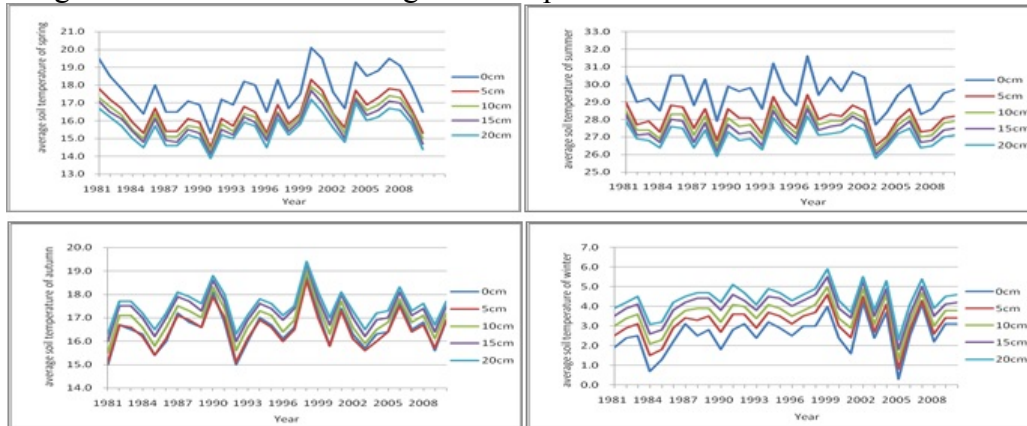


Fig. 3. Annual curve of average soil temperature in four seasons of Henan

Climate trend rate of annual and seasonal average soil temperature

In order to analyze the change trend of soil temperature of Henan Province, linear equation $y=a+bt$ was used to calculate the trend rate of annual and seasonal average temperature of 0-20cm soil. From Table 2, it can be seen that average soil temperature of Henan of the past 30 years shows an increasing trend, of which soil temperature increase of 0cm soil is the highest, which is $0.17^{\circ}\text{C}/10\text{a}$, and 15cm is the lowest, which are $0.08^{\circ}\text{C}/10\text{a}$. Average soil temperature variation of spring, autumn and winter is consistent with the annual variation. The maximum warming of soil temperature is in spring, and the second maximum is in winter. The average soil temperature shows a downward trend in summer.

Table 2: Climate trend rate of average temperature of 0-20cm soil of Henan from 1981 to 2010 $^{\circ}\text{C}/10\text{a}$

layer//cm	0years	spring	summer	autumn	winter	1981-1990 year	1991-2000 year	2001-2010 year
0	0.017	0.038	-0.012	0.015	0.031 [▲]	-0.008	0.147 [▲]	-0.037
5	0.010	0.028	-0.011	0.009	0.020	0.001	0.127 [▲]	-0.021
10	0.011	0.030 [▲]	-0.006	0.008	0.016	0.007	0.128 [▲]	-0.026
15	0.008	0.028	-0.006	0.004	0.012	-0.000	0.140 [■]	-0.030
20	0.010	0.027	-0.005	0.004	0.012	0.002	0.139 [■]	-0.025

Note: ▲ Pass by 95% the significant test, ■ Pass by 99% the significant test

Conclusion

From the perspective of space, 0-20cm soil temperature of Henan Province increases with increasing of latitude. From south to north, annual average soil temperature gradually reduces. Soil temperature of mountains is lower than that of plains at the same latitude. The annual average temperature of 0-20cm soil is $0\text{cm} > 15\text{cm} > 20\text{cm} > 5\text{cm} = 10\text{cm}$. Variation trend in autumn and winter

of the same year is consistent, the average soil temperature gradually reduces with increasing of latitude and is not obvious in spring and summer.

During 1981 to 2010, the average temperature of 0-20cm soil of Henan Province gradually increases from January to July, the highest value is in July, and the average temperature of each layer reduces with increasing of the depth. From August to December, the average soil temperature gradually reduces and the average temperature of each layer increases with increasing of depth. As for annual and seasonal change of average soil temperature, the average soil temperature of 0cm soil of 0cm is obviously higher than those of other layers, and the difference of the average temperature of 5cm soil, 10cm soil, 15cm soil and 20cm soil is very small. During these 30 years, annual change trend of each layer of soil is consistent in soil temperature. From the point of view of climate trend rate, average soil temperature of Henan of the past 30 years shows an increasing trend, of which soil temperature increase of 0cm soil is the highest, which is $0.17^{\circ}\text{C}/10\text{a}$, and 15cm is the lowest, which is $0.08^{\circ}\text{C}/10\text{a}$. Average soil temperature variation of spring, autumn and winter is consistent with annual variation and it shows a downward trend in summer.

As for the vertical change of 0-20cm average soil temperature in the whole year, the average soil temperature gradually reduces from surface layer to bottom layer in spring and summer and gradually increases in autumn and winter.

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References

- [1] Meng Guiyun and Yu Yan. Response of shallow soil temperature to climate change in Xishuangbanna from 1961 to 2005 [J]. *Meteorological Science and Technology*, 2010,38(03):316-320.
- [2] Jia Jinming, Zhu Tengran and Wang Huifang et al. Change characteristics of temperature of 0cm soil in Puyang City and analysis of cause [J]. *Meteorological Science and Technology*, 2009,37(03):330-335.
- [3] Ren Guoyu, Guo Jun and Xu Zhiming et al. Basic characteristics of Chinese ground climate change during the past 50 years [J]. *Acta Meteorologica Sinica*. 2005, 63(6): 942-952.
- [4] Yuan Wentao, Liu Binhui and Liu Yanling et al. Change trend of soil temperature of Heilongjiang Province from 1960 to 2000 [J]. *Journal of Northeast Forestry University*, 2011,(02): 67-71.
- [5] Shi Neng, Chen Jiaqi and Tu Qipu. Climate change characteristics of China during the four inter-decadal years of the past 100 years [J]. *Acta Meteorologica Sinica*. 1995, 53(4): 431-439.
- [6] Hu Jun, Du Jun and Bian Duo et al. Annual and inter-decadal change of soil temperature in Tibet [J]. *Acta Geographica Sinica*, 2007, 62(9): 925-934.