Journal of Geoscience and Environment Protection, 2022, 10, 158-169
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Variation Characteristics of Heat Resources in Liaoning Province, China in Recent 60 Years and Their Impact on Meteorological Services

Yuqi Zhang[1], Lin Ma[2*]

[1]Liaoning Provincial Meteorological Service Center, Shenyang, China
[2]Liaoning Provincial Meteorological Equipment Support Center, Shenyang, China
Email: *malin20051335001@126.com

How to cite this paper: Zhang, Y. Q., & Ma, L. (2022). Variation Characteristics of Heat Resources in Liaoning Province, China in Recent 60 Years and Their Impact on Meteorological Services. *Journal of Geoscience and Environment Protection, 10,* 158-169.
https://doi.org/10.4236/gep.2022.108012

Received: June 13, 2022
Accepted: August 26, 2022
Published: August 29, 2022

Copyright © 2022 by author(s) and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access

Abstract

To study the temporal and spatial changes of heat resources to serve agricultural production and economic development. The climate data from 1958 to 2017 were selected, and the temporal and spatial changes of heat resources in Liaoning, China were analyzed by using the method of climate diagnosis and analysis. The results show that: the southern coastal area of Liaoning has the most heat resources, the northwestern hilly area and the eastern mountainous area the least, and the central plain area in the middle distribution pattern; compared with 1958-1980, 1981-2017 ≥0˚C, ≥10˚C accumulated temperature, etc. The value line is advanced 100-160km northward. The accumulated temperature of ≥0˚C and ≥10˚C in Liaoning experienced abrupt changes in climate in 1993 and 1994, and the climate abrupt change in the southern coastal area was earlier than that in the inland. , the increase in the northwestern hilly area and the eastern mountainous area is less than that in the central plain area and the southern coastal area. The study on the impact on meteorological services found that the increase or decrease of heat resources has a significant impact on agro-meteorological services, which can prolong the growing season of crops, relatively reduce the damage of frost, improve comprehensive utilization of land, and increase crop yields; at the same time, with the increase of heat resources and the northward expansion of the isoline of accumulated temperature, the area affected by pests and diseases has expanded, which has aggravated the harm to agriculture economic burden.

Keywords

Heat Resource, Meteorological Service, Accumulated Temperature, Temporal and Spatial Evolution

1. Introduction

Heat resources are one of the important climatic resources and are closely related to human life. Studying the changes and spatial distribution of heat resources is of great significance to agricultural economy, the layout of agricultural planting, and the coordinated development of rural agriculture, forestry, animal husbandry and fishery. Since the 1980s, the climate has been warming significantly (Zuo et al., 2001; Ren et al., 2005). According to the research of the World Meteorological Organization (IPCC), the annual average temperature will increase by 1.1˚C to 6.4˚C by the end of the 21st century (Qin et al., 2007). The positive and negative effects of the increase in the heat resources of the climate warming on the natural world exist at the same time. Zhang et al. (2015), Qu (2010), Liu et al. (2005) and other studies believe that the positive effects of the increase in the heat resources of the climate warming can prolong the growth period of crops. The possibility of multiple cropping index also brings development space for frost season agriculture and facility agriculture. Zhou et al. (1997), Jiang et al. (2003) and other studies believe that the negative impact of climate warming on human beings is more obvious, such as exacerbating extreme meteorological disasters, destroying inherent natural ecosystems, glaciers melting, sea level rise, land salt Alkalization, and massive transpiration of water make land desertification, etc. The heat resource changes with time and space, which directly affects the plant distribution, crop maturity and planting structure in a region, and is an important factor that causes changes in the yield of agricultural products (Zhang et al., 2004; Shi et al., 2005; Cai et al., 2009). With the gradual warming of the climate, studying the changes in the temporal and spatial distribution of heat resources in Liaoning Province, China has an important reference role in the utilization of climate resources and land resources, the rational distribution of agriculture, the promotion of targeted poverty alleviation in rural areas, and the sustainable development of agriculture. Therefore, this paper selects the accumulated temperature data of ≥0˚C and ≥10˚C in the past 60 years from 1958 to 2017, and uses the climate diagnostic analysis method to analyze the temporal and spatial evolution of heat resources in Liaoning. Aiming at the zoning of heat resources in Liaoning, the research results are expected to provide decision-making basis for the development and utilization of heat resources, agro-climatic zoning and adjustment of agricultural industry structure.

2. Data and Methods

2.1. Geographical Overview

Liaoning Province is located in the southern part of Northeast China, between 118˚53'E - 125˚46'E and 38˚43'N - 43˚26'N. From east to south are the Yalu River waters and the Yellow Sea and the Bohai Sea, echoing the Shandong Peninsula across the Bohai Strait; from the southwest ring to the northeast, it borders Hebei Province, Inner Mongolia Autonomous Region and Jilin Province. The province's total land area is 148,000 km^2, accounting for 1.5% of the country's total land area. Liaoning is horseshoe-shaped, with mountains in the east, hills in the west, the Liaohe Plain in the middle and the coastal plain in the south. Liaoning has a temperate continental monsoon climate with four distinct seasons, rain and heat in the same season, and abundant sunshine. The annual sunshine hours are 2000 - 3000 h, the annual average temperature is 5.1˚C - 12.4˚C, the annual precipitation varies greatly between 300 - 1000 mm, and the average frost-free period is about 150 days.

2.2. Data Sources

The research data comes from the Liaoning Meteorological Information Service Center, and 46 national-level meteorological reference stations are selected to compile climate data. According to the principles of agrometeorology (Feng, 1991), the heat resources in the climate resources from 1958 to 2017 were counted, that is, the accumulated temperature of ≥0˚C and the accumulated temperature of ≥10˚C with obvious agricultural significance. ≥0˚C accumulated temperature is the sum of the daily average temperature between the beginning and the end of the day when the daily average temperature stably passes 0˚C, which is the ploughing period in agricultural production and the heat index at the beginning and end of the growth of cool plants; ≥10˚C accumulated temperature is the sum of the daily average temperature between the beginning and the end of the day when the daily average temperature is stable at 10˚C, and it is the heat index for the start and end of the rapid growth period of temperature-loving crops (Gao et al., 2004).

2.3. Analysis Methods

In order to study the regional distribution, inter-annual variation trend and mutation characteristics of heat resources in Liaoning, the Surfer mapping software (Lu & Lu, 2005) was used to draw the regional distribution of ≥0˚C accumulated temperature and ≥10˚C accumulated temperature in Liaoning Province from 1958 to 2017 and regions in different time periods. Distribution map; the variation characteristics of heat resources in Liaoning were analyzed using methods such as the univariate linear regression climate tendency rate (Wei, 2007) and the Mann-Kendall climate abrupt change test (Duan & Jiang, 2006). Computational analysis is performed with the support of the Excel program (An, 2003).

3. Results and Analysis

3.1. Spatial Variation of Heat Resources

The spatial variation characteristics of accumulated temperature ≥0˚C in Liaoning from 1958 to 2017 are related to the terrain, and the lowest value is distributed in the Laoha River Basin north of the Nurul Hushan Mountains in western Liaoning and the mountainous area in eastern Liaoning, with the lowest The value is 3028˚C·d; the highest value is distributed in southern Liaoning and the area 110 km away from the coastline, and the highest value is 4731˚C·d.

According to the threshold value of 200˚C·d (Feng, 1991; Gao et al., 2004; Duan & Jiang, 2006), the accumulated temperature distribution of Liaoning ≥0˚C was divided into three different regions. The first area ≥0˚C accumulated temperature ≤3750˚C·d, with an average of 3514˚C·d, is located in the Laoha River Basin in the northwest of Liaoning, represented by Jianping Station; Jilin Hada extends from north to south in the mountainous area of eastern Liaoning Ridge, Moli Hongshan and the east of Motianling in Benxi, including Xifeng, Qingyuan, Fushun, Huanren, Xiuyan, Kuandian and other places. The second zone ≥0˚C accumulated temperature is between 3750˚C·d~3950˚C·d, with an average of 3871˚C·d, located in the Liaohe Plain, bounded between the mountainous area of eastern Liaoning and the hilly area of western Liaoning. Specifically, it includes Zhangwu, Fuxin, Kangping, Tieling, Liaozhong, Yixian, Heishan, Shenyang, Liaoyang, Benxi, south of Dandong, Zhuanghe and other places. The third area is ≥0˚C accumulated temperature ≥3950˚C·d, with an average of 4111˚C·d. It is located in the southern part of the western Liaoning region, along the coast of the Yellow Sea and the Bohai Sea and the Dalian region, including the southern part of Chaoyang region, the southern part of Jinzhou region, Panshan and Anshan, Huludao, Suizhong, Yingkou, Wafangdian, Dalian and other places. The second zone is 357˚C·d more than the first zone, the third zone is 240˚C·d more than the second zone, and the third zone is 597˚C·d more than the first zone.

For the spatial distribution of accumulated temperature ≥0˚C in three time periods from 1958 to 1980, 1981 to 1999 and 2000 to 2017 in **Table 1**, it shows that the evolution process of accumulated temperature ≥0˚C in Liaoning in space shows that With the change of age ≥0˚C, the accumulated temperature gradually increases while the accumulated temperature isoline expands to the north.

From 2001 to 2017, compared with 1981 to 2000, the accumulated temperature of the first area ≥0˚C increased by 109˚C·d on average, the second area ≥0˚C accumulated temperature increased by 116˚C·d on average, and the third area ≥0˚C The accumulated temperature increased by 112˚C·d on average, and the accumulated temperature isoline moved northward by 70 - 90 km.

Table 1. Average accumulated temperature (AT) of ≥0˚C and ≥10˚C in different regions and different time periods in Liaoning.

Years	≥0˚C AT (˚C·d)			≥10˚C AT (˚C·d)		
	Zone I	Zone II	Zone III	Zone I	Zone II	Zone III
1958-2017	3514	3871	4111	3076	3431	3676
1958-1980	3410	3764	4005	2985	3340	3582
1981-2000	3511	3866	4108	3080	3437	3686
2001-2017	3620	3982	4220	3162	3517	3760

From 1981 to 2000, compared with 1958 to 1980, the accumulated temperature of the first area ≥0˚C increased by 101˚C·d on average, the second area ≥0˚C accumulated temperature increased by 102˚C·d on average, and the third area ≥0˚C the accumulated temperature increased by 103˚C·d on average, and the isoline of accumulated temperature moved northward by 50 - 70 km.

From 2001 to 2017, compared with 1958 to 1980, the average increase of accumulated temperature ≥0˚C in the first area was 210˚C·d, the average increase in accumulated temperature ≥0˚C in the second area was 218˚C·d, and the average increase in the accumulated temperature in the third area ≥0˚C The accumulated temperature increased by 215˚C·d on average, and the isoline moved northward by 120 - 160 km.

Spatial distribution of accumulated temperature ≥10˚C in Liaoning from 1958 to 2017 is consistent with the spatial distribution of accumulated temperature ≥0˚C. The lowest value is distributed in the Laoha River Basin in the northwest and the mountainous area in eastern Liaoning, and the lowest value is 2400˚C·d; the highest value is distributed in the coastal area of southern Liaoning, the highest value is 4236˚C·d.

According to the threshold value of 250˚C·d (Feng, 1991; Gao et al., 2004; Duan & Jiang, 2006), the spatial distribution of accumulated temperature of ≥10˚C in Liaoning is divided into three regions, which are consistent with the division of accumulated temperature of ≥0˚C. The accumulated temperature of ≥10˚C in the first zone is below ≤3300˚C·d, with an average of 3076˚C·d; the accumulated temperature of ≥10˚C in the second zone is between 3300˚C·d - 3600˚C·d The average temperature is 3431˚C·d during the period; the accumulated temperature of ≥10˚C in the third area is above ≥3600˚C·d, and the average is 3676˚C·d. the second zone is 355˚C·d more than the first zone, the third zone is 245˚C·d more than the second zone, and the third zone is 600˚C·d more than the first zone.

From the spatial distribution map of accumulated temperature ≥10˚C in the three time periods of 1958-1980, 1981-2000 and 2001-2017 in **Table 1**, it shows that the evolution process of accumulated temperature ≥10˚C in Liaoning in space, the performance is It shows that with the change of age, the accumulated temperature of ≥10˚C gradually increases and the accumulated temperature line expands to the north.

From 2001 to 2017, compared with 1981 to 2000, the accumulated temperature of the first zone ≥10˚C increased by 95˚C·d on average, the second zone ≥10˚C accumulated temperature increased by 93˚C·d on average, and the third zone ≥10˚C the accumulated temperature increased by 106˚C·d on average, and the accumulated temperature isoline moved northward by 60 - 70 km.

From 1981 to 2000, compared with 1958 to 1980, the accumulated temperature of the first area ≥10˚C increased by 82˚C·d on average, the second area ≥10˚C accumulated temperature increased by 80˚C·d on average, and the third area ≥10˚C the accumulated temperature increased by 74˚C·d on average, and the isoline of accumulated temperature moved northward by 40 - 50 km.

From 2001 to 2017, compared with 1958 to 1980, the accumulated temperature of the first area ≥10˚C increased by 177˚C·d on average, the second area ≥10˚C accumulated temperature increased by 173˚C·d on average, and the third area ≥10˚C the accumulated temperature increased by 180˚C·d on average, and the isoline moved northward by 100 - 120 km.

3.2. Time Distribution and Trend Change of Heat Resources

The accumulated temperature ≥0˚C in Liaoning region averaged 3826˚C·d from 1958 to 2017, the lowest value appeared in 1976 (Jianping) was 3028˚C·d, and the highest value appeared in 2014 (Anshan) was 4731˚C·d. Figure 1(a) shows the interannual variation trend of ≥0˚C accumulated temperature in the Liaoning region from 1958 to 2017. The accumulated temperature from 1958 to 1993 was low and the fluctuation was large. After 1994, the accumulated temperature was high. The whole series showed an increasing trend. The correlation coefficient was 0.5877 ($p < 0.01$), which reached a very significant level, and the climate trend rate was 49.528˚C·d/10a, with a linear increase of 297˚C·d. According to the Mann-Kendall mutation test analysis, the accumulated temperature of ≥0˚C mutated in 1993 and 1994. Before the mutation (1958-1993), the accumulated temperature of ≥0˚C was 3749˚C·d on average, and after the mutation (1994-2017) was 3943˚C·d on average, an increase of 195˚C·d year-on-year.

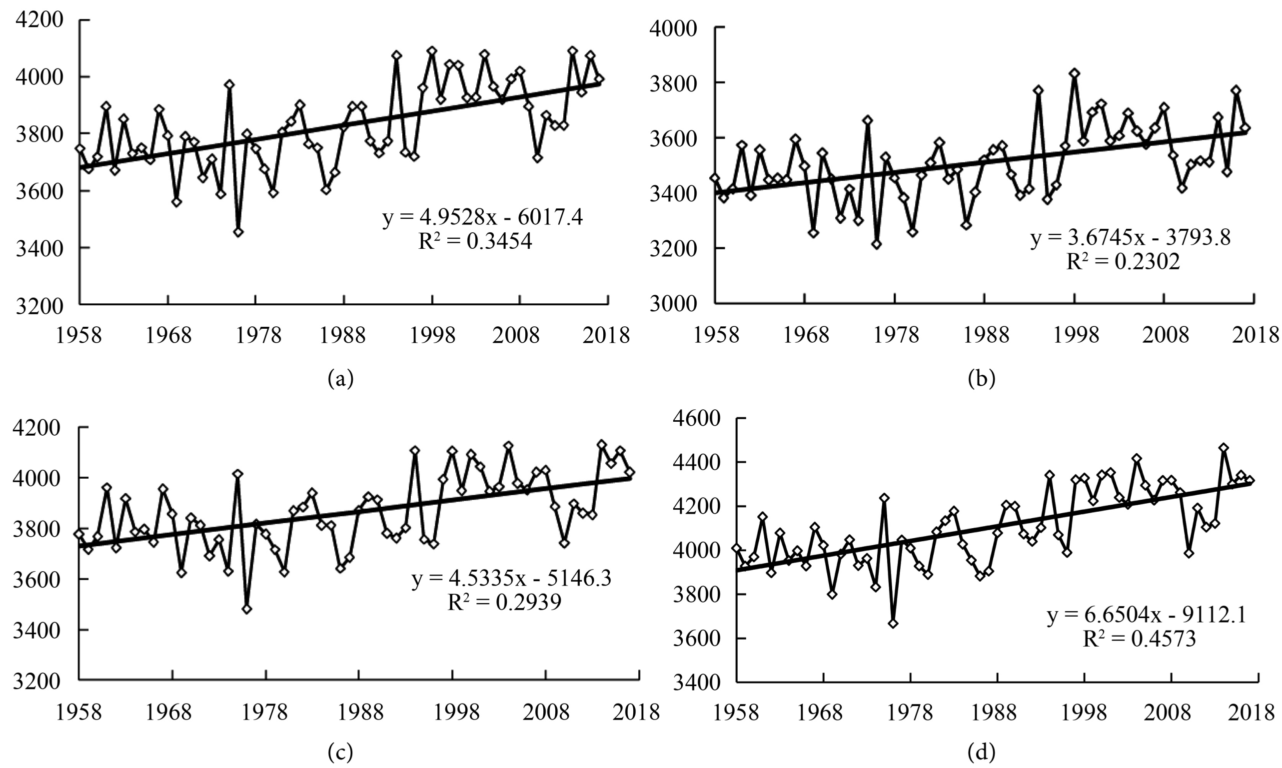

Figure 1. Inter-annual variation of ≥0˚C accumulated temperature in Liaoning in each zone ((a). the whole province of Liaoning, (b). zone I, (c). zone II, (d). zone III; X coordinate is year, Y coordinate is accumulated temperature in the unit of ˚C·d).

From 1958 to 2017, the average accumulated temperature of ≥0˚C in the first area of heat resources was 3509˚C·d, the lowest value appeared in 1976 (Jianping) and it was 3028˚C·d, and the highest value appeared in 2014 (Xiuyan) is 4 024˚C·d. Figure 1(b) shows the interannual variation trend of accumulated temperature ≥0˚C in the first region from 1958 to 2017. The accumulated temperature from 1958 to 1993 was low, and the accumulated temperature after 1994 was high. The whole series showed a gradual increasing trend. The serial correlation coefficient the climatic trend rate was 36.745˚C·d/10a, which increased linearly by 208˚C·d. According to the Mann-Kendall mutation test analysis, the accumulated temperature ≥0˚C mutated in 1993 and 1994. Before the mutation (1958-1993), the average accumulated temperature ≥0˚C was 3447˚C·d, and after the mutation (1994-2017) was 3603˚C·d on average, an increase of 156˚C·d year-on-year.

From 1958 to 2017, the average accumulated temperature of ≥0˚C in the second area of heat resources was 3864˚C·d, the lowest value appeared in 1976 (Zhangwu) and it was 3366˚C·d, and the highest value appeared in 2004 (Tieling) is 4306˚C·d. Figure 1(c) shows the interannual variation trend of accumulated temperature ≥0˚C in the second region from 1958 to 2017. The accumulated temperature from 1958 to 1993 was low, and after 1994, the accumulated temperature was high. The whole series showed a gradual increasing trend. The serial correlation coefficient the climatic trend rate was 45.335˚C·d/10a, with a linear increase of 272˚C·d. According to the Mann-Kendall mutation test analysis, the accumulated temperature ≥0˚C mutated in 1993 and 1994. Before the mutation (1958-1993), the average accumulated temperature ≥0˚C was 3791˚C·d, and after the mutation (1994-2017) was 3972˚C·d on average, an increase of 182˚C·d year-on-year.

From 1958 to 2017, the average accumulated temperature ≥0˚C in the third area of heat resources was 4106˚C·d, the lowest value appeared in 1976 (Chaoyang) was 3640˚C·d, and the highest value appeared in 2014 (Anshan) as 4 731˚C·d. Figure 1(d) shows the interannual variation trend of accumulated temperature ≥0˚C in the third region from 1958 to 2017. The low value fluctuates from 1958 to 1989, and the high value fluctuates after 1990. The whole series shows a gradual increase trend. The coefficient was 0.6762 ($p < 0.01$), which reached a very significant level, and the climate trend rate was 66.504˚C·d/10a, a linear increase of 399˚C·d. According to the Mann-Kendall mutation test analysis, the accumulated temperature ≥0˚C mutated in 1989 and 1990. Before the mutation (1958-1989), the average accumulated temperature ≥0˚C was 3 995˚C·d, and after the mutation (1990-2017) was 4232˚C·d on average, an increase of 237˚C·d year-on-year.

Among the three heat resource climate zones, the third zone has the largest increase in accumulated temperature ≥0˚C and the earliest climate mutation, while the first and second regions have relatively late climate mutation and the accumulated temperature increase is also less.

From 1958 to 2017, the average accumulated temperature of ≥10˚C in Liaoning region was 3393˚C·d, the lowest value appeared in 1969 (Qingyuan) was 2400˚C·d, and the highest value appeared in 1998 (Anshan) was 4236˚C·d. **Figure 2(a)** shows the interannual variation trend of accumulated temperature ≥10˚C in the Liaoning region from 1958 to 2017. The whole series showed a gradual upward trend of fluctuation. The series correlation coefficient was 0.4820 ($p < 0.01$), which reached a very significant level, and the climate trend rate was 45.169˚C·d/10a, linearly increasing by 271˚C·d. According to the Mann-Kendall mutation test analysis, the accumulated temperature of ≥10˚C mutated in 1996 and 1997. Before the mutation (1958-1996), the average accumulated temperature of ≥10˚C was 3325˚C·d, and after the mutation (1997-2017) was 3519˚C·d on average, an increase of 194˚C·d year-on-year.

From 1958 to 2017, the average accumulated temperature of ≥10˚C in the first area of heat resources was 3051˚C·d, the lowest value appeared in 1976 (Qingyuan) and was 2400˚C·d, and the highest value appeared in 1998 (Fushun). is 3737˚C·d. **Figure 2(b)** shows the interannual variation trend of accumulated temperature ≥10˚C in the first region from 1958 to 2017. The change trend in the first half of the series from 1958 to 1996 was stable, and the change in the second half of the series from 1997 to 2017 showed a fluctuating downward trend. The series showed an increasing trend, and the series correlation coefficient was 0.3484 ($p < 0.01$), which reached a significant level, and the climate trend rate was 33.445˚C·d/10a, a linear increase of 207˚C·d. According to the Mann-Kendall mutation test analysis, the accumulated temperature of ≥10˚C

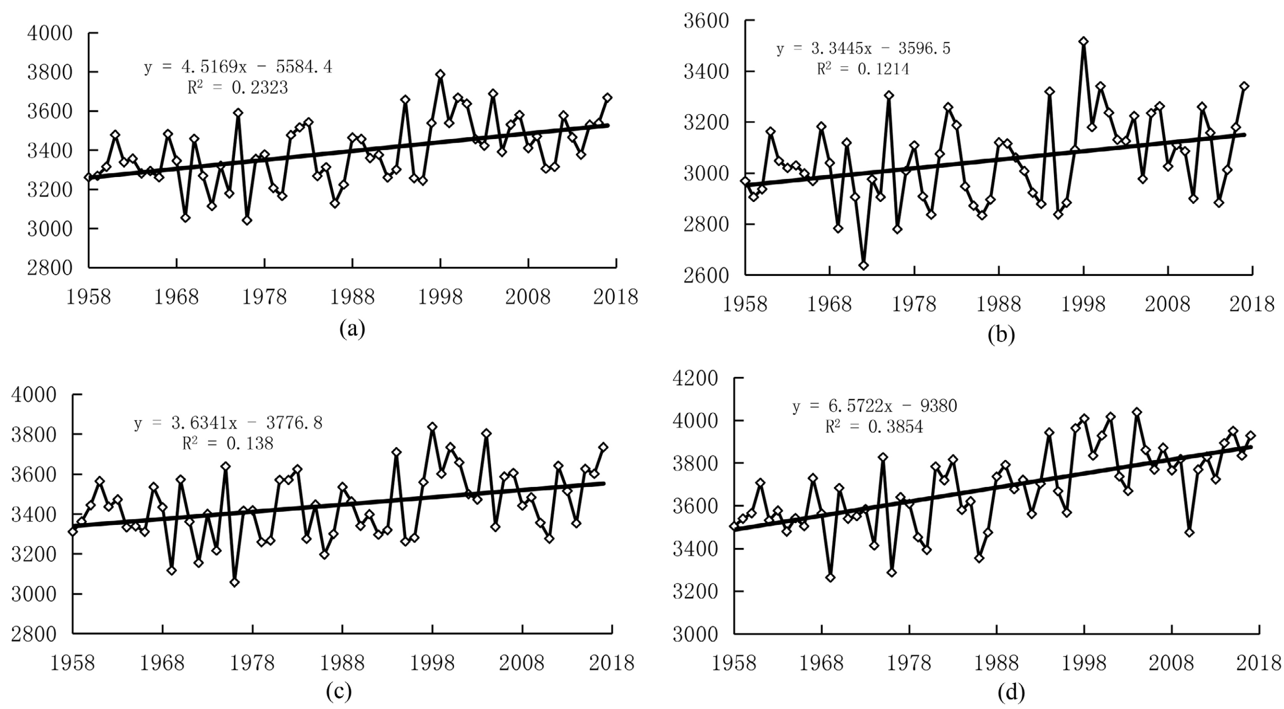

Figure 2. Inter-annual variation of ≥10˚C accumulated temperature in Liaoning in each zone ((a). the whole province of Liaoning, (b). zone I, (c). zone II, (d). zone III; X coordinate is year, Y coordinate is accumulated temperature in the unit of ˚C·d).

mutated in 1996 and 1997. Before the mutation (1958-1996), the average accumulated temperature of ≥10˚C was 2994˚C·d, and after the mutation (1997-2017) was 3156˚C·d on average, an increase of 162˚C·d year-on-year.

From 1958 to 2017, the average accumulated temperature of ≥10˚C in the second area of heat resources was 3446˚C·d, the lowest value appeared in 1972 (Tieling) was 2873˚C·d, and the highest value appeared in 1998 (Shenyang) as 4011˚C·d. Figure 2(c) shows the interannual variation trend of accumulated temperature ≥10˚C in the second region from 1958 to 2017. The change in the first half of the series from 1958 to 1996 showed a downward trend, and the second half of the series from 1997 to 2017 also showed a downward trend. The whole series showed an increasing trend, and the series correlation coefficient was 0.3715 ($p < 0.01$), which reached a very significant level. The climate trend rate was 36.341˚C·d/10a, a linear increase of 218˚C·d. According to the Mann-Kendall mutation test analysis, the accumulated temperature ≥10°C mutated in 1996 and 1997. Before the mutation (1958-1996), the average accumulated temperature ≥10˚C was 3385˚C·d, and after the mutation (1997-2017) was 3559˚C·d on average, an increase of 173˚C·d year-on-year.

From 1958 to 2017, the average accumulated temperature of ≥10˚C in the third area of heat resources was 3682˚C·d, the lowest value appeared in 1976 (Chaoyang), which was 3640˚C·d, and the highest value appeared in 2014 (Anshan), which was 3640˚C·d. 4731˚C·d. Figure 2(d) shows the interannual variation trend of accumulated temperature ≥10˚C in the third region from 1958 to 2017. The whole sequence shows a gradual increasing trend. The sequence correlation coefficient is 0.6208 ($p < 0.01$), reaching a very significant level, and the climate trend rate is 65.722˚C·d/10a, a linear increase of 394˚C·d. According to the Mann-Kendall mutation test analysis, the accumulated temperature ≥10˚C mutated in 1988 and 1989. Before the mutation (1958-1988), the average accumulated temperature ≥10˚C was 3562˚C·d, and after the mutation (1989-2017) was 3803˚C·d on average, an increase of 241˚C·d year-on-year.

Among the three heat resource climate zones, the third zone has the largest increase in accumulated temperature ≥10˚C and the earliest climate abrupt change, while the first and second zones have a relatively late increase in accumulated temperature.

4. Conclusions and Discussion

4.1. Conclusions

According to the topography, topography and geographical distribution characteristics of heat resources in Liaoning, there are two low-value centers, the north of the Nurul Hushan Mountains and the eastern mountainous area of Liaoning, and the high-value areas appear in the southern coast. According to the zoning indicators of ≥0˚C accumulated temperature of 200˚C·d and ≥10˚C of 250˚C·d accumulated temperature, Liaoning Province can be divided into three distinct regions of heat resource climate.

The heat resources in Liaoning fluctuated from 1958 to 2017. The ≥0˚C accumulated temperature isoline advanced northward by about 120 - 160 km, and the ≥10˚C accumulated temperature isoline advanced northward by about 100 - 120 km. The average ≥0˚C and ≥10˚C accumulated temperature interannual variation climatic tendency rates in Liaoning Province are 49.528˚C·d/10a and 45.169˚C·d/10a, respectively, with a linear increase of 297˚C·d and 195˚C·d. The climatic tendency rate of each climatic region is different, and the accumulated temperature value of linear increase is also different. The accumulated temperature value increases gradually from north to south, and the heat resources increase more obviously in the area with high accumulated temperature in the south. In other words, the heat resource increase in the first zone is the least.

In 1993 and 1994, the accumulated temperature of ≥0˚C in Liaoning province experienced abrupt climate change, and the accumulated temperature increased by 195˚C·d after the abrupt change. The accumulated temperature of ≥10˚C changed abruptly in 1996 and 1997, and the accumulated temperature increased by 194˚C·d after the mutation. The abrupt change of heat resource climate in the third region is earlier than that in the second and first regions.

4.2. Discussion

In summary, the heat resources in Liaoning have increased significantly in the past 25 years (1994-2017), and the southern coast is higher than the northwestern hills and eastern mountainous areas. The isolines of accumulated temperature ≥0˚C and ≥10˚C representing the agricultural limit temperature advance 100 - 160 km northward, and the accumulated temperature value increases by about 200˚C·d on average. Judging from the interannual variation of accumulated temperature, it is a fluctuating and increasing trend, not a steady increase process. For example, 2010 was a low temperature year, and the accumulated temperature value ranked seventh from the bottom in the past 60 years (1958-2017). It can be seen that climate change Warm instability.

In addition, for agriculture, the increase in heat resources can prolong the growing season of crops, accelerate the growth rate of crops, and relatively reduce the harm of frost. It can introduce crops with longer growth periods to increase biological yield, which is helpful for adjusting the structure of crop varieties and intercropping in the farming system. It is very beneficial to expand the facility agriculture to the north, improve the comprehensive utilization rate of land, and increase the yield per unit area. However, the negative impact brought by the increase of heat resources cannot be ignored. For example, with the increase of heat resources and the northward expansion of the isoline of accumulated temperature, the overwintering and reproduction of pests and diseases increase, and the damage area expands, etc. Harm to agriculture, the temperature rises, the evaporative power increases, and the warming and aridification become more and more serious, which increases the economic burden on agriculture.

The temporal and spatial distribution of heat resources is one of the important elements of agro-climatic resource zoning and agricultural resource zoning. The results of this study are greatly changed and different from the results of agro-climatic zoning studies in the 1980s, which are reasonable for the current guidance of agricultural production. The development and utilization of heat resources in Liaoning has important reference value.

Conflicts of Interest

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

References

An, W. M. (2003). *Using Excel to Manage and Analyze Data* (pp. 208-263). People's Posts and Telecommunications Press.

Cai, F., Zhang, Y. S., Chen, P. S. et al. (2009). Analysis on the Temporal and Spatial Evolution Characteristics of Heat Resources in Liaoning in the Past 50 Years. *Journal of Natural Resources, 24,* 1635-1645.

Duan, R. X., & Jiang, H. F. (2006). *Agricultural Temperature* (pp. 5-35). China Meteorological Press.

Feng, X. Z. (1991). *Principles of Agricultural Meteorology* (pp. 72-127). China Meteorological Press, Beijing.

Gao, S. F., Chen, W. L., Zhu, C. Q. et al. (2004). *Applied Climatology* (pp. 40-46). China Meteorological Press.

Jiang, X. D., Liu, Y., & Xia, B. C. (2003). Global Climate Change and Its Impact on Ecosystems. *Journal of Sun Yat-sen University, 23,* 257-262.

Liu, D. X., Dong, A. X., & Deng, Z. Y. (2005). The Impact of Climate Warming on Agriculture in Northwest China. *Journal of Natural Resources, 20,* 119-125.

Lu, Z. B., & Lu, Y. S. (2005). The Application of Surfer8.0 in Environmental Assessment and Planning. *Journal of Tongji University (Natural Science Edition), 33,* 191-195.

Qin, D. H., Luo, Y., & Chen, Z. L. (2007). The Latest Progress in Climate Change Science—Analysis of the IPCC Fourth Assessment Comprehensive Report. *Advances in Climate Change Research, 3,* 311-314.

Qu, Z. J. (2010). Study on the Response of Heat Resources to Climate Change during Crop Growth Period in Shaanxi. *Resources and Environment in Arid Areas, 24,* 75-79.

Ren, G. Y., Guo, J., Xu, M. Z. et al. (2005). Basic Characteristics of China's Surface Climate Change in the Past 50 Years. *Acta Meteorology, 63,* 942-956.

Shi, J., Du, C. Y., Wang, Y. G. et al. (2005). Heat Resources and Their Distribution in Heilongjiang Province. *Heilongjiang Meteorology, 29,* 29-32.

Wei, F. Y. (2007). *Modern Climate Statistical Diagnosis and Prediction Technology* (pp. 13-204). China Meteorological Press.

Zhang, F. R., Yin, H. T., Zhang, G. L. et al. (2015). Heat Resources and Frost Period Variation Characteristics in Western Liaoning. *China Agricultural Science Bulletin, 31,* 183-187.

Zhang, Y. S., Ban, X. X., Ji, R. P. et al. (2004). Analysis of Climate Resources in Liaoning Province. *Meteorological Science and Technology, 32,* 39-43.

Zhou, G. S., Zhang, X. S., Gao, S. H. et al. (1997). Study on the Response of Chinese Vegetation to Global Change. *Chinese Journal of Botany, 39,* 879-886.

Zuo, H. C., Lv, S. H., & Hu, Y. Q. (2001). Analysis on the Changing Trend of Temperature and Precipitation in China in the Past 50 Years. *Plateau Meteorology, 23,* 238-244.