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The Establishment of Heilongjiang Agricultural Climate Resource Set Based on DEM

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Abstract

In order to comprehensively understand the current status of agricultural climate resources in Heilongjiang Province, the climate observation data of 110 meteorological stations in Heilongjiang Province from 1953 to 2013 and the geographical basic information data of the corresponding stations are used, and the method of residual error correction is calculated by using a small grid. The elevation data uses 90m * 90m SRTM DEM data to extract the latitude, longitude, altitude, slope and aspect information of each grid point, and establishes the Heilongjiang Province agroclimatic resource set, and analyzes it with 7 climate resource elements as examples. The results show that the multiple linear regression complex correlation coefficients of average temperature, annual average temperature, accumulated temperature greater than 0 ℃ and accumulated temperature greater than 10℃ from May to September reached 0.930, 0.950, 0.944 and 0.930. The results of the agricultural climate resource set obtained through the residual error correction are detailed and practical and can describe the spatial distribution characteristics of climate resources in Heilongjiang Province under different terrain conditions. This study can provide a scientific method and a basis for decision-making for the rational layout and planning of agriculture.

Keywords

Heilongjiang Province; Agricultural climate resources; GIS; DEM.

1. Introduction

Agricultural climate resources refer to climate resources that provide materials and energy for agricultural production. The quantity, combination, and distribution of light, heat, water, air, and other elements that constitute agricultural climate resources determine the agricultural production type, production efficiency, and agricultural production potential of a region to a certain extent [1]. Heilongjiang has a continental monsoon climate between temperate and cold regions, with an average annual temperature of -4~4 degrees Celsius. The temperature decreases from south to north, with a difference of 8 degrees Celsius. In summer, the temperature is high, there is much precipitation, and the light time is long, which is suitable for the growth of crops. The solar radiation resources are abundant, the annual solar radiation energy is 100-120 kilocalories per square centimeter. The wind speed in spring is the largest, the number of strong wind days in the southwest is the largest, and the wind energy resources are rich. However, the topography and landform of the area are complex, with different site conditions. The temperature difference between winter and summer is large, the

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temperature difference between day and night is large, the difference between north and south and vertical is large, the climate types are diverse, the climate resources are rich, and the development potential is good. With the rapid development of modern agricultural production, the analysis of agricultural climate resources has put forward higher requirements[2] . In the past, the discrete point analysis used in the evaluation of agricultural climate resources has failed to meet the requirements of objective quantitative analysis. Therefore, it is necessary to use the existing site climate data to reasonably calculate the climate resource elements on the small grid points. The research in Heilongjiang Province has not yet been carried out. The author has used the data of 110 weather stations in Heilongjiang Province for nearly 60 years and established a set of Heilongjiang agricultural climate resources based on the method of DEM-based multiple linear regression and variance correction. With a view to providing a basis for agricultural development planning, crop layout and planting system planning in Heilongjiang Province.

2. Data sources and processing

The meteorological data selected the daily observation values of the ground meteorological elements of 110 weather stations in the whole Heilongjiang Province from 1953 to 2013, including the geographic information of each station, latitude and longitude, altitude (m), daily maximum temperature (℃), daily minimum Parameters such as temperature (℃), precipitation (mm) from 20 to 20 hours, and sunshine hours (h). Use MySQL to build a database to store the original data of weather stations, write data processing programs in Go language, filter and carefully process the data, remove the missing elements in daily observation data, and calculate the temperature of each meteorological station during the 60 years, months, seasons, and years , Precipitation and sunshine data, as well as the accumulated temperature of each station greater than 0℃ and greater than 10 ℃. Download the Chinese digital elevation model from the scientific data sharing platform of the Chinese Academy of Sciences (http://datamirror.csdb.cn/index.jsp), 90m*90m SRTM DEM[3]data to extract the latitude, longitude and altitude of each grid point , Slope and aspect information. Information on administrative boundaries (including county boundaries) of 1:250000 in Heilongjiang Province [4].

3. Climate resource small network calculation

According to the results of many years of research [5-7], the elements of climate resources are divided into macro geographic factors (longitude, latitude, altitude) and micro geographic factors. The model of climate elements can be expressed as

$$y = y^* + y_g = f(\alpha,\beta,\gamma) + y_g$$

In the formula: y for climate resources factors(average temperature of the year, average temperature of the year, and accumulated temperature greater than 10 °C), y^* for general topographic factors, can be generally fit a certain climate equation, y_g for micro-geographic factors affects the residual of the fitted climate equation, α,β,γ stand for longitude, latitude, and altitude[8-10].

3.1 Multiple linear regression

According to the climate characteristics and terrain characteristics of Heilongjiang Province, based on the data of 110 stations, a multiple stepwise linear regression model was established using SPSS software. The three trend equations of Heilongjiang Province's average temperature from May to October, average temperature from June to August, and accumulated temperature greater than 10 °C are established (all passed the 0.01 reliability test), and the model fitting effect is good. Table 1 lists the estimated model and the F-test, complex correlation coefficient, and adjusted R-square of the model.

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Table 1 Climate factors multivariate stepwise linear regression model

Index	Model	F test	Complex correlation coefficient	Adjusted R2
Avg temp (May-Sep)	$y^* = -0.187 \cdot \alpha + (-0.471) \cdot \beta + (-0.007) \cdot \gamma + 64.924$	221.065	0.930	0.862
Annual avg temp	$y^* = -0.105 \cdot \alpha + (-0.841) \cdot \beta + (-0.006) \cdot \gamma + 56.718$	316.212	0.950	0.899
Accumulated temp (> 0 °C)	$y^* = -33.703 \cdot \alpha + (-117.282) \cdot \beta + (-1.484) \cdot \gamma + 13081.919$	279.388	0.944	0.887
Accumulated temp (> 10 °C)	$y^* = -28.582 \cdot \alpha + (-72.012) \cdot \beta + (-1.125) \cdot \gamma + 9935.498$	221.139	0.930	0.862

The simulated value of the meteorological elements of the station is calculated based on the above prediction model and the geographic terrain data of each meteorological station. We use the difference between the actual meteorological element value of each station and the model predicted value as the residual value($y_g = y - y^*$). It is the residual information that has not been explained by multiple linear regression, and is often a small fluctuation caused by the fact that the elements of climate resources are affected by micro-topographic factors. In order to improve the fitting accuracy, it is necessary to spatially interpolate the residual part of each climate resource element, which is used to correct the climate resource network data.

3.2 Residual interpolation, rainfall and sunshine hours interpolation

There are generally two types of spatial interpolation methods. According to the use of interpolation points or control points, the first method it is divided into global methods and local methods [11]. The global method uses all known points to estimate the data value of unknown points, while the local method uses some known points (ie, known point samples) to estimate unknown points. The other is divided into deterministic interpolation methods and geostatistical methods based on mathematical principles (determination of interpolation results or not). The classification of spatial interpolation methods is shown in the figure.

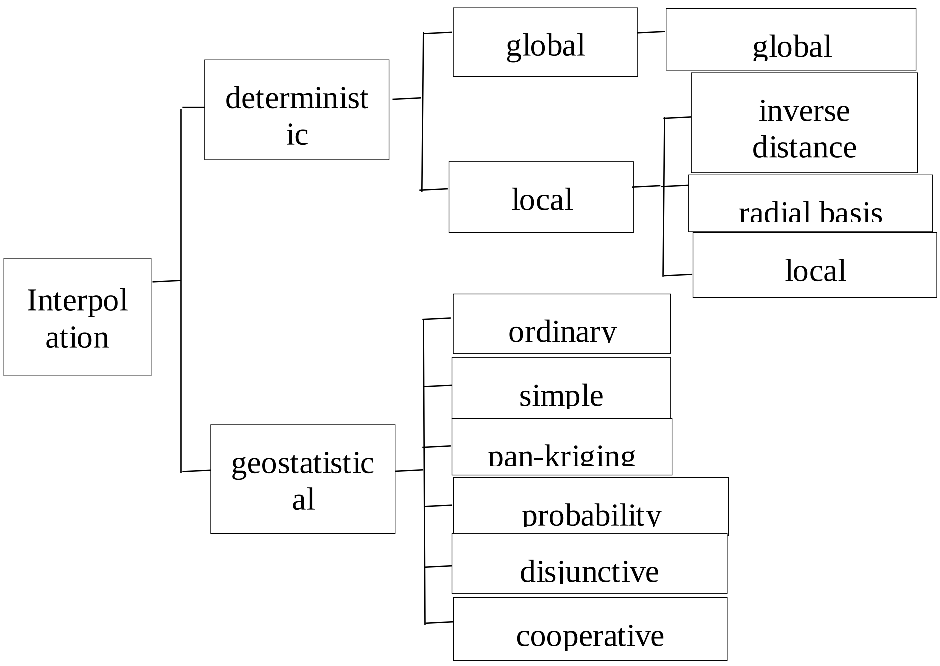

Fig.1 The types of Kriging methods divided according to the mathematical principles of their realization

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In the meteorological factor spatial interpolation method, there is no universal optimal interpolation method, only the most suitable interpolation method under specific conditions. Commonly used spatial interpolation methods include ordinary kriging, universal kriging, inverse distance weighting (IDW), spline method, and natural neighbor method, etc. At present, the residual interpolation of various climate elements has not yet formed a mature plan . In this study, through cross-validation and comparison of different interpolation results, the most appropriate average temperature residuals from May to September, annual average temperature residuals, accumulated temperature residuals greater than 0℃ and accumulated temperature residuals greater than 10℃ are selected.

The cross-validation method verifies the absolute error of the simulated values of different interpolation methods, using mean prediction error (Mean) and root mean squared error (RMS) as the test standards.

$$E_{Mean}=\frac{\sum_{i=1}^{n}(P(S_i)-L(S_i))}{n} \qquad E_{RMS}=\sqrt{\frac{\sum_{i=1}^{n}(P(S_i)-L(S_i))^2}{n}}$$

Above, $P(S_i)$ is predicted value for site, $L(S_i)$ is observed value for site. Compare the interpolation results of different interpolation methods with the actual residual values of each meteorological factor of the station, and cross-validate the accuracy of the spatial interpolation results under different methods in Table 3. The mean error of meteorological factor residual interpolation is closer to 0, and the smaller the root mean square error, the better. It can be seen from Table 3 that the most suitable method for the residual interpolation of the average temperature from May to September is the radial basis function interpolation method. Then the global polynomial interpolation method.

Table 2 Cross-validation of Residual Errors of Different Meteorological Indexes by Different Interpolation Methods

	index	Common kriging (1x)	Global polynomial	Local polynomial	Inverse distance weighting	Radial basis function
Average temperature residuals (May-Sep)	RMS	0.9924665	0.8113704	0.9955351	0.7654754	**0.7415208**
	Mean	0.1929158	-0.0261377	-0.1850724	-0.085157	**-0.0230655**
Average temperature residuals (year)	RMS	0.4623465	**0.5214987**	0.4701436	0.4687173	0.464669
	Mean	-0.003050	**-0.0012279**	0.0135772	0.0328391	0.0038939
Accumulated temperature residual (>0℃)	RMS	55.04853	**66.00627**	56.99531	55.70141	56.38404
	Mean	0.6061889	**0.3347383**	-6.652683	6.37864	3.465549
Accumulated temperature residual (>10℃)	RMS	56.53162	**63.79448**	54.80321	54.5608	54.96333
	Mean	2.83819	**0.3765645**	-3.561428	6.75166	3.960085

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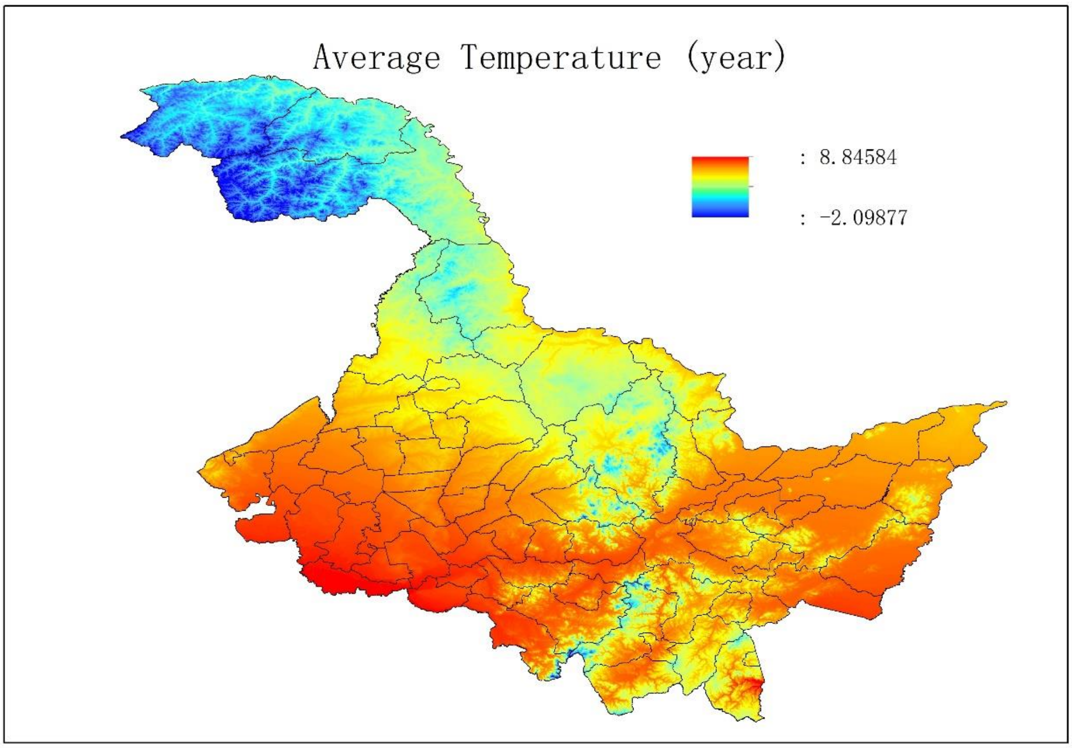

Fig. 2 Distribution map of annual average temperature in Heilongjiang Province

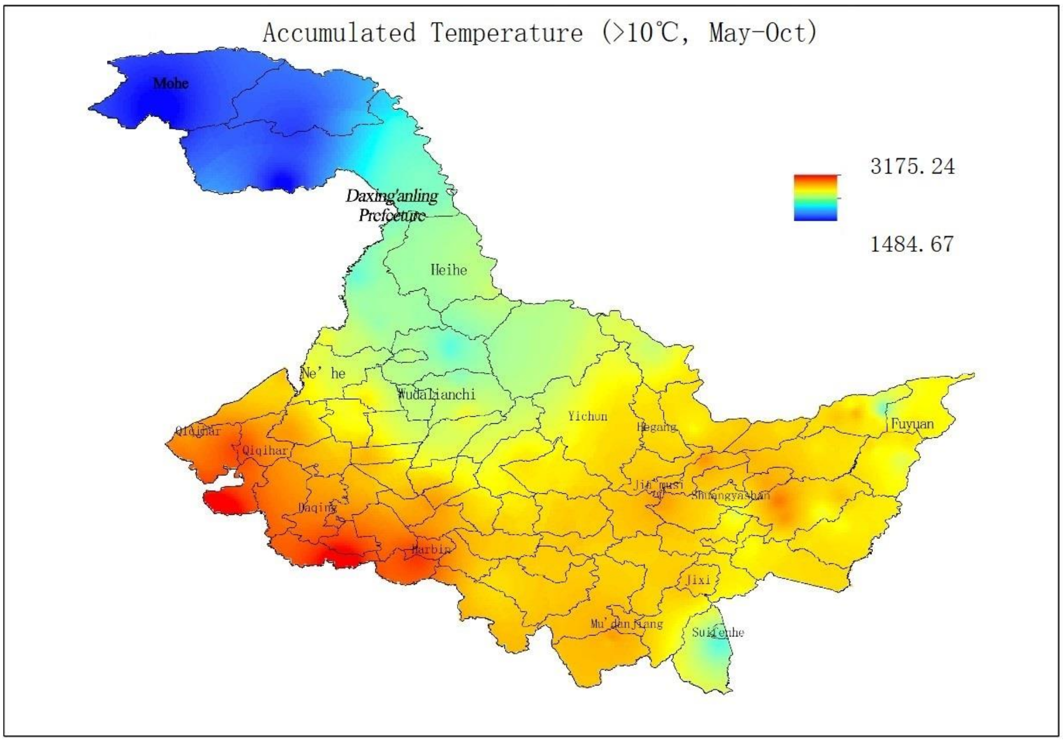

Fig. 3 Distribution map of accumulated temperature in Heilongjiang province from May to October(>10℃)

Sunshine hours refer to the hours when the sun actually shines in one place. In a given time, the number of hours of sunshine is defined as the sum of the periods when the direct irradiance of the sun reaches or exceeds 120 watts per square meter, in hour units, taking two decimal places. Sunshine hours can also be called real hours. There are four main factors that affect the solar sunshine time: day length, terrain, weather conditions, and latitude. Day length: the longer the daytime, the longer

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the sunshine time. Terrain: Higher terrain, earlier morning sunrise and evening sunset, with longer sunshine time. Weather conditions: The weather is sunny, the temperature is warm, the sunshine duration is relatively long, and vice versa. Latitude: The lower the latitude, the longer the sunshine time, and the higher the latitude, the shorter the sunshine time. Due to the diversity and instability of the climate in Heilongjiang Province, the altitude varies greatly from place to place. The simulation of sunshine hours and annual sunshine hours from May to September is very difficult. R2 is less than 0.30 in multiple stepwise regression analysis, and the fitting effect is poor. The cross-validation results show the evaluation of the model, and the following model is optimal. The standard average is closest to 0, the root mean square is the smallest, the average error is closest to the root mean square error, and the average standard error is closest to 1. Therefore, this study adopts the global polynomial interpolation method in deterministic interpolation for the sunshine hours from May to September and the annual sunshine hours.

Table 3 Cross-validation by interpolation of sunshine hours

	index	Common kriging(1x)	Inverse distance weighting	Global polynomial	Radial basis function	Local polynomial value
Sunshine hours(May-Sep)	RMS	216.4412	217.7849	**211.6261**	214.3384	210.6633
	Mean	-6.656615	-24.7746	**-0.0754071**	-10.47475	-12.12381
Annual sunshine hours	RMS	353.6798	388.2527	**364.3203**	362.6504	363.7858
	Mean	-0.71362	-50.72755	**0.12976**	-16.42728	-4.98839

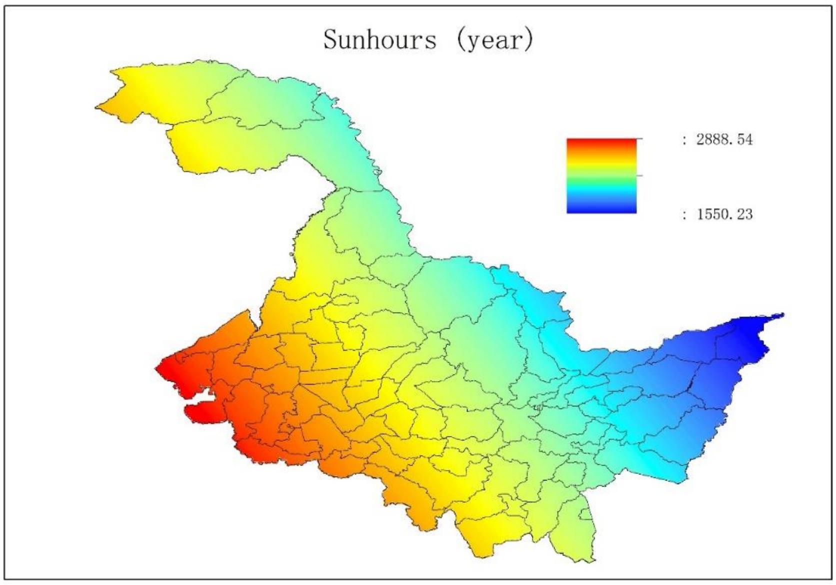

Fig. 4 Distribution map of annual sunhours in Heilongjiang Province

There are many factors that affect the spatial distribution of rainfall in Heilongjiang Province, mainly including the latitude and longitude of the meteorological station, altitude, topography, forest vegetation and the distance from the water source. Precipitation is affected by many factors and shows a certain regional spatial distribution law, but there is still some randomness and irregularity. Compared with air temperature, there is not so obvious trend, the spatial variability is greater, and interpolation analysis is more difficult. Therefore, this study uses a synergistic Cokriging method that combines the overall trend surface with local variation and can take into account the main influencing factors. Through the precipitation data of Heilongjiang Province from 1953 to 2013 for 60 years, taking into account the impact of altitude, forest cover, etc., interpolating the 90m * 90m grid rainfall data of the province to lay the foundation for the province's ecological suitability zoning.

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After exploratory data analysis tools, including Histogram, Normal QQPlot, Trend Analysis, Semivariogrom / Covariance Cloud, Crosscovariance Cloud, the distribution trend and anisotropy of spatial data are detected, and the interpolation model (such as sphere, index, Gaussian, rational two Equation), evaluation of interpolation accuracy, error modeling, completion of statistical analysis of precipitation, and creation of precipitation surface prediction maps (fitting).

In the exploratory analysis, it was found that the precipitation observations of each meteorological station showed a normal (n) distribution. Normal QQPlot and Trend Analysis were mainly in the southeast-northwest (SE-NW) direction and met the conditions of Co-kriging interpolation. The change trend coincides with the trend of Daxing, Xiaoxinganling, Zhangguangcailing and Laoyeling and the distribution direction of forest cover, and the precipitation data in the corresponding ten days are mostly normally distributed. It can be seen that the correlation between precipitation and landform and vegetation is high.

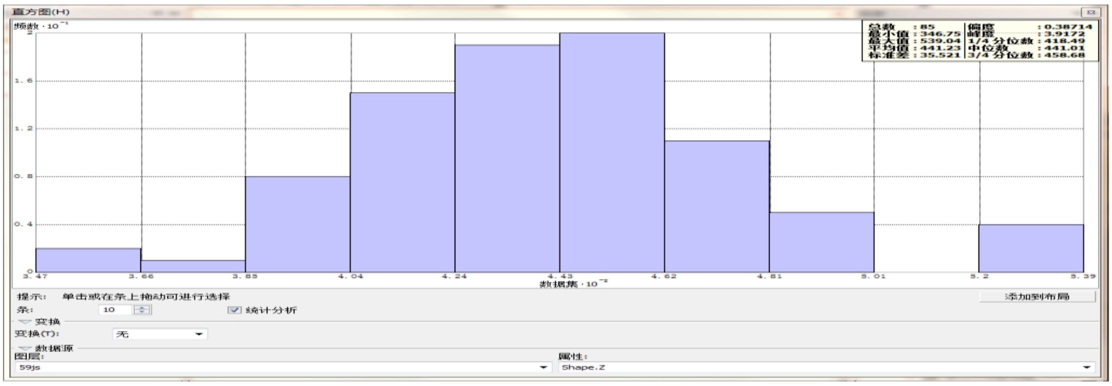
Fig.5 Meteorological Station May-September Precipitation Histogram

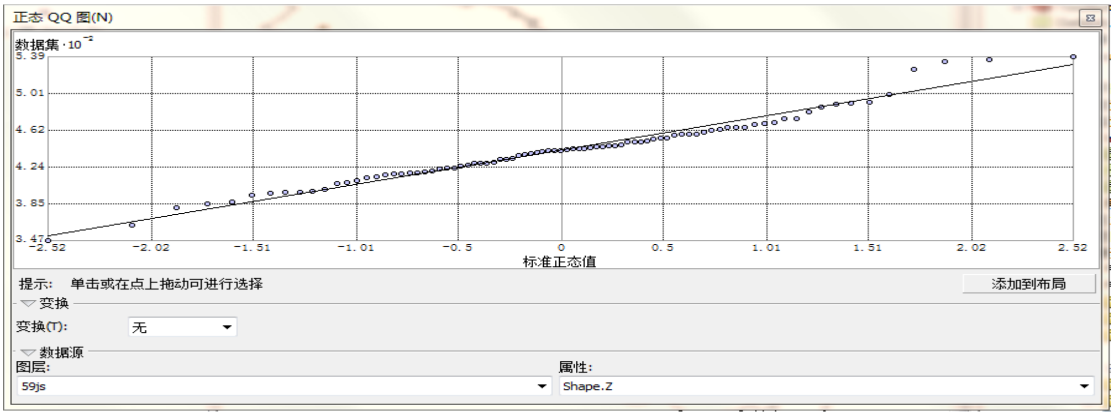

Fig. 6 Meteorological Station May-September Precipitation Normal QQPlot

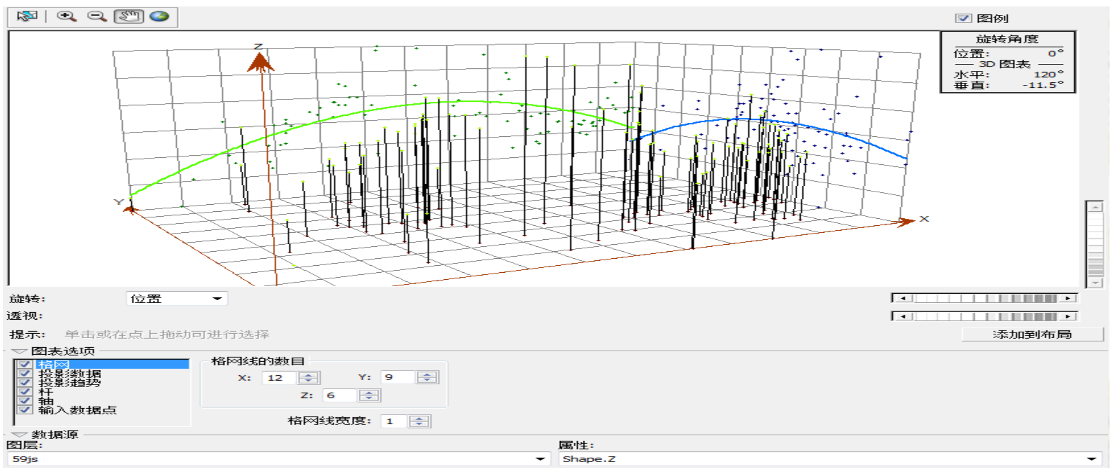
Fig. 7 Trend Analysis of Meteorological Station May-September Precipitation

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Interpolation results are cross-validated (Table 4), and validation can be used to evaluate predictions through data sets that were not involved in creating the prediction model. As with cross-validation, the purpose should include the following: the average error close to 0,

The smaller rms prediction error, the average standard error similar to the rms prediction error, and the standard average prediction error close to zero. According to the principle of geostatistical cross-validation, the interpolation result has higher accuracy. Statistics of the interpolation results show that the most suitable interpolation method for precipitation is the pan-Kriging-constant function with a step size of 12. The resulting spatial distribution data of precipitation from May to September in the 90m * 90m grid across the province, both in terms of cross-validation of the interpolation results and the agreement between the predicted values and the observed values, are highly accurate and fully meet the regional macro The need for climate and related analysis makes up for the lack of regional and local precipitation data due to the lack of meteorological stations.

Table 4 Cross-validation of May-Sep Precipitation Interpolation Results at Meteorological Stations

	RMS	Standard average	Standard RMS	Mean standard error
Exponential function 0	25.03996	0.02802881	1.033058	23.66992
Polynomial520	25.77068	0.013133	1.078937	22.57898
Gaussian function 27	25.89502	0.007523	1.09871	14.0306
Epanechnikov23	25.67481	0.0172385	1.05877	23.25059
Quartet 21	25.73215	0.014296	1.073288	22.99769
Constant 45	**25.49016**	**0.0000479**	**1.134668**	**22.0264**

Fig. 8 Meteorological Station Annual Precipitation Histogram

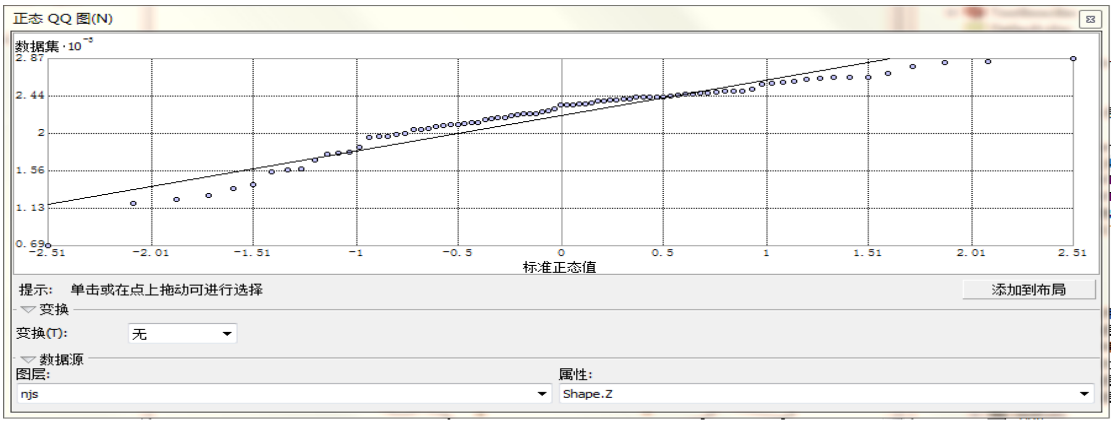

Fig. 9 Meteorological station annual precipitation Normal QQPlot

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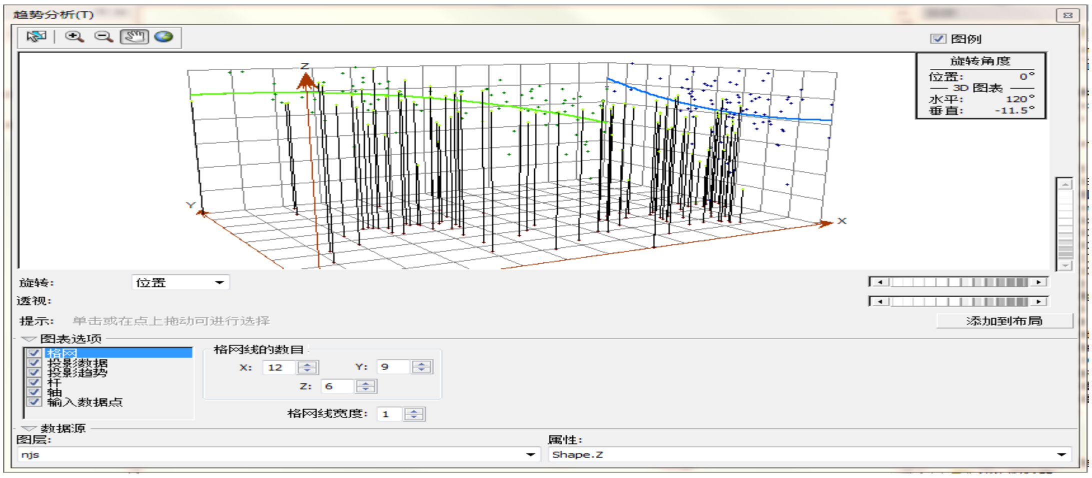

Fig.10 Trend Analysis of Meteorological Station May-September Precipitation

According to the principle of geostatistical cross-validation, the interpolation result has higher accuracy. Statistics of the interpolation results show that the most suitable interpolation method for precipitation is the pan-Kriging with exponential function, the trend surface is 0, the order is 1, and the step size is 12. The resulting spatial distribution data of annual precipitation in the province's 90m * 90m grid, both in terms of cross-validation of the interpolation results and the agreement between the predicted and observed values, are highly accurate and fully meet the regional macroclimate and related The need for analysis makes up for the lack of regional and local precipitation data caused by fewer weather stations.

Table 5 Cross-validation of interpolation results of annual precipitation of meteorological stations

	RMS	Standard average	Standard RMS	Mean standard error
Exponential function 0	**388.557**	**0.01458**	**0.8673107**	**508.8685**
Polynomial51	388.5697	0.01452267	0.8667935	509.3974
Gaussian function 1	388.5643	0.014542	0.8670293	509.1848
Epanechnikov1	388.5591	0.01456001	0.8670584	509.089
Quartic 1	388.5643	0.01454086	0.8669421	509.237
Constant 3	388.557	0.01457874	0.8672644	508.8981

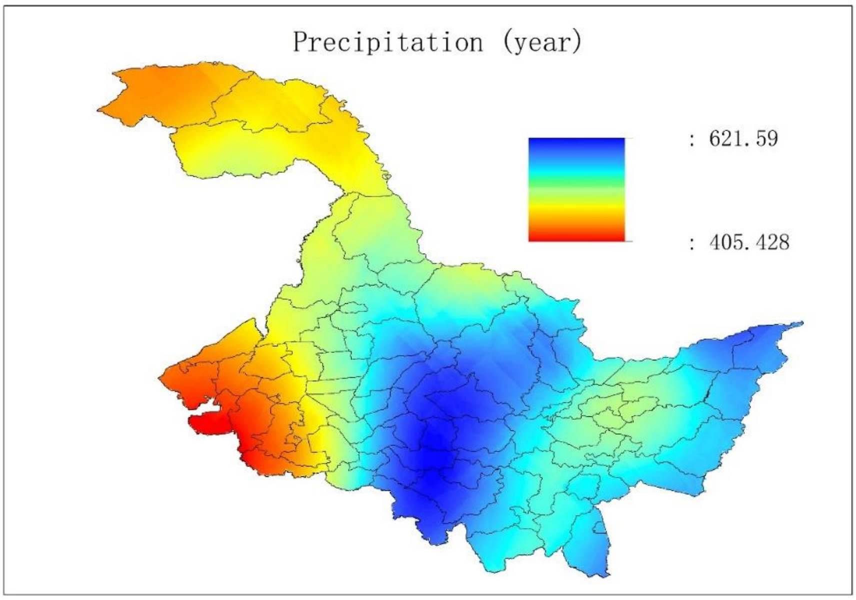

Fig. 11 Distribution map of annual precipitation in Heilongjiang Province

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4. Production and analysis of climate resource map

Heilongjiang Province is China's largest commodity grain production base, with the number of chain commodities and commodity rate ranking first in the country. In recent years, many scholars have conducted a lot of research on the spatial and temporal distribution characteristics and causes of precipitation in Heilongjiang Province. However, due to the complicated terrain of Heilongjiang Province, the regional differences in precipitation are large. In addition, considering that the main crops growing season in Heilongjiang Province is concentrated in May-September, first, the average temperature in May-September of Heilongjiang Province, the accumulated temperature in May-October(>0℃), the sunshine hours in May-September The precipitation in September are discussed.

4.1 May-September average temperature distribution

The growth and development of various crops have certain suitable temperature conditions. The photosynthesis and respiration of crops accelerate with the increase of temperature and will weaken when they exceed a certain range. The suitable temperature conditions are to ensure the normal physiological performance of crops. The environmental conditions necessary for the activity.

It can be seen from Figure 12 that the average temperature from May to September gradually decreases from south to north, the south is higher than the north, and the plain is higher than the mountainous land. Among them, the southern part of the Songnen Plain in the southwest is the highest, more than 16℃ above, the northern part of the Songnen Plain, the area south of Xiaoxing'an Mountains and most parts of Yichun City and the east side of Shuangya are at 10℃ -15℃. In Heihe City near Xiaoxinganling, the Wudalianchi area of Xunke County, Yichun City is around 10℃, and this area is rich in heat resources; the temperature in Huma, Mohe, and Tahe counties in the Greater Xing'anling area is below 10℃。

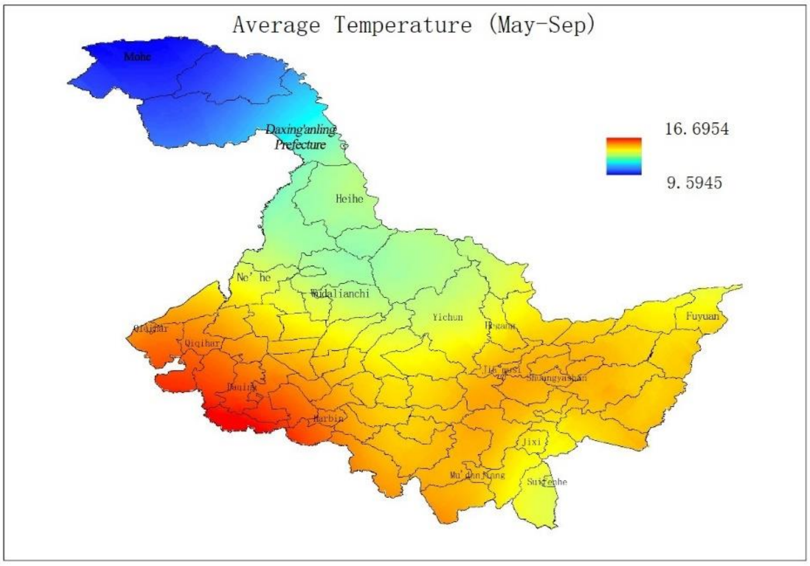

Fig.12 Distribution map of average temperature (May-Sep) in Heilongjiang Province

4.2 Distribution map of accumulated temperature from May to October

Heilongjiang Province is the northernmost province in China. When the average daily temperature is above 0℃, the snow melted and the spring returned to the earth. Production of crops begins. When the average daily temperature is below 0℃, the crops stop growing and the ground is frozen. Generally, it is not suitable for farming, so the duration of days during above 0℃ is the suitable farming period, and the accumulated temperature during above 0℃ reflects the local The amount of heat resources in the agricultural season.

It can be seen from Fig. 13 that Nehe City, Helen City, south of Suihua City, Shangzhi City and west of Wuchang City often reach above 3500℃. The area east of Nehe City, Beian City, Tieli City and

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Shuangyashan City is between 3000℃~3400℃. Heihe City, Nenjiang County, and Yichun City near Xiaoxing'anling are mostly between 2500℃~3000℃. In some areas of Yichun City, Xunke County, and Heihe City, some areas are between 2400℃~2800℃. Mohe County, Huma County, Tahe County near Daxinganling are mostly below 2400℃.

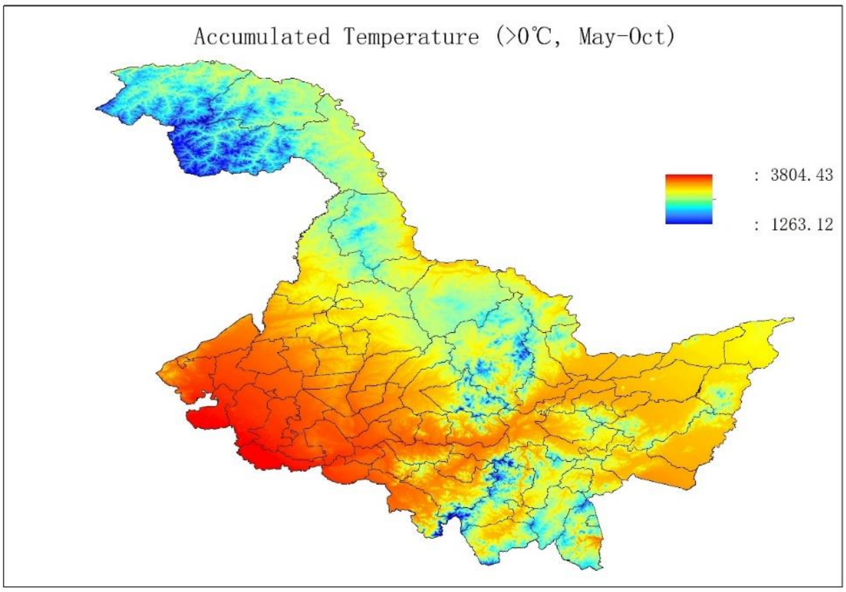

Fig.13 Distribution map of accumulated temperature (>0℃, May-Oct) in Heilongjiang Province

4.3 Distribution of sunshine hours from May to September

Sunshine is the source of heat in all physical processes in the atmosphere and on the earth, and is the basic condition for the growth and development of organisms everywhere. Sunshine hours characterize the length of sunshine time and are one of the main meteorological elements of climate change.

It can be seen from Figure 14 that it gradually decreases from the north to the south, gradually decreases from the east to the west, and more in the southwest than in the northeast. Among them, the sunshine hours from May to September in Qiqihar, Daqing, and Harbin are greater than 1400h; Nehe City, Nenjiang City, Wuchang City, and the southern area of Yichun City are between 1000h-1300h; the area north of Xiaoxing'anling, Heihe City, Most areas of Yichun City are less than 1000h.

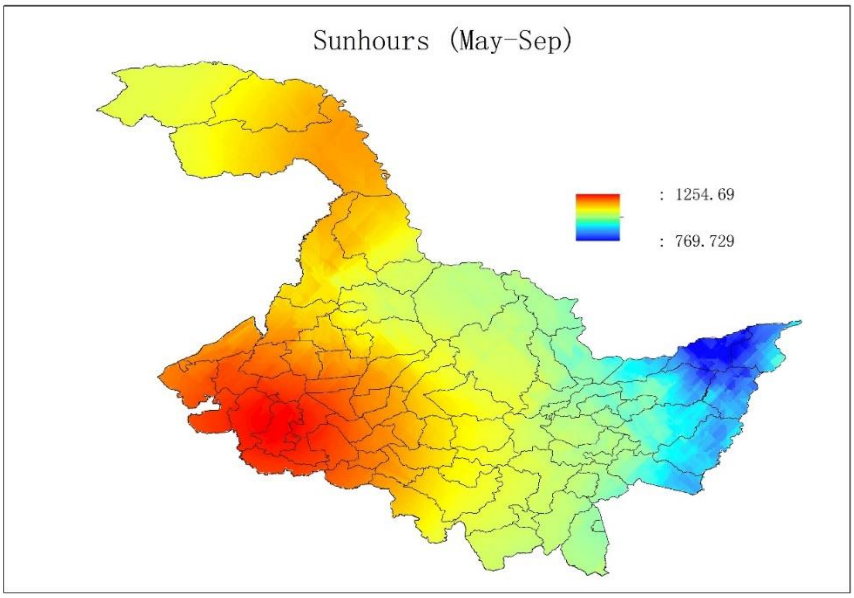

Fig.14 Distribution map of sunhours (May-Sep) in Heilongjiang Province

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4.4 Distribution map of precipitation from May to September

Under the circumstance of satisfying solar and thermal resources, water is an important factor that determines agricultural development and output levels. Especially in Heilongjiang Province, where the climate is relatively arid, precipitation has become a limiting factor for agricultural and animal husbandry production development. Even if there is sufficient solar thermal resources in a region, if there is not enough water guarantee to maintain the consumption of transpiration of its crop physiological activities, it still cannot exert its ability to increase production.

It can be seen from Figure 15 that the south is more than the north, the plain is less than the forest area, and the west is lower than the east. Among them: the precipitation in May-September in some areas of Yichun City and Harbin is up to more than 500mm, with abundant water resources; Qiqihar and Daqing have precipitation between 400mm-500mm, with the highest water resources Area; the area of Heihe City and other areas north of Xiaoxinganling area is less than 400mm, and the area with less precipitation; the precipitation in Mohe County, Tahe County, Huma County and other areas near Daxinganling Area is about 350mm.

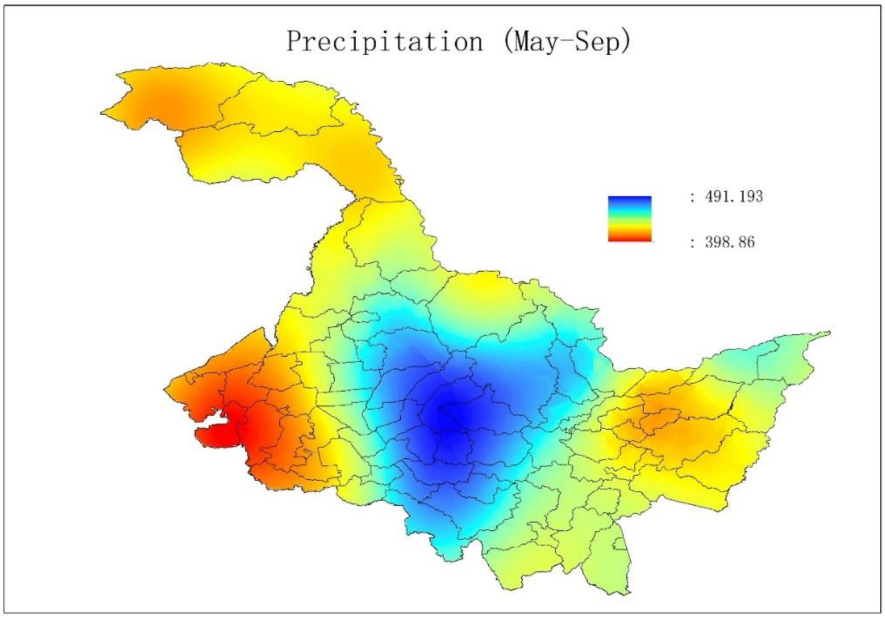

Fig.15 Distribution map of precipitation (May-Sep) in Heilongjiang Province

5. Conclusion

With the development of computer information technology, the calculation of large amounts of data is no longer a problem, which provides technical support for the accurate study of the characteristics of agricultural climate resources under complex terrain . Based on DEM's small network calculation method, the author established the Heilongjiang Province agroclimatic resource set and analyzed it with 4 climate resource elements as an example. It can be seen that the simulation results are detailed and realistic, and can describe the Heilongjiang Province under different terrain The current status of agricultural climate resources, and can provide a scientific analysis method for the rational layout and planning of agriculture and then the basis for decision-making.

This study uses the same impact factor interpolation variance for different climatic factors. If different factors are added according to the characteristics of the climatic factors (including surface coverage in the air temperature model and terrain cover in the sunshine model) or different spatial interpolation methods are selected, it may Get better accuracy.

There are many kinds of interpolation methods. This method has obtained good results in Heilongjiang Province, but there is no absolute optimal spatial interpolation method. All regions should choose the appropriate interpolation method according to actual conditions.

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