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Study on Geothermal Resource Potential Area in Heishui County Based on Landsat 8

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Abstract: The study of geothermal potential areas can provide help for the exploration of geothermal resources. Taking Heishui County, China as an example, this paper adopts the idea of comprehensive application of multiple information, inverts the surface temperature based on Landsat8 remote sensing data, obtains the distribution pattern of thermal anomaly in the study area, and comprehensively analyzes the geothermal resource potential by integrating multiple information of geology and geomorphology, eliminates the geothermal false anomaly, and effectively extracts the distribution range of geothermal resource potential area. The application of this method not only reflects the comprehensive influence and effect of geothermal anomaly, geology, structure and geomorphology on geothermal resources, but also avoids the shortage caused by single remote sensing data and greatly improves the precision of geothermal resource exploration.

Keywords: Surface temperature; Geothermal resources; Heishui County; Landsat8.

1. Introduction

With the decrease of traditional energy sources, it has become a trend to find an energy source that is more in line with the future development trend to replace traditional energy sources. Therefore, new energy sources have been widely promoted. Wind power generation, solar power generation, geothermal resources and other new energy sources have been gradually applied to alleviate environmental degradation and energy shortage. Geothermal is a kind of natural resource, which is favored by people because of its characteristics of large energy, regeneration and water as the main waste. Geothermal resources refer to renewable heat energy stored in the interior of the earth, generally concentrated in the edge of tectonic plates, originating from the melting magma of the earth and the decay of radioactive substances. Geothermal resources are a very valuable comprehensive mineral resources, its multiple functions, wide use, play a greater role in national economic development [1].

The existing mature methods for detecting geothermal resources include geological methods, geophysical exploration methods, geothermal anomaly investigation methods, geochemical methods and remote sensing thermal infrared band detection methods [2,3]. In production practice, people still use traditional methods to explore geothermal resources. This method requires a lot of manpower and material resources, and the return cycle of funds is long. It not only destroys the natural environment, but also is difficult to achieve the expected results in a short time. Compared with other methods, thermal infrared remote sensing technology has the characteristics of high efficiency, wide range and low cost in geothermal resource investigation, and can find hidden fault structures closely related to geothermal formation that can not be directly seen in conventional field investigation. Meanwhile, thermal infrared bands of remote sensing images can be used to invert primary geothermal anomaly areas of surface bright temperature.

Given this, this paper takes Heishui County as the research area, using Landsat8 thermal infrared band to reverse the primary geothermal anomaly area, combining with the regional geological and geomorphological data of the research area for spatial analysis, extracting the potential value range of the research area and studying the geothermal resource potential of the research area according to the potential value, showing the distribution characteristics of geothermal resources through visual visualization, providing certain help for the exploration of geothermal resources.

2. Overview of the Study Area

Heishui County belongs to Aba Tibetan and Qiang Autonomous Prefecture of Sichuan Province. Its geographical location is between 102°35 '-103 ° 30' east longitude and 31°35 '-32 ° 38' north latitude. It is located in the east of Qinghai-Tibet Plateau and in the middle of Aba Tibetan and Qiang Autonomous Prefecture. The terrain inclines from northwest to southeast, with an average altitude of 3544 meters. Heishui belongs to monsoon plateau climate, dry and rainy season are distinct, sunshine is sufficient, annual temperature difference is small, daily difference is large, and it varies greatly with altitude. The annual average temperature difference between high mountains and river valleys reaches 20°. The general trend of topography in Heishui County is high in northwest and low in southeast. River valleys crisscross the territory, surrounded by mountains, steep abnormal. The highest elevation is 5286 meters, the lowest elevation is 1790 meters, and the average altitude is 3544 meters. The strike of the mountain is from northwest to southeast, the cutting feeling of the terrain is strong, the valley is deep and steep, the mountains and high mountains are mainly deep, the sharp ridge is the main shape of the ridge, and the rounded ridge accounts for a minority. There are 4 snow peaks above 5200 meters above sea level. Sergu River Dam is the lowest, with an altitude of 1790 meters.

3. Data Preparation and Processing

The data involved in the project include remote sensing images, a digital elevation model (DEM), a hidden danger point map of geological hazards, a geological map and a structural map.

(a) Remote sensing image acquisition and processing

Heishui County is located in the western part of Sichuan Basin. It has long winter and no summer, and spring and autumn are connected. The annual rainfall is wavy, with two peaks in May-June and September-October. The radiation energy absorbed by rainfall is the main factor of image data quality. In order to reduce the influence of rainfall on the experiment, December with less rainfall is selected. The data involved in the project is Landsat8-OLI-TIRS data on December 29,2021, which is downloaded from the Geodata Space Cloud (http://www.gscloud.cn/) and the Institute of Remote Sensing and Digital Earth of the Chinese Academy of Sciences. The strip number is 130, the line number is 38, and the cloud amount is 4.36%. The geographical reference information of the image is UTM Zone 48 North,WGS84 projection and coordinate system. For remote sensing data preprocessing, including image cropping, radiometric calibration, atmospheric correction and terrain correction.

(b)Digital Elevation Model (DEM), Slope Map, and Aspect Map

DEM of the study area adopts GDEMV2, resolution is 30m, geographical reference information is UTM Zone 48 North, WGS84 projection and coordinate system. DEM data of Heishui County are processed to obtain slope and aspect maps of Heishui County. See Figures 1, 2 and 3 for results.

(c)Geological hazard hidden danger point map, geological map and structural map

The geological structure line map of Heishui County is obtained by experts 'experience according to DEM and geological hazard map, as shown in Figure 4. The hidden danger points of geological hazards are closely related to geological data. At the same time, stratum lithology and geological structure are the necessary conditions for the formation of surface hot spring exposed points. Mesozoic sedimentary rocks provide material basis for storing heat and directly affect the formation and development of hot spring exposed points. Both are shown in Figure 5 and Figure 6.

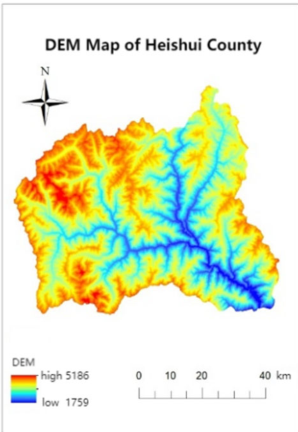

Figure 1. DEM Map

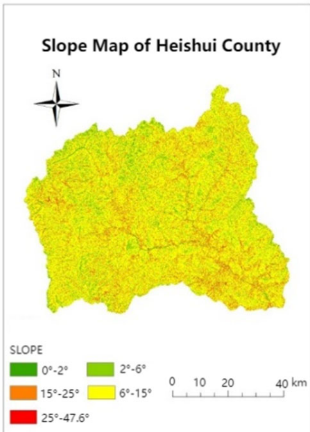

Figure 2. Slope Map

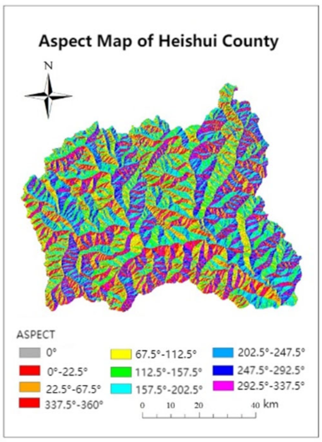

Figure 3. Aspect Map

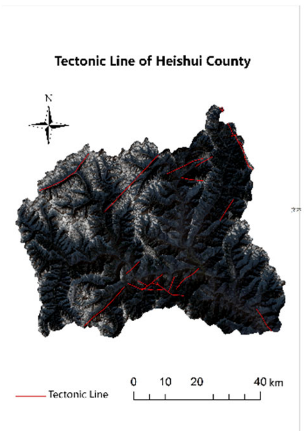

Figure 4. Tectonic Line Map

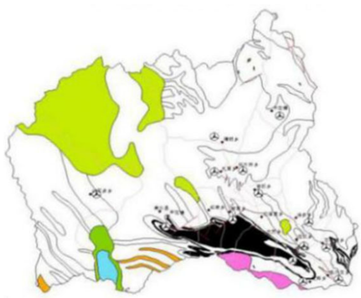

Figure 5. Geological Hazard Hidden Danger Map

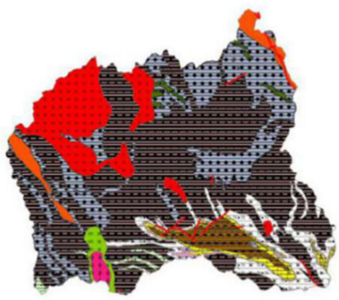

Figure 6. Geological Map of Heishui County

4. Land Surface Temperature Retrieval

4.1. Inversion algorithm

Scholars at home and abroad have done a lot of research on surface temperature inversion [4-6]. Qin Zhihao et al. proposed an algorithm for land surface temperature inversion with only one thermal infrared band for TM6 satellite data, which is called single window algorithm [7]. The algorithm needs few parameters and only one thermal infrared band, so it is widely used. The Landsat8 TIRS sensor has two thermal infrared bands (Band10 and Band11) with a spatial resolution of 100m. However, the calibration of Landsat8 TRIS band 11 is unstable temporarily, so it is not recommended to use split window algorithm for quantitative research. It is recommended that users use band 10 as single band thermal infrared data, so single window algorithm is used for land surface temperature retrieval in this project. The inversion model is as follows:

$$\mathrm{Ts} = \{\mathrm{a}(1 - \mathrm{C} - \mathrm{D}) + [\mathrm{b}(1 - \mathrm{C} - \mathrm{D}) + \mathrm{C} + \mathrm{D}]T_{10} - \mathrm{DTa}\}/\mathrm{C}, \quad (1)$$

where Ts is the surface temperature; Ta is the average atmospheric temperature; T_{10} is the brightness temperature (K) of the 10 band; a and b are constants, and a = -67.355351 and b = 0.458606 are taken under normal circumstances (the surface temperature is in the range of 0~70°C).

$$\mathrm{C} = \boldsymbol{\varepsilon\tau}, \quad (2)$$

$$\mathrm{D} = (\mathbf{1} - \boldsymbol{\tau})(\mathbf{1} + (\mathbf{1} - \boldsymbol{\varepsilon})\boldsymbol{\tau}), \quad (3)$$

where $\boldsymbol{\varepsilon}$ is the surface specific emissivity; $\boldsymbol{\tau}$ is the atmospheric transmittance.

Due to the difference between the Landsat 8 TIRS remote sensing image adopted in this study and Landsat TM adopted in Qin Zhihao's above formula, according to the conclusion obtained from Jiang Dalin's research on Landsat 8 based surface temperature inversion algorithm, the parameters of single-window algorithm are modified as follows: a = -62.735657, b = 0.434036 [8].

4.2. Land surface temperature retrieval

According to the above theory, the basic flow of surface temperature inversion in this paper is shown in Figure 7. According to this process, the surface temperature of December 2021 in Heishui County, Sichuan Province is retrieved by using Landsat8 data (B10 band is used for the thermal band) in the study area in combination with the single-window algorithm and relevant parameters mentioned above. The results are shown in Figure 8. Red in the figure is the area with abnormally high temperatures. It can be seen that the lowest ground temperature in the study area is-16.7°C, mainly located in the northwest mountainous area of the study area; the highest ground temperature is 29.5°C, mainly located in the east and northwest.

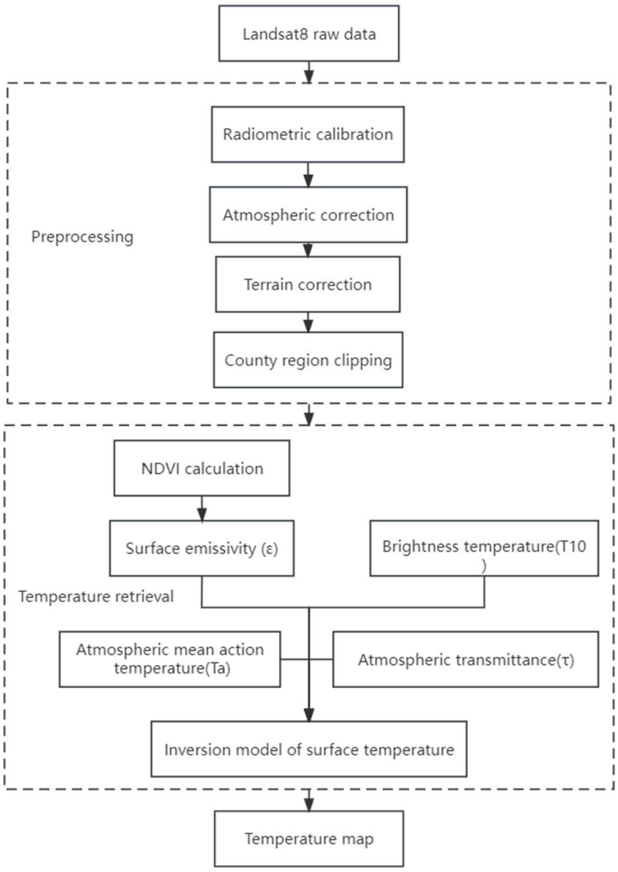

Figure 7. Flow chart of inversion of surface temperature

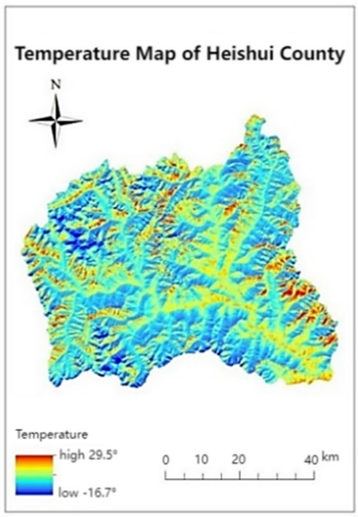

Figure 8. Retrieval Results of Surface Temperature in December 2021

5. Evaluation of Geothermal Resource Potential Area

Geothermal energy is a kind of natural heat energy stored in the earth's interior. Like coal, oil, natural gas and other minerals, it is also a valuable mineral resource. Based on the inversion results of surface temperature in the study area, the paper comprehensively applies multiple data such as geomorphology and geology, and realizes the determination of geothermal resource potential value range in the study area according to the different extraction weights of geothermal resource information from each data. The specific idea is shown in Figure 9, and the distribution map of potential value range obtained according to the process is shown in Figure 10.

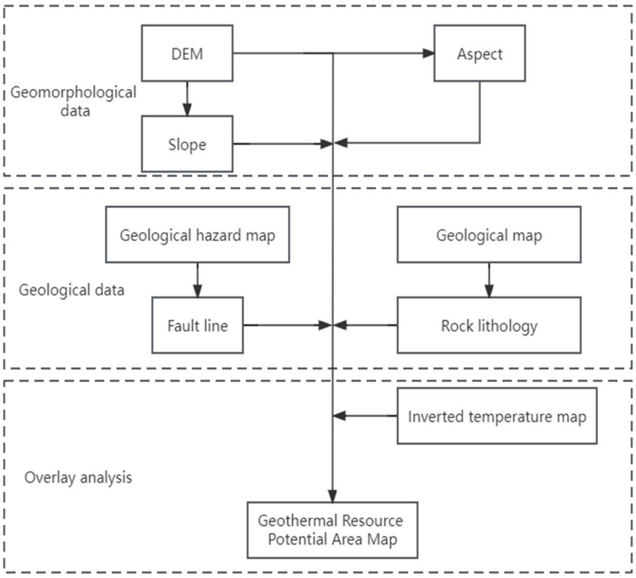

Figure 9. Flow chart of geothermal anomaly extraction

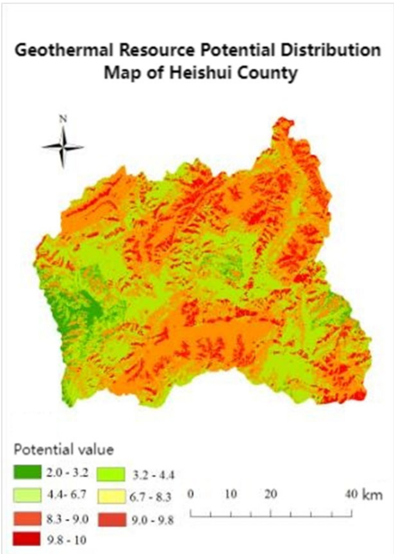

Figure 10. Geothermal Resource Potential Value Distribution Map

As shown in Figure 10, green represents low-potential areas and red represents high-potential areas. After dimensionless processing, the data gets a better visual effect. The higher the potential value, the redder the color, and the greater the possibility of geothermal resources in the area near geological structural lines, heat storage strata, high-temperature anomalies and other factors. Conversely, the lower the value, the greener the color, and the less likely there is geothermal resources. According to the known coordinates of hot spring distribution, the data have been tested for many times, and the distribution law is determined as elevation 3330m-3500m; slope is 5°-15°; slope direction is 0°-22.5° N and 292.2°-360° N; heat storage lithology is Mesozoic sedimentary rock. The areas with the greatest potential are mainly distributed in the north, northeast, south and southeast of the study area.

Temperature retrieval results are affected by solar radiation energy, vegetation growth status, topography and other factors, although in the process of temperature retrieval, through various efforts to remove the impact of these factors, such as selecting satellite image acquisition time, selecting low temperature time with low solar radiation, and avoiding rainy season as much as possible; considering normalized vegetation index, try to remove the impact of vegetation growth status; Through data preprocessing terrain correction, try to remove the influence of elevation, slope, aspect and so on. However, the temperature inversion results may still deviate from the actual situation, and the real distribution of geothermal resources cannot be revealed. The corrected surface temperature data is combined with rock lithology and geological structure line that may appear geothermal resources, and delineated by computer on a larger area, so as to obtain all potential areas that may exist geothermal resources, and classified according to potential value. The higher the potential value, the more suitable for the development and utilization of geothermal resources, and provide preliminary clues for searching geothermal resources.

6. Conclusions

In this paper, we try to introduce new information, such as geological and geomorphological data, to improve the accuracy of geothermal potential areas, and obtain certain results, as follows.

(1) By determining the range of geothermal resource potential value in the study area, it can be concluded that the regions with the greatest potential are mainly distributed in the north, northeast, south and southeast of the study area. Heishui County is located in the mountainous area with obvious topographic changes. Due to the influence of topography, plus the influence of sun, vegetation, topography and other important factors, the thermal infrared temperature inversion results can not point out the real distribution of geothermal resources, and the potential geothermal resources cannot be revealed. Therefore, all the areas that may exist geothermal resources delineated are larger than the temperature anomaly areas.

(2) Using the idea of comprehensive application of multiple information, remote sensing geothermal resources detection is carried out through surface temperature anomaly caused by geothermal, and the inversion results of surface temperature are combined with geological and geomorphological environment data, which improves the exploration efficiency of geothermal resources and greatly improves the accuracy of geothermal resources exploration.

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