

RESEARCH ON THE INFORMATION EXTRACTION OF PERIGLACIAL GEOMORPHOLOGY IN QINGHAI-TIBET PLATEAU

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Commission VIII, WG VIII/12

KEY WORDS: Image Interpretation, Digital Elevation Models (DEM), Image Understanding, Feature Extraction, Geomorphology, Qinghai-Tibet Plateau

ABSTRACT:

Takes Qinghai-Tibet Plateau as a research field, this paper based on the models and algorithms, completes the numerical information extraction of periglacial geomorphology distribution by using SRTM-DEM and annual mean temperature data. Based on the extracted results and remote sensing images, the periglacial geomorphology distribution in Qinghai-Tibet Plateau is achieved by visual interpretation. According to the visual interpreting results, the quality and precision of the extracted information are discussed and analysed. Finally, on the foundation of the 4 permafrost regions in Qinghai-Tibet Plateau, the quality and precision of the extracted information of periglacial geomorphology are studied accordingly; taking Massive Continuous Permafrost Region in Qiangtang Plateau as an example, the quality and precision of the extracted results in this area are analyzed specifically.

1. INTRODUCTION

With vast area and high altitude of 4000~5000m, Qinghai-Tibet Plateau Locating in southwestern China is one of the most important geomorphological units in Chinese terrestrial part. Because of its high altitude, vast area, harsh climate and the mid-latitude location, known as “the third pole of the earth”, it has close correlation with the biggest monsoon system on the globe which has not only sensitive responding character but significant impact to the global climate change (Liu Tungsheng, et al, 1999). Hence it becomes one of the hot spots of research.

Geomorphology is one of the most predominant components of physical geography environment. It directly influences and even determines the distribution and change of ecological and environmental factors. So it becomes one of the key and fundamental research fields in geographical sciences (Cheng Weiming, 2005). Periglacial geomorphology is a kind of earth surface form which results from periglacial process such as frost weathering and freeze-thaw process; it mainly distributes in harsh climate region but without covered by glaciers. Various kinds of stone and soil which contains ice and whose temperature is not above 0 °C is called geocryology. The geocryology whose freezing state keeps more than several years or more than several thousand years is called permafrost. Permafrost is divided into continuous permafrost and discontinuous permafrost. Geological process and phenomenon of geocryology are generally called periglacial process and shape (Zhou Youwu, et al, 2000). In addition, the distribution of periglacial geomorphology is approximate to it of geocryology, so periglacial geomorphology is also called geocryology (Zhou Chenghu, 2006). Periglacial geomorphology is a widely distributing and one of the most important geomorphology types in Qinghai-Tibet Plateau, which has close relation to global climate change, the distribution and exploitation of new

energy sources (such as natural gas hydrate), road construction and so on (Wu Qing-bai, et al, 2006; Wang Genxu, et al, 2008).

With the rapid development of remote sensing technology, it has more and more application in most national economic departments. Hence, geomorphology research by using remote sensing technology becomes an important topic in geomorphology research. SRTM-DEM data is used to depict the ground altitude in every place, which has broad application in geographic research (G. Jordan, et al, 2005). Therefore, research on the numerical extracted method of periglacial geomorphology in Qinghai-Tibet Plateau has important significance.

2. RESEARCH AREA SITUATION AND INFORMATION SOURCE

In this part, the general situation of research area is described at first. Then, the information source in this research is discussed. They are the foundation to carry out this research.

2.1 Research area situation

Know as its low latitude, high altitude and particular harsh climate, Qinghai-Tibet Plateau locating in Asian Continent is the most widely distributing area of periglacial geomorphology in China. In China, its boundary from west to east is from Pamirs to Hengduan Mountains and the length is about 2945km; the boundary from south to north is from southern edge of Himalayas to northern side of Kunlun Mountains and the width is about 1532km. The bound of Qinghai-Tibet Plateau is 26°00'12"N~39°46'50"N, 73°18'52"E~104°46'59"E. The area is about $257.2 \times 10^4 \text{ km}^2$, which accounts for about 26.8% of total area of China (Li Bingyuan, 1987; Zhang Yi-li, 2002).

The distribution of geocryology is approximate to it of periglacial geomorphology, which is divided into 4 parts in Qinghai-Tibet Plateau. They are: Alpine Permafrost in Qilian Mountains-Altun Range locating in northeast part, Massive Continuous Permafrost in Qiangtang Plateau locating in northwest part, Alpine Sporadic Permafrost in Nianjingtanggula Hill and Himalayas locating in southwest part, Sporadic Permafrost in Southern Mountain Plateau and Eastern Mountain locating in southeast part (BAOLAI WANG, et al, 1995). The specific distribution is shown as in Figure 1. The climate of Qinghai-Tibet Plateau is transited from oceanic climate to continental climate gradually along the southeast to northwest direction. Hence, Alpine Sporadic Permafrost in Nianjingtanggula Hill and Himalayas and Sporadic Permafrost in Southern Mountain Plateau and Eastern Mountain are mostly controlled by oceanic climate and the other two parts by continental climate.

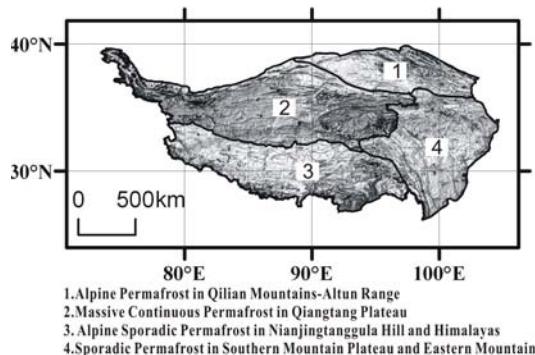


Figure 1. Frozen Ground of the Qinghai-Tibet Plateau and the study area (reference the map of snow, ice and frozen ground in China by Shi Yafeng, 1988)

2.2 Information source

In this research, the main information source are ETM and TM images acquired by USA Landsat satellites, SRTM-DEM digital elevation model data and annual mean temperature data obtained by standard stations of China (ZHAO Shang-min, et al, 2007).

The remote sensing images are TM images collected in 1990 summer and ETM images in 2000 summer. The spatial resolution is 30m and the format is img. They are artificial multicolour compounded images and compounded by the bands of 7, 4 and 2. The compounded images have good quality and abundant information, which is benefit for the interpretation of geomorphology type.

SRTM-DEM is digital elevation model data, whose format is grid. SRTM-DEM data records the elevation information of every pixel in the research area, and the pixel is 90m. The geomorphic form information such as relief, elevation, slope and aspect in research area can be computed by using SRTM-DEM data, so SRTM-DEM data plays an important role in acquainting the ground form characteristics.

Based on more than 600 observation stations' data in China and through the method of "regression equation + residual error", annual mean temperature data is rasterized and obtained by using the linear correlation among temperature, latitude and

altitude. The annual mean temperature data in research area can be achieved by clipping the data of China.

3. METHODS AND RESULTS

Firstly, this research extracted the periglacial geomorphology distribution in Qinghai-Tibet Plateau by using SRTM-DEM data and annual mean temperature data respectively. Based on the extracted results, the periglacial geomorphology distribution is interpreted by using remote sensing images and other data. Then the comparison between extracted results and interpreted result is carried out. Finally, based on the distribution of 4 permafrost regions in Qinghai-Tibet Plateau, the precision and quality of every result in different permafrost regions are studied and discussed.

3.1 Study on the distribution of periglacial geomorphology in Qinghai-Tibet Plateau

Because the distribution of permafrost is approximate to it of periglacial geomorphology, so the distribution of permafrost is extracted to replace the distribution of periglacial geomorphology in some cases. At first, the distribution of permafrost region in Qinghai-Tibet Plateau is extracted by SRTM-DEM digital elevation model data and annual mean temperature data respectively. Then, according to the remote sensing images and visual interpretation experience, the periglacial geomorphology distribution in Qinghai-Tibet is achieved by referencing the extracted results. Generally speaking, the interpreted result is better than the extracted results in both precision and quality. Consequently, we evaluate the precision and quality the extracted results based on the interpreting results at last.

3.1.1 Distribution extraction of periglacial geomorphology in Qinghai-Tibet Plateau by using SRTM-DEM data: To extract the distribution of periglacial geomorphology, the main aim is to acquire the elevation range of periglacial geomorphology distribution anywhere in Qinghai-Tibet Plateau. That is, to acquire the lower and upper limits of the distribution of periglacial geomorphology. The lower limit of periglacial geomorphology distribution is approximate to it of permafrost distribution, so we extract the lower limit of permafrost distribution to instead. The upper limit of periglacial geomorphology distribution is the elevation of snow line.

As to the elevation of lower limit of permafrost distribution, Cheng Guodong holds that the distribution of permafrost in Qinghai-Tibet Plateau has obvious zonality law of three directions (latitude direction, longitude direction and vertical direction), so the relation between the elevation of lower limit of permafrost distribution (H) and latitude (φ) can be expressed by the following Gauss distributing function (Cheng Guodong, et al, 1983, 1984, 2000; Wu Qing-bai, et al, 2000):

$$H = 3650 \exp[-0.003 (\varphi - 25.37)^2] + 1428 \quad (1)$$

where H = the lower limit elevation of permafrost distribution
 φ = geographical latitude

The scholars such as Ding Dewen and so on also studied the lower limit elevation of permafrost distribution in Qinghai-Tibet Plateau (Ding Dewen, et al, 1982). After synthesizing

analyse, experimentation and research, we choose to extract the lower limit by using the method of Cheng Guodong.

The upper limit of periglacial geomorphology in Qinghai-Tibet Plateau is the elevation of snow line. The scholars such as Jiang Zhongxin and so on had studied the elevation of global snow line (Jiang Zhongxin, 1984). Considering the terrain particularity of Qinghai-Tibet Plateau, however, it is better to obtain the snow line elevation by interpolating the snow line elevation data measured by observation stations in and around Qinghai-Tibet Plateau. The interpolation method is Inverse Distance Weighted Interpolation, whose idea is “the distance to the interpolated point is farther, the effect is less”. It is interpolated by the power of the reciprocal value of the distance. The interpolation equation is as follows (Chen Shupeng, et al, 1999):

$$f(x,y) = \frac{\sum_{i=1}^n 1/d_i^n \cdot Z_i}{\sum_{i=1}^n 1/d_i^n}, \quad n=1 \text{ or } 2 \quad (2)$$

where d_i = the distance between the interpolated point and the known data

Z_i = the value of the i known point

n = the power

$f(x, y)$ = the value of the interpolated point

Now that the snow line elevation in Qinghai-Tibet Plateau has been calculated, the upper and lower limit of periglacial geomorphology distribution everywhere has been worked out. So the periglacial geomorphology distribution in Qinghai-Tibet Plateau can be extracted by using SRTM-DEM data. The extracted map is shown as Figure 2.

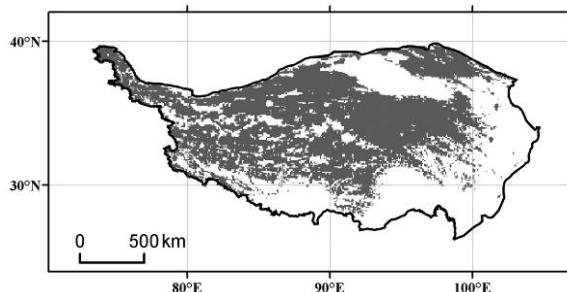


Figure 2. The extracted result of the distribution of periglacial geomorphology by using SRTM-DEM data

3.1.2 Distribution extraction of periglacial geomorphology in Qinghai-Tibet Plateau by using annual mean temperature data: The elevation of Qinghai-Tibet Plateau is about 4000~5000m, which provides the condition of the harsh climate to the formation of periglacial geomorphology and creates unique periglacial environment for the growth of various frost process and the generation of plateau geomorphology. According to the research, the condition of the existence of periglacial geomorphology is that the annual mean ground temperature is less than 0°C. As the annual mean ground temperature can not be obtained easily, so we take annual mean air temperature to replace it (Lanzhou institute of glaciology

and geocryology, 1988).

According to the literatures and experiments, the annual mean temperature data range of periglacial geomorphology distribution everywhere is not exactly the same, but the generally range is between -6.5°C and -2.5°C. Hence, if the region where the annual mean temperature is between -6.5°C and -2.5°C is extracted, the distribution of periglacial geomorphology in Qinghai-Tibet Plateau is achieved accordingly. The extracted result is shown as in Figure 3.

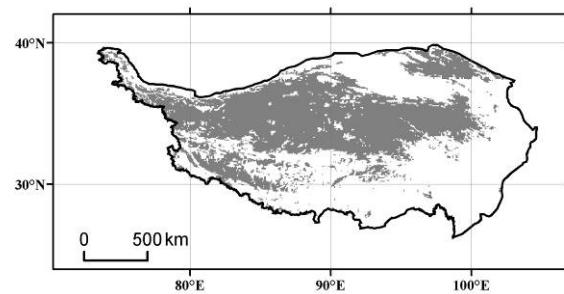


Figure 3. The extracted result of the distribution of periglacial geomorphology by using annual mean temperature data

3.1.3 Distribution acquisition of periglacial geomorphology in Qinghai-Tibet Plateau by visual interpretation: Visual interpretation is a method to acquire information from remote sensing images by interpretation marks and experiences. Because the visual interpretation results reference the previous maps and achievements and are completed by expert knowledge and judgement, so the quality and precision of the interpretation result are much better than the extracted results.

In this research, based on the extracted results by SRTM-DEM data and annual mean temperature data, we interpret the distribution of periglacial geomorphology in Qinghai-Tibet Plateau by using remote sensing images, other maps and data, interpretation marks and interpreting experiences. Through field investigation, validation and revision to the preliminary interpreted result, the final result by visual interpretation is achieved. It is shown as in Figure 4.

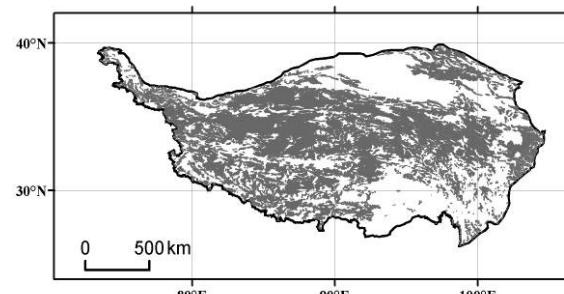


Figure 4. The interpretation result of the distribution of periglacial geomorphology in Qinghai-Tibet Plateau

As the result by visual interpretation has better quality and precision, so we can estimate the precision and quality of the

extracted results by SRTM-DEM data and annual mean temperature data based on the interpreted result.

3.1.4 Estimation to the precision and quality of the extracted results: Compared to the extracted results of the distribution of periglacial geomorphology in Qinghai-Tibet Plateau obtained by various methods as shown in Figure 2, Figure 3 and Figure 4, the conclusions are as following:

(1) The extracted results of periglacial geomorphology distribution in Qinghai-Tibet Plateau by using SRTM-DEM data and annual mean temperature data are generally exact, which can reflect the distribution of periglacial geomorphology well. So the extracted results can provide a good basis for visual interpretation.

(2) The quality and precision of the extracted results are not the same in different place in Qinghai-Tibet Plateau. According to the 4 permafrost regions in Qinghai-Tibet Plateau, the precision of the extracted results in Alpine Permafrost in Qilian Mountains-Altun Range and Massive Continuous Permafrost in Qiangtang Plateau is better than it in other two permafrost regions. The comparison of the two extracted results in the east district of Qaidam Basin is shown as in Figure 5. The grey background in Figure 5 is the distribution obtained by visual interpretation. From Figure 5 we can see that in some place the extracted results are similar and exact. In addition, they are approximate to the final interpreting results. Hence, they can play an import role in visual interpretation.

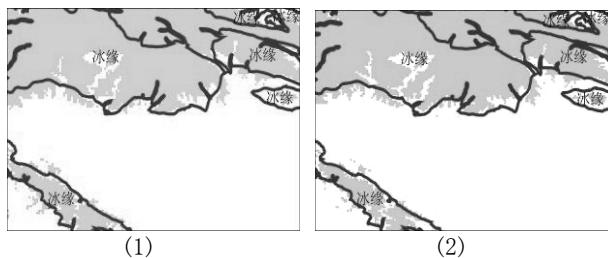


Figure 5. Comparison between the two extracted results
(1. by SRTM-DEM data; 2. by annual mean temperature data)

(3) The difference of the precision of the extracted results in various permafrost regions perhaps due to the different climate types. In the southern part of Qinghai-Tibet Plateau, the climate is mainly controlled by oceanic type; from the southeast to northwest direction, the climate is gradually transformed from oceanic type to continental type. Different climate, precipitation and temperature result in different distribution situation of periglacial geomorphology in Qinghai-Tibet Plateau. Hence, it may be one of the big factors to affect the quality and precision of the extracted results.

3.2 Study on the extracted results in different permafrost regions of Qinghai-Tibet Plateau

There are 4 permafrost regions in Qinghai-Tibet Plateau. The precision and quality of the extracted results in different permafrost regions are not the same, and the difference can not be neglected. The area of the periglacial geomorphology distribution results in every permafrost region is shown in Table 1.

There are some conclusions can be obtained from Table 1: According to the total area, the area of the extracted results from SRTM-DEM data and annual mean temperature data are $105.48 \times 10^4 \text{ km}^2$ and $103.86 \times 10^4 \text{ km}^2$ respectively, while the area of the interpreting result is $97.53 \times 10^4 \text{ km}^2$. So the total area obtained by different methods is similar. This means that the extracted results are generally consistent with visual interpreting result and they can provide important basis and reference for the visual interpretation of periglacial geomorphology distribution. In different permafrost regions, however, the situation of the extracted result in area is not the same. In Alpine Permafrost in Qilian Mountains-Altun Range and Massive Continuous Permafrost in Qiangtang Plateau, the areas of the extracted results by SRTM-DEM data and annual mean temperature data are bigger than the area of interpreting result. Nevertheless, the areas of the extracted results are less than the area of the interpreting result in other two permafrost regions. The difference between the extracted results and interpreting result perhaps dues to the climate change from the southeast direction to northwest direction and the change of temperature and precipitation resulting from the climate change.

Area($\times 10^4 \text{ km}^2$)	Extracted result by SRTM-DEM data	Extracted result by annual mean temperature data	Interpretation result
Alpine Permafrost in Qilian Mountains-Altun Range	9.91	7.78	5.72
Massive Continuous Permafrost in Qiangtang Plateau	64.19	70.15	50.55
Alpine Sporadic Permafrost in Nianjingtanggula Hill and Himalayas	19.16	15.65	22.03
Sporadic Permafrost in Southern Mountain Plateau and Eastern Mountain	12.22	10.28	19.23
Total Area	105.48	103.86	97.53

Table 1. The area of different extracted results in the 4 permafrost regions

Taking Massive Continuous Permafrost in Qiangtang Plateau as an example area, we make the comparison among the visual interpretation result and the extracted results of periglacial geomorphology distribution shown as in Figure 6. From Figure 6 we can see that the distribution of periglacial geomorphology is widely distributed in Qiangtang Plateau, especially in the middle part of the Qiangtang Plateau. But both the extracted result from SRTM-DEM data and the extracted result from annual mean temperature data have obvious less exactness than the interpreting result. Comparatively, the quality of the extracted result by SRTM-DEM data is better than the quality of the result extracted by annual mean temperature data. In addition, the area of the extracted result by SRTM-DEM data is more approximate to the area of the visual interpreting result than the extracted result by annual mean temperature data do.

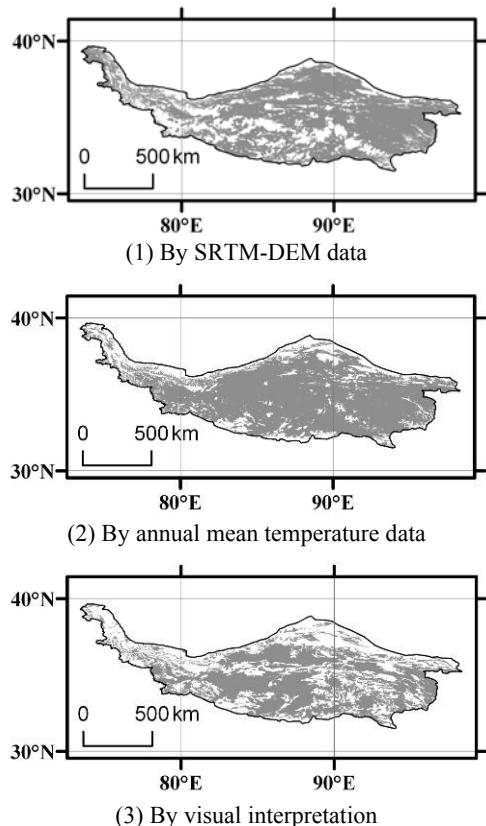


Figure 6. Comparison of the results by different methods in Massive Continuous Permafrost in Qiangtang Plateau

The difference between the extracted results and the visual interpretation result can not be evitable. The area is only one index to evaluate the quality of the extracted result. In fact, the approximation of the area can not fully guarantee the quality of the extracted results. Other than the area, the error of other indexes such as the shape and the location are also important for the precision of the extracted results.

The distribution situation of periglacial geomorphology in Qinghai-Tibet Plateau is different in the 4 permafrost regions, so the precision and quality of the extracted results have difference, too. If we study the distributing rules of periglacial geomorphology in different permafrost regions deeply and extracted it by using different methods in different regions, the

quality and precision of the extracted results may have a big improvement.

4. CONCLUSIONS

Through the above research, the following conclusions can be achieved:

- (1) Comparing the extracted results by SRTM-DEM data and annual mean temperature data and the interpreting result by remote sensing images and visual interpretation, we can find that the extracted results are generally consistent with the interpreting result. Hence, the extracted results can provide important basis and reference for the visual interpretation.
- (2) The quality and precision of the extracted results of periglacial geomorphology distribution in Qinghai-Tibet Plateau are different in various permafrost regions. The areas of the extracted results are bigger than the visual interpreting result in northern part, but less in southern part. According to the precision, the precision of the extracted results is better in northern part than in southern part compared to the visual interpreting result.
- (3) As the distribution situation of periglacial geomorphology in Qinghai-Tibet Plateau is not the same in different permafrost regions, the precision and quality of the extracted results will be improved largely by using different method in various permafrost regions.
- (4) The quality of the data sources and the research level are important factors to affect the precision of the extracted results. With the continuous improvement of the data quality and the advancement of research level, the quality of the automatic extraction of periglacial geomorphology distribution will be improved accordingly. It will be provide significant basis for automatic mapping and visual interpretation of periglacial geomorphology.

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ACKNOWLEDGEMENTS

This work is supported by “the Research on the Extracted Method of the Morphological Characteristics of Typical Geomorphology” of the Knowledge Innovation Program of Chinese Academy of Sciences and “the Experiments on the Geographical Unit Maps Design Based on Remote Sensing Images” of National Surveying Project of Western Area without 1:50000 Topographic Maps from China.