Research on glacier DEM extraction method based on ASTER Data

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Abstract. The greenhouse effect has led to a large area shrinkage of glaciers in the west of China, resulting in great changes in glacial landforms. In this paper, we use remote sensing satellite to obtain timely and accurate DEM, and use remote sensing technology to process DEM effectively, so as to obtain high-precision results, which can be used as the basic model to study glacier area change. In this paper, the DEM of Malan ice cap in Xinqingfeng is extracted from the orthoengine module of PCI, and the results of DEM obtained are compared with the reference DEM by using aster stereo image pair, and the results of Aster meeting the accuracy requirements are analyzed, which is helpful for the application of Aster stereo image pair in DEM production process.

1. Introduction

China is the country with the most developed glaciers in the middle and low latitudes in the world. Based on the second glacier catalogue [1], there are 48571 glaciers over 0.01km² in China, covering an area of 5.188×10⁴km², accounting for about 0.54% of the national land area. The glacier ice reserves are about 4.3×10⁵km³, distributed in Tibet, Qinghai, Gansu, Xinjiang, Sichuan and Yunnan. However, in recent years, under the background of global warming, the glaciers in Western China are generally shrinking. By 2020, the area of glaciers in Western China has shrunk by about 18%, with an average annual area of 243.7km². This phenomenon has attracted the attention of a large number of researchers. At the same time, there are many reports and literatures about glaciers in Western China. The retreat of glaciers will lead to a series of potential disastrous consequences [2]. Therefore, it is very important to correctly evaluate the glacier change and reveal the impact of glacier change on river runoff in Northwest China [3-4].

DEM (digital elevation model) is the basic data for studying glacier area change, and digital elevation model (DEM) is a branch of digital terrain model (DTM). Digital elevation model (DEM) is one of the core databases of geographic information system (GIS) and the basic data for geoscience modeling. As the most basic data of glacier analysis [5], DEM plays a more and more important role in studying the disasters caused by glacier shrinkage.

Since the 1990s, the research on glacier area mainly relies on remote sensing, and digital photogrammetry is the main method to obtain glacier DEM [5], which is also the most commonly used method. In recent years, a series of high-performance remote sensing satellite systems have developed rapidly [6]. The images obtained by a variety of high-resolution, multi temporal and multi spectral
sensors have been used in Glacier research. At present, IKONOS, IRS-P5, ALOS, QuickBird, ASTER and SPOT5 are the main mapping satellites or sensors that can form the same orbit stereo pairs. When IRS-P5 extracts DEM, its theoretical accuracy can reach 5m and is not limited by the measuring area. In this paper, ASTER data is used to obtain glacier results, which provides a reliable scientific basis for monitoring in this area.

2. Experimental study

2.1 Overview of the experimental area

Xinqingfeng is located in Hoh Xil area, the middle part of Kunlun Mountains. It is a small ice cap developed on the planation surface of Kunlun Mountains, with the highest altitude of 6860m. The north side of the ice cap is the source of the Beitiilikdarya River, and the south side is the source of the Hongshui River. Around the main peak in the south, 46 glaciers of various types are developed in the north side. The total area of the glacier is about 419.9 km², and the area of west Xinqingfeng glacier on the northwest side of the ice cap is 67.91 km², up to 16km. It is the second largest overflow valley glacier of the ice cap, and the total area of the two glaciers accounts for 40% of the total area of Xinqingfeng ice cap [7]. Malan ice cap is located in the southwest of Xinqingfeng ice cap, the North belongs to Taiyang lake water system, and the South belongs to Yinma Lake Hoh Xil lake water system. The highest point of the ice cap is 6056m above sea level. There are 42 glaciers in the surrounding area and adjacent areas, with a total area of 195.12 km² and a glacier reserve of 24.95 km³. This area belongs to the area with little influence of westerly circulation and monsoon circulation. The precipitation observed from June to July in Kumukuli basin, which is located in the north of Xinqingfeng, is 216mm [8], and it is estimated that the local annual precipitation is more than 300mm. Xie Zichu [8] showed that: the annual precipitation in the Taiyang Lake area on the north side of Malan ice cap is 170mm, and about 80% of the precipitation is concentrated in the warm season. According to the glacier catalogue data, the average altitude of the snow line of Malan ice cap is 5455m, and the estimated annual average temperature near the snow line is -11.5 °C. The experimental area is shown in Figure 1.

![Figure 1. Experimental area.](image)

2.2. Data sources

2.2.1. ASTER data Aster sensor is one of the high-resolution multispectral sensors carried on the Terra satellite of EOS program of the United States [9]. It has 14 spectral bands in the visible and thermal infrared range [11], and its spatial resolution is as high as 15m. Two imagers can overlap and nearly synchronously image the same ground object with reasonable parallax and heading [12]. Compared with other remote sensing satellite sensors, aster is unique in its high spatial resolution and stereo observation ability [13]. The elevation extraction accuracy of ASTER data can reach 60m [5]. Because
aster has high spatial resolution, and has stereo pairs ((a), (b)) in the same orbit, and the polar coverage is larger than that of Landsat 5 / 7 [7], which has become one of the main sensors for monitoring glaciers.

In this paper, the aster two scene image on July 6, 2014 is used, and the stereo pair is opened by envi software, as shown in Figure 2. Through the comparison of the two images, it is found that for the study area, the coverage area of the two images is roughly the same. The range of glacier height is 3000-6800m. Through the comparison of the two images, it is found that the features of the glacier area to be studied are obvious. Generally speaking, the feature points are obvious, which can be used for DEM extraction experiment.

![ASTER image](image1)

(a) 
(b) 

Figure 2. ASTER image.

2.2.2. SRTM data SRTM is used as the auxiliary data of this paper (as shown in Figure 3), as the 1:50000 DEM of this experiment coverage area, its data is downloaded from Google online, its image reference ig75 ellipsoid, geodetic datum is xian80. The benchmark of Aster satellite measurement is WGS-84. Because the data coordinate systems of SRTM and aster are different, it is necessary to convert the two kinds of data to the same projection benchmark before extracting DEM.

![The reference image](image2)

Figure 3. The reference image.

2.3. Experimental process

2.3.1. Setting parameters Using the geomatica module of PCI, firstly, the down looking 3N band and back looking 3B band images are extracted from aster-hdf file, and then the projection mode of output DEM is defined as utm42 and the resolution is 15m.

2.3.2. Acquisition control point and the same name point There are two methods of acquisition control point and the same name point, which are manual acquisition and automatic acquisition. In order to
ensure the accuracy, this paper uses the manual acquisition method. In the process of collection, the control points should be evenly distributed in the whole image. For the main glacier area, the density of control points can be increased, and the control points can not be in a straight line. Finally, 48 control points and 23 points with the same name are collected. The precision of some control points is shown in Table 1.

| Point ID | Residual | Rex X | Rex Y | Type |
|----------|----------|-------|-------|------|
| P01      | 1.02     | 2.35  | 0.21  | GCP  |
| P02      | 2.56     | 0.99  | 3.21  | GCP  |
| P03      | 5.26     | 6.56  | 1.25  | GCP  |
| P04      | 3.21     | 2.13  | 4.11  | GCP  |
| P05      | 7.25     | 1.36  | 8.21  | GCP  |
| P06      | 2.01     | 1.01  | 3.25  | GCP  |
| P07      | 4.02     | 1.37  | 5.23  | GCP  |

2.3.3. Generate the kernel projection Image is used to eliminate the parallax in X direction between stereo images. After generating the epipolar projection image, there is only disparity in Y direction between stereo images. Re projection reduces the registration error of stereo pair in X direction to the minimum (relative to the reference image). Combined with the results of steps 2.1, 2.2 and 2.3, the final result of glacier extraction can be obtained by superposing and analyzing the image data.

3. Results and evaluation

3.1. Results
The result of DEM extraction in this paper is shown in Figure 4. According to the result of DEM extraction from ASTER data, it can be seen that the effect of DEM extraction is better in a small range away from the control point, and the quality of DEM extraction far away from the control point is poor. At the same time, according to the DEM results, the glacier extraction rate below the image is more than 93%. Black holes exist in the middle of the image because the representative object of black holes is Qinghai Lake. The reason for black holes in the image is that there are heavy snow cover and shadow in this area.

![Figure 4. The result of DEM.](image)

3.2. Accuracy evaluation
In this experiment, checkpoint method is used to test the accuracy of DEM obtained by aster. Checkpoint [6] is to realize the distribution of checkpoint according to grid or any form, compare the elevation of DEM generated at these points with the actual elevation one by one to get the error of each point, and then calculate the mean square error. In this experiment, the mean square error is calculated based on some control points extracted from this experiment, and some experimental control points and field control points are compared to calculate the mean square error.
\[ \sigma = \left( \frac{1}{n} \sum_{k=1}^{n} (R_k - Z_k)^2 \right)^{1/2} \]  

(1)

\( \sigma \) is the mean square error, \( R_k \) is the elevation value of srtm-dem, \( Z_k \) is the elevation value of indoor DEM, and \( n \) is the number of control points.

### Table 2. DEM elevation values and measured values.

| checking point | aster-DEM(m) | DEM(m) | diff H(m) |
|----------------|-------------|--------|-----------|
| P01            | 3568.315    | 3578.274 | 9.959     |
| P02            | 3973.608    | 3999.115 | 25.507    |
| P03            | 4600.104    | 4512.588 | 87.516    |
| P04            | 4013.520    | 4058.366 | 44.846    |
| P05            | 4705.684    | 4700.258 | 5.462     |
| P06            | 3970.309    | 4000.120 | 29.811    |
| P07            | 4211.752    | 4250.165 | 38.413    |
| P08            | 4474.857    | 4490.256 | 15.399    |
| P09            | 7701.073    | 7770.148 | 69.075    |
| P10            | 4366.711    | 4388.579 | 21.868    |
| P11            | 3952.373    | 4000.625 | 48.252    |
| P12            | 3969.318    | 3895.310 | 74.008    |
| P13            | 4494.162    | 4500.000 | 5.838     |
| P14            | 5999.772    | 5839.856 | 59.916    |
| P15            | 4162.519    | 4189.367 | 27.048    |

According to the mean square error formula and the 15 control points provided in this experiment, the RMSE is 45.064m, of which the maximum error is 87.516m and the average error is 37.528m. In general, the accuracy of Aster can reach within 60m, and can reach 30m under the ideal condition of good ground control points.

### 4. Conclusion

This paper mainly studies ASTER Remote sensing data processing software combined with PCI, and compares the results with the reference SRTM image, and finally verifies the results of DEM extraction by ASTER Remote Sensing stereo image. The mean square error of DEM in this experiment is 45.064m, which leads to the unsatisfactory accuracy of DEM. The main reasons are: the limitation of image quality, the existence of snow in Glacier survey area, the existence of shadow occlusion problems in the image, if the number of control points and the resolution of remote sensing image can be increased, the quality of glacier DEM will be improved.

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