REMOTE SENSING APPLICATION IN ANTARCTIC INLAND AREAS

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ABSTRACT:

Grove Mountains is located to the southwest of Princess Elizabeth Land, Antarctic inland areas, 400km away from the Chinese Zhongshan Station. This paper will discuss the application of the SAR, optical and altimetry data in Grove Mountains. Firstly, the improved DEM is generated. It is still difficult to get the accurate DEM of the whole Grove Mountains which is about 8000 kilometers square because the sloping terrain and the baseline error exist. Based on the InSAR DEM and ICESat footprints, the high precision DEM of the whole area can be obtained. Secondly, the distribution of blue ice is obtained both in optical image and coherence map. Based on the different spectrum characteristics of snow, blue ice and bared rocks, blue ice can be extracted in the optical image. And because of the higher coherence of the blue ice than snow and mountains area, it can also be identified easily in the coherence map derived from the ERS-1/2 tandem SAR data. Finally, crevasse detection is studied base on SAR image, optical image and coherence map. Based on the texture characteristics, gray level co-occurrence matrix and Gabor filter are chosen to recognize the crevasse. Basing on the study of Grove Mountains, more new technologies and satellite data shall be adopted to detect the ice surface change, ice flow velocity, etc, which are signal to the global environment change.

1. INTRODUCTION

The Antarctic is in very close relationship with the global climate, ecology environment, and the future of the human being. It is impossible to explore the Antarctic without any touch, and it is unscientific to reveal its mysteries foot by foot. The technologies of the earth observation from space provide us more approaches to understand the Antarctic profoundly, and open a new situation for us to explore the ice cap, the continent, and detect its mechanism. It is significant and efficient to combine the earth observation data from the space and the field survey data.

Grove Mountains, covered by ice snow and bare peaks, is located to the southwest of Princess Elizabeth Land, Antarctic inland areas, 400km away from the Chinese Zhongshan Station. Its geographical extension is 72°20′ – 73°12′ south latitude, 73°40′ – 75°50′ east longitude, and the area is about 8000 km^2; meanwhile, the core area extension is 72°50′54″ – 72°56′20″ south latitude, 74°54′07″– 75°14′09″ east longitude, and its area is about 110 km^2. Figure 1 shows the whole Grove Mountains, and the core area is marked in the rectangle.

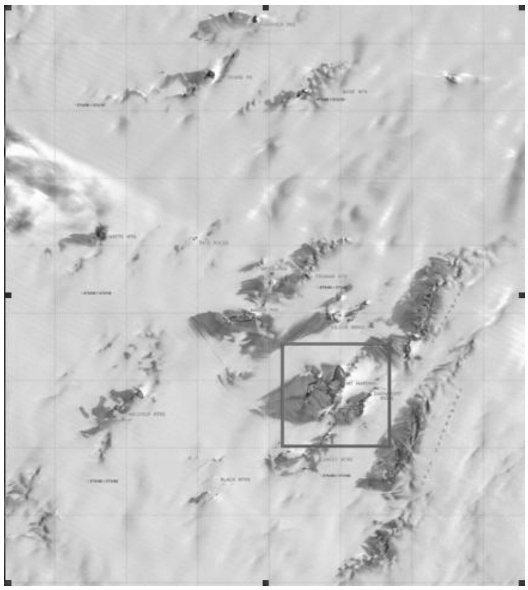

Figure 1. The Grove Mountains and core area in TM image

Grove Mountains is of typical in-land character and also an ideal midway station place for expedition teams extending to the South Pole. The weather there is atrocious for it has blustery or milky weather half of a year and the average temperature is about -30℃, which brings great difficulties for field surveying and operations. With the special terrain, blue ice and the meteorite enrichment, it is also the typical and important test site for correlative research. Chinese National Antarctic

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Research Expedition (CHINARE) has carried out expedition to the Grove Mountains four times during the 15th CHINARE (1998/1999), 16th CHINARE (1999/2000), 19th CHINARE (2002/2003) and 22nd CHINARE (2005/2006) summer expedition respectively.

In 1998, China planned to carry out expedition to Grove Mountains Area for the first time. Adopting Landsat-4 TM images, Chinese Antarctic Center of Surveying and Mapping (CACSM) had completed the colourful satellite image map of the Grove Mountains in August 1998 to ensure the expedition route and navigation to Grove Mountains Area. In 2000, the topographical map of the core area was printed after the field surveying was carried out by two geodetic surveyors of our center with GPS and total station under the atrocious weather conditions. In 2003, additional 7 ground control points (GCP) were set in the whole area. Meanwhile, SAR and other optical satellite image data are adopted for further study in this area.

2. DEM GENERATION

In 1998, Synthetic aperture radar interferometry (InSAR) was utilized to generate digital elevation model (DEM) with ERS-1/2 tandem SAR data for Grove Mountains since it has the advantage of all time, all weather operation and cost-effective data acquisition for large area, especially those areas that are more inaccessible, even in polar night. Then In 2000, the field surveying of the core area about 110 kilometers square was finished with GPS and total station in one month by two geodetic surveyors.

2.1 The core area

In the core area, there are two exposed mountains, many rock peaks, and detritus strips on the surface of the ice sheet with the altitude of 2000 meters, which has great topographical undulation and is densely covered by ice crack. Based on the ERS-1/2 tandem data which were collected on 10 Feb 1996 and 11 Feb 1996 respectively, the DEM of the core area is obtained. A point to the west of Mount Harding with rough elevation of 1867 meters is selected as the height reference point because area west to Mount Harding is relatively stable because of its blocking effect.

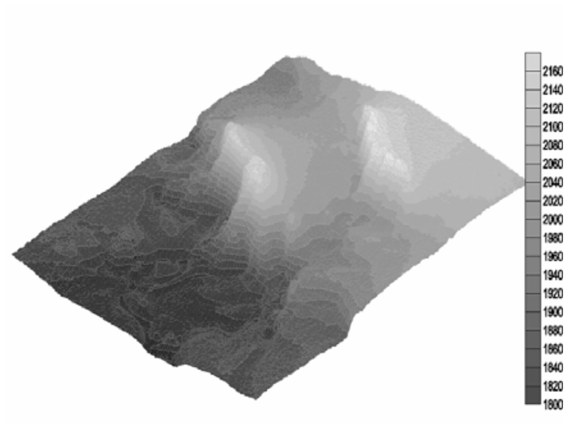


Figure 2. DEM generated using tandem SAR image data

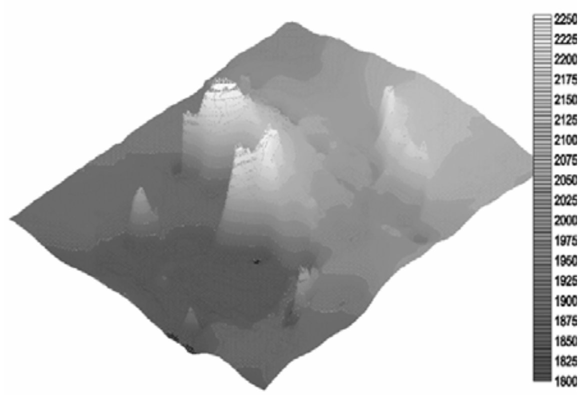
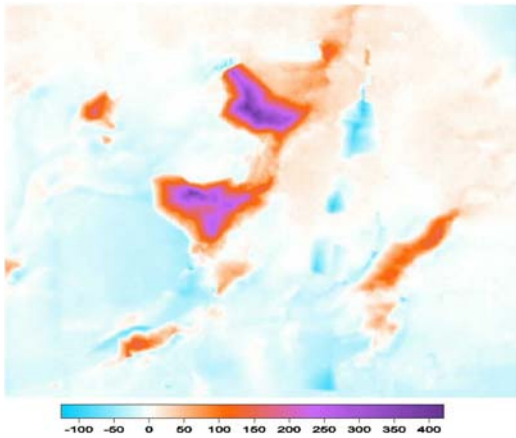
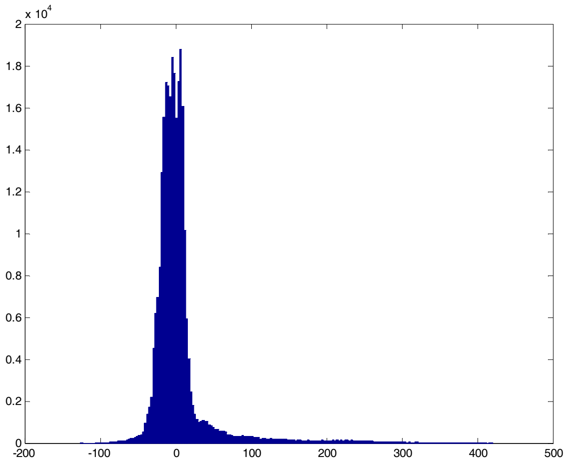


Figure 3. DEM from the topographic points obtained during the field survey

The difference between the DEM derived by tandem radar image data and DEM generated with the topographic points obtained during the field surveying is shown in Figure 4. The differences of the mountain area are quite large for there are cliffs, which induce the phase error and the unwrapping error. In addition, low-lying lands in the GPS-DEM bring large difference, which may be induced by the GPS observation error and the terrain change from 1996 to 2000. While, it is feasible to get the height of the ice surface according to the histogram. Penetration depth was not considered here.



（a）Height difference



（b）Histogram

Figure 4. Height difference of InSAR-DEM and GPS-DEM

2.2 The whole scene

With one height reference point, we can get the DEM of the core area in good accuracy. While, it is not enough to get the accurate DEM of the whole scene which is about 10000 kilometers square because the sloping terrain and the baseline error exist and the ground control points which are set on the bared rocks are difficult to recognize. The contour lines in figure 6 are dense since there are no GCPs, and ICESat data are not utilized in the SAR data processing. Meanwhile, compared with the actual terrain and the RAMP DEM, the result is not correct. The height of ICESat laser altimetry footprints are utilized to remove the residual fringe in the interferogram, which provide several profiles in this area (see also figure 5). Based on the InSAR DEM and ICESat footprints, the high precision DEM of the whole area can be obtained. It is obvious that the tilt plane was removed and the contours become sparse and reasonable in Figure 7. ICESat data is efficient for the InSAR-DEM correction especially in the area lack of GCPs.

Figure 5. ICESat Footprint in Grove Mountains (version026，GLA12)

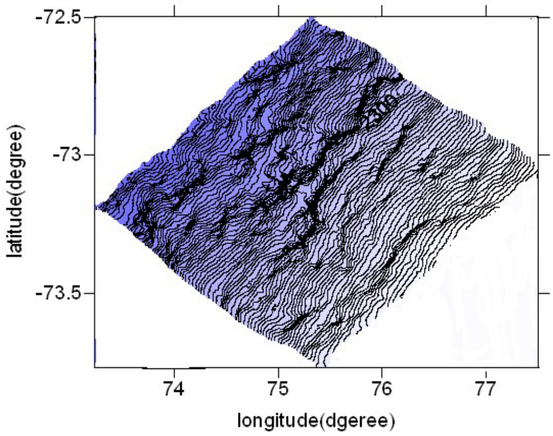


Figure 6. Contour map without tilt correction (interval: 20m)

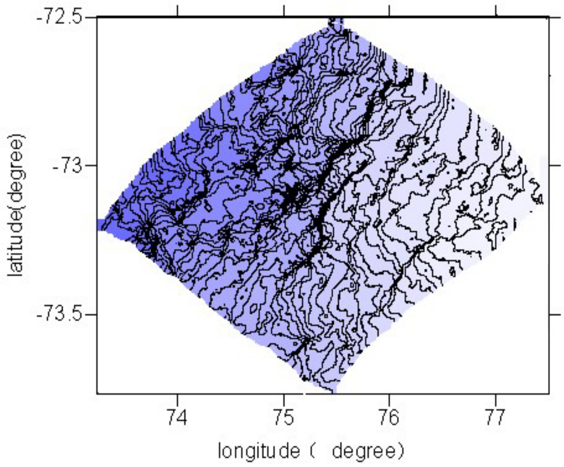


Figure 7. Contour map after tilt correction (interval: 20m)

3. BLUE ICE DISTRIBUTION

In Grove Mountains, the surface can be classified as snow, ice and rocks. In the blue ice area, the snow was cleaned off by the strong wind. The blue color of the ice is a result of an overtone of an OH molecular stretch in the ice which absorbs light at the red end of the visible spectrum. The large distribution of the blue ice indicates the enrichment of meteorite. During the 15th CHINARE (1998/1999), 16th CHINARE (1999/2000), 19th CHINARE (2002/2003) and 22nd CHINARE (2005/2006) summer expedition, totally 9834 pieces of meteorites were collected in Grove Mountains. Before the field expedition, blue ice distribution map was produced based on the Landsat TM image. Blue ice can also be recognized based on the coherence map and SAR image, while the latter provides relatively poor information.

3.1 In optical image

For the different spectrum characteristic of the blue ice, snow and bared rock, they are presented in different color in optical image such as Landsat TM (see also figure 1), SPOT (see also figure 5) and ASTER (see also figure 16) satellite image, etc. And the darkest areas are blue ice, and it can be extracted easily by unsupervised classification.

3.2 In Coherence map

Coherence is the most effective criterion to weigh the quality of the interferogram. Furthermore, it can be used for feature classification. The coherence of the main blue ice area is showed in Figure 8. In the coherence map, the blue ice, which is the brightest, has the highest coherence since there are little change between the ERS-1/2 tandem SAR images. As an example, the blue ice distribution is detected by unsupervised classification based on the coherence map.

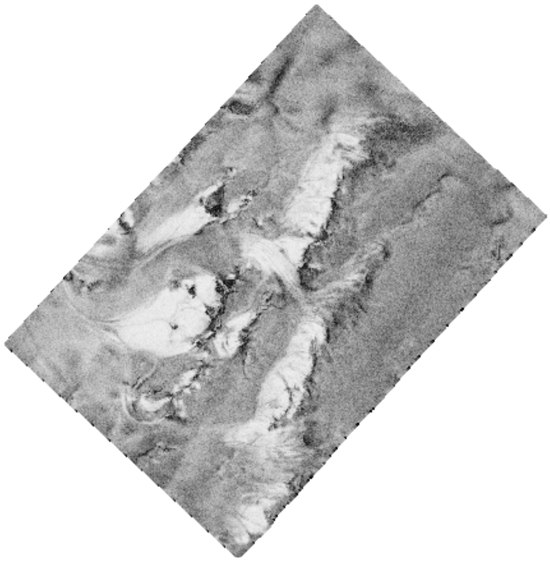


Figure 8 Coherence of the main blue ice area

Figure 9 Blue ice distribution derived from the coherence

3.3 In SAR image

According to the different surface characteristics and the backscattering coefficient, the amplitude of the blue ice is lower than other objects. The difference between the blue ice and other objects is obvious in the optical image and coherence map, while it is relatively poor in the SAR image (see also figure 10). The penetration characteristic of Radar is one of the main reasons. Optical image and coherence map are recommended for blue ice detection.

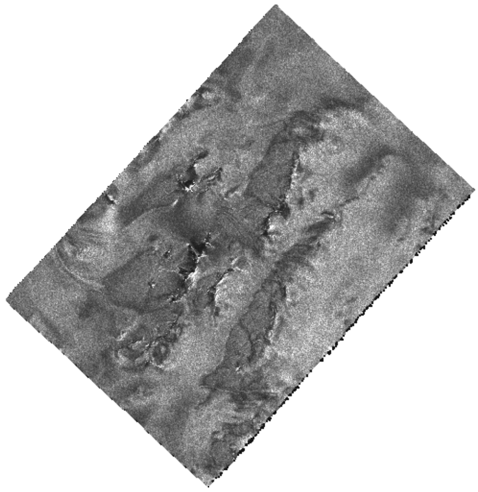


Figure 10 Master SAR image of the main blue ice area

4. CREVASSES DETECTION

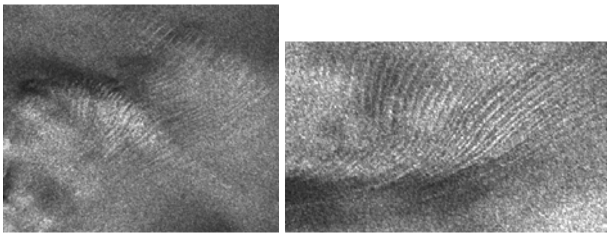
A crevasse is a fracture in a glacier caused by large tensile stresses at or near the glacier's surface. Accelerations in glacier speed cause extension and can initiate a crevasse. In Antarctica, some of the crevasses are about as wide as a finger, while some are about 100m or even wider. The depth of the crevasse is about several meters or abysmal. At the surface, a crevasse may be covered, but not necessarily filled, by a snow bridge made of the previous year's snow. Falling into a hidden crevasse that is covered by a weak snow bridge is thus a danger for expedition members and the snow tractor. During the expedition from Zhongshan Station to Grove Mountains and to the summit Dome A, quite a number of crevasse were found.

Crevasse detection is very important in polar scientific research expedition for the safety; meanwhile, it is also meaningful information for ice flow monitoring. Radar is a useful method for ice crevasse detection, which has been used in Antarctica since 1975. Early, radar crevasse detection systems could not sense a crevasse until the vehicle or sensor was directly above it. Subsequently, airborne radar was adopted for ice crevasse detection in the Antarctic expedition. Then in 80s of 20th Century, TM satellite image was utilized in this area, and later more data with higher resolution was used.

4.1 In SAR image and coherence map

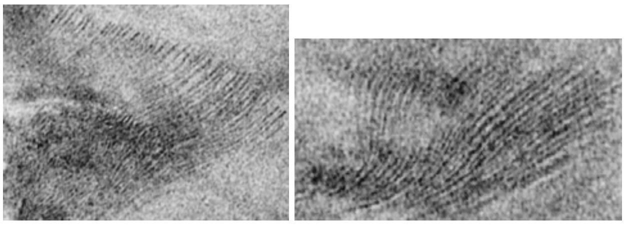
Compared with optical satellite image, SAR image can detect crevasse under the snow bridge because radar can penetrate the snow surface. But, it is correlated with the direction of the crevasse and radar beam. So it is not sure that SAR can detect all the crevasse covered or not covered by the snow.

In addition, it is found that the crevasse texture is more obvious in the coherence map derived from two SAR image data than the SAR image itself. Based on figure 11 and figure 12, it can be seen that the crevasse in SAR image is not as obvious as the ones in the coherence map. Figure 11(A) and Figure 12(A) covers the same area, so as B.



(A) (B)

Figure 11. Crevasses in SAR image



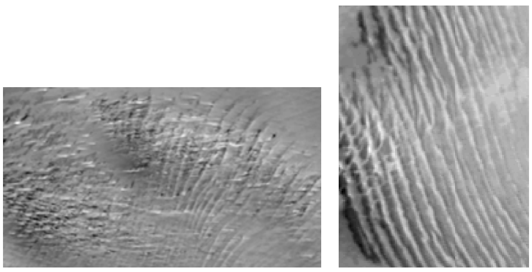
(A) (B)

Figure 12. Crevasses in coherence map

It is reasonable to combine the optical and SAR image data or coherence map. Regarding to the preliminary study of ice crevasse detection, more crevasses can be seen much more clearly in SPOT image since it has higher resolution than ERS SAR image. The study is based on the SPOT5 image with 10m resolution and the coherence map with 25m resolution. Here the example of crevasse detection in optical image is given.

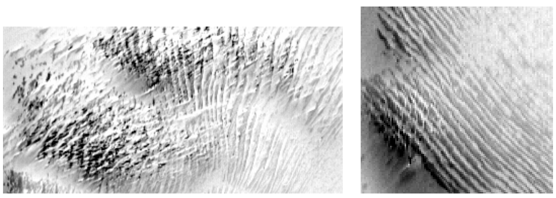
4.2 In the optical image

The SPOT image and ASTER image are adopted for crevasse detection. Figure 13(A) and Figure 14(A) covers the same area, so as B. The different resolution in 10m and 15m doesn't bring much difference in the result.



(C) (D)

Figure 13. Crevasses in SPOT image (10m resolution)



(C) (D)

Figure 14. Crevasses in ASTER image (15m resolution)

Many texture features can be derived from the GLCM matrix. After evaluating 14 second-order statistics of texture from GLCM, angular second moment, contrast, entropy and correlation have been found with enough texture information. Based on the GLCM and entropy feature of the SPOT image, the crevasse distributions of the whole Grove Mountains are generated (see Figure 15). But it is found that the borders of snow, rock and blue ice are recognized as the feature of crevasse, and some weak texture information can't be detected. Moreover, this method is time consuming.

Figure 15. Crevasses detection in SPOT image

Gabor wavelet is utilized for the further texture analysis. Based on the vectors of texture features conducted by Gabor filters, distance function is chosen for classification. Through the design of Gabor wavelet filter, we can improve the efficiency of the algorithm. The detection result is better than the former one.

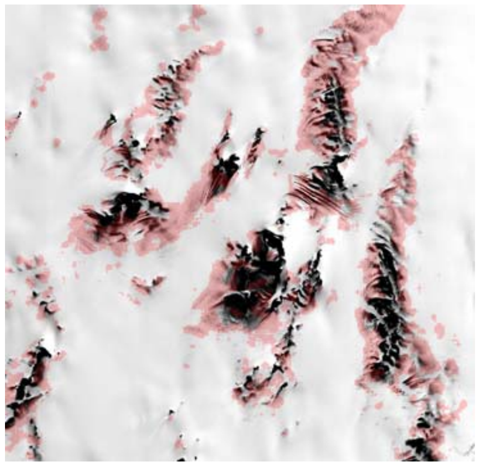


Figure 16. Crevasses detection in ASTER image

For the obvious crevasse, it can be detected by both methods. Gabor filter obviously improved the efficiency and there are no errors in the borders of snow, rock and blue ice. Field work and experience are needed for the accuracy assessment.

5. SUMMARY

Parts of the remote sensing technology have been applied in the Grove Mountains. Optical image data can be utilized for image mapping, stereo mapping, and classification. SAR image data are mainly used for DEM generation and classification. Meanwhile, ICESat data is very meaningful for polar research. Besides the DEM generation, blue ice distribution, crevasse detection, ice movement can also be monitored by differential InSAR. Basing on the study of Grove Mountains, more new technologies and satellite data shall be adopted to detect the ice surface change, ice flow velocity, etc, which are signal to the global environment change.

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