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Motion of the Lambert Glacier estimated by using differential Interferometric Synthetic Aperture Radar

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Abstract: Interferometric Synthetic Aperture Radar (InSAR) is one of the most promising remote sensing technologies and has been widely applied in constructing topographic information and estimating the deformation of the Earth's surface. Ice velocity is an important parameter for calculating the mass balance and modelling ice shelve dynamics. Ice velocity is also an important indicator for climate changes. Therefore, it plays an important role in studying the global climate change and global sea level rise. In this paper, the ERS-1/2 tandem data and the ASTER GDEM are combined together to obtained the deformation in line of sight by using the differential Interferometric SAR for the Lambert Amery glacier in Antarctica. Then the surface parallel assumption is adopted in order to achieve the ice flow velocity. The results showed that ice velocity would be increased along the Lambert glacier; the maximum ice velocity would be reach about 450m/year in the study area.

1. Introduction

The Antarctica ice sheets take 90% of the world's ice which account for 77% fresh waters of the world. If all of the ice sheet were completely melted, the global sea level will rise almost 60 meters [1]. During the past century, the global sea level raised at an average velocity of 0.6 millimeters, so it is very urgent and necessary to monitoring the sea level changes and ice sheet changes of the Antarctica. Glaciers are not only the indicator of the global climate change but also critical parameters for studying the mass balance and modeling the ice sheet dynamics. However, the condition of the Antarctica is very harsh, it is very difficult to observation the dynamic characters using field survey methods.

Interferometric Synthetic Aperture Radar (InSAR) can obtain the deformation of the earth surface in centimeter even millimeter accuracy level by employing more than two coherence SAR images of the same study area. Comparing with the traditional optical remote sensing, SAR is an active remote sensing technology. It transmits the microwave signals to the targets on the earth and receives the reflected signals from the targets. It could not be affected by the sunlight, so it could obtain the SAR images day and night especially in rainy and cloudy weather condition, therefore it is more suitable for studying the dynamic characters and monitoring the ice velocity of glaciers in Antarctica. During the past decades, InSAR has being widely used to studying the ice velocity since 1993 and achieves many surprising results[1-4], however much attention has been paid to the West Antarctica, there is rare research work has been done in the East Antarctica. Although the East Antarctica's contribute to the sea level changes is not as significant as the West Antarctica, but there is still a large uncertainty in

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the results, so it is very necessary to study the ice sheet changes of East Antarctica in order to estimate the contribution to the sea level changes more accuracy.

Lambert glacier is one of the largest glaciers in East Antarctica. it is about 100 km wide and 400 km long. It drains nearly 12 percent of the total East Antarctic ice volume into Amery ice sheet. So it is a very important glacier for research the ice sheet changes of East Antarctica. In this article, the ERS-1/2 tandem data and the ASTER GDEM are firstly processed to obtain the deformation in line of sight by using the differential Interferometric SAR, and then the surface parallel assumption is adopted in order to achieve the ice flow velocity. The article is organized as follows, section 2 introduces the basic methods and the workflow for data processing and ice velocity estimation, and then the study area and the data are described in section 3. In section 4 the results of the experiment are presented and discussed. Finally, the conclusions are drawn out.

2. Methods and Data Processing

The phase information other than the magnitude of the SAR images is used for monitoring the deformation of the earth surface by Interferometric SAR. In order to obtain the interferogram, two or more SAR images must be co-registered with each other within sub-pixel accuracy, and then the interferogram can be obtained by conjugated complex the coregistrated SAR images.

The interferogram not only contains the phase of the deformation but also contains the phase of topography, flat earth effect, atmospheric distortions and the thermal noise. In order to obtain the deformation, the topographic phase and the other phase must be removed. With the flattening operation the flat earth effect could be removed. The atmospheric could be eliminated by selecting the SAR images carefully. The thermal noise can be reduced by applying the filter operators to interferogram. In order to remove the topographic phase, many research works have been done. In this paper the simulated topographic phase from the digital elevation model (DEM) and the orbit data are used to simulate the topographic phase and subtracted from the interferogram. Finally only the deformation phase duo to ice flow is contained in the interferogram. However, the phase in the interferogram are modulated by 2π, namely the value of the interferogram only with $[-\pi, \pi]$. In order to obtain the deformation, the phase unwrapping must be performed, the minimum cost flow (MCF)[5] technology is one of the most famous phase unwrapping methods which used to obtain the unwrapping phase of the interferogram.

The deformation obtained from the unwrapping phase is only in the line of sight, in order to obtain the actual ice velocity, the assuming that the glacier is flow along the direction of the maximum gradient and parallel to the ice surface must be employed. Therefore the DEM is transformed from the geophysical coordinate to the SAR image coordinates and the gradient and the aspect are computed respectively to obtain the ice flow direction and ice velocity. Finally the ice velocity is estimated from the deformation in line of sight.

3. Study Area and Data

Lambert Amery ice sheet, East Antarctica is one of the three major glaciers contributing to the Amery ice shelf.

One of the major limitations for interferogram is the temporal decorrelation arising from melting of snow and ice, snow accumulation or distribution through precipitation or wind. Therefore the interferogram will severely affected if the time interval between the SAR images acquired are very long. Fortunately, ERS-1/2 tandem, which temporal baseline is only one day, provides a lot of valuable SAR data suited for estimating the ice velocity in Antarctica and construction the topography. In this paper, the data is acquired on Feb. 15, 1996 and Feb. 16, 1996 respectively by ERS-1 and ERS-2 satellites, the orbit numbers are 23982 and 4309. The perpendicular baseline between the two SAR images is 148 meters. The amplitude image of the SAR image is shown as figure 1, which has been multi-look with the multi-looking factors 2:10, the resolution of the amplitude image is 40 meters.

The orbit ephemeris play an importance role in the InSAR data processing such as flatten the interferogram and remove the topographic phase, however the orbit parameters within the leader file of the SAR images is not accuracy enough. In order to improve the reliability of the data processing, the precise orbit data provided by DEOS is used.

In order to remove the topographic phase in the interferogram and obtain the gradient and the aspect for estimating the ice flow, the ASTER GDEM with 30 meters resolution is adopted and geocoded to the radar coordinates as shown in figure 2. Finally the interferogram could be produced and the ice velocity could be estimated from the deformation in light of sight direction.

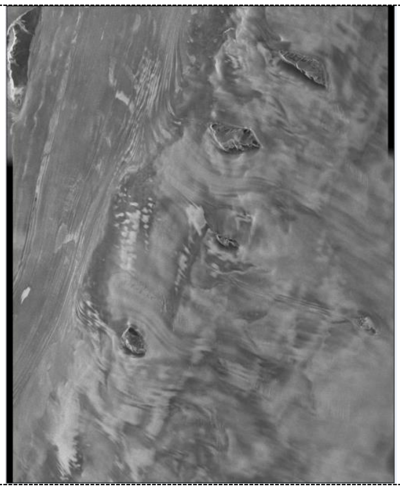

Figure 1. Amplitude data of the ERS-1/2 SAR images with 40 meters resolution

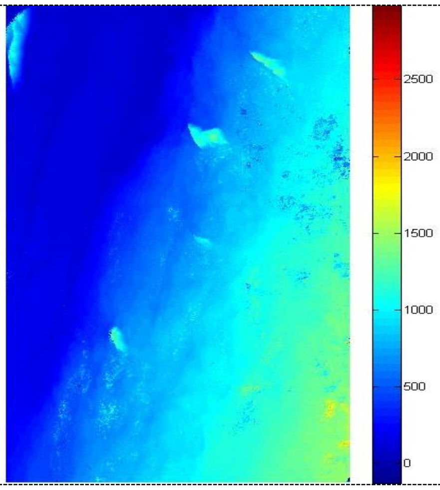

Figure 2. ASTER GDEM data of the study area in the SAR image coordinates(unit: meters)

4. Results and Discussion

Using the described method, the differential Interferogram is obtained as figure 3 after removing the flat earth effect and the topographic phase with ASTER GDEM data. The wavelength of the ERS1/2 is 5.6cm, so one fringe of the differential interferogram represents 2.8mm deformation of the line of sight. It could be found that the fringes are very clear at the shelf, It is mainly due to the temporal baseline is only one day, the correlation between the SAR images could be maintain very well.

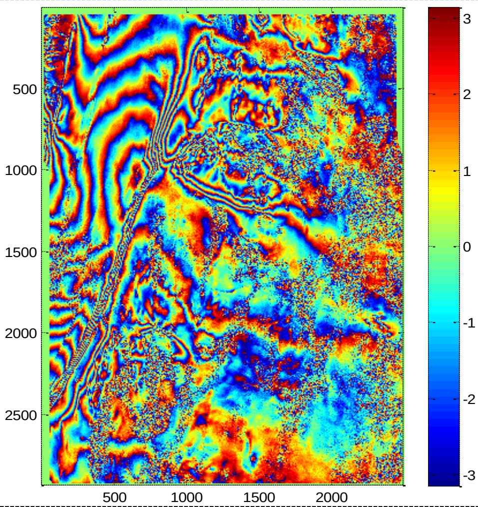

Figure 3. Differential interferogram of the study area obtained from the SAR images(unit:radian)

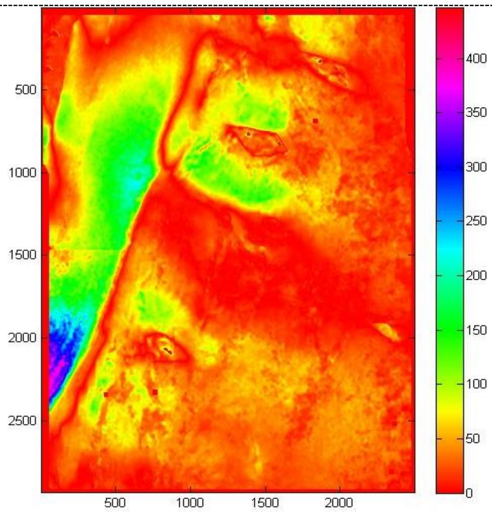

Figure 4. ice velocity of the study area estimated from the unwrapping phase (unit:m/year).

The unwrapping phase could be reconstructed from the interferogram by adopting the MCF phase unwrapping technology. Finally, the ice velocity is estimated from the unwrapping phase by using the methods described above with the gradient and aspect obtained from the DEM as shown in figure 4. The value of the ice velocity ranges between 0 and 450m/year. From figure3, it could be found that the ice velocity will be increased along the Lambert glacier, the maximum ice velocity is about 450 meters per year.

5. Conclusion

The ERS-1/2 tandem SAR data and the ASTER GDEM data are cooperately used to estimate the ice velocity of the Lambert glacier in East Antarctica by adopting the differential interferometric SAR technology. With the assuming that ice flows along the direction of the maximum gradient and parallel to the ice surface, the actual ice velocities are estimated. The results show that ice velocity will be increased along the Lambert glacier and the maximum ice velocity can reach about 450m/year.

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