TIDAL DEFLECTION OF ROSS ICE SHELF, ANTARCTICA, OBSERVED BY SENTINEL-1A DOUBLE-DIFFERENTIAL INTERFEROMETRIC SAR

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ABSTRACT

This paper reports the tidal deflection of Ross Ice Shelf, Antarctica, observed from Sentinel-1A data processed by using double-differential interferometric synthetic aperture radar (DDInSAR) technique. Sentinel-1A single look complex SAR data of 2015-2016, along the east and the west coast of Ross Ice Shelf, were obtained and interferometrically processed by Sentinel Application Platform (SNAP) program. GETASSE30 digital elevation model was used to remove the topographic fringes. After the phase unwrapping using SNAPHU program, the two interferograms were subtracted to obtain DDInSAR image to highlight the tidal deflection signals under the assumption of steady gravitational glacial flow. As a result, we can identify grounding lines and hinge zones in the east and the west coast of Ross Ice Shelf. The wider hinge zone in the west indicates thicker ice shelf than the east. Comparison of the tidal deflection with tidal model remind us the importance of barometric correction.

Index Terms— Ross Ice Shelf, Sentinel-1A, DDInSAR, Tidal deflection, grounding line, hinge zone

1. INTRODUCTION

Sentinel-1A satellite was launched in 2014 by European Space Agency (ESA). Its main sensor mode is intererometric wide-swath (IW) mode and has a spatial resolution of 5 m x 20 m with 250 km swath. TOPSAR technique obtains homogeneous images over the three sub-swath (IW1, IW2, and IW3). It operates in C-band SAR capable of obtaining all-weather images over the cloudy Antarctic region.

Interferometric SAR (InSAR) images with 12-day temporal baseline can be obtained over the glacial region in the Antarctic coastal region where horizontal motion from gravity and vertical tidal deflection occurs simultaneously. Due to the 12-day revisit cycle and the spatial resolution of Sentinel-1A, interferometric displacement signals from glaciers moving slower than ~10 cm/day can be obtained [1].

Under the assumption of steady gravitational flow, tidal deflection of glacier can be obtained by applying double-differential interferometric SAR (DDInSAR) technique. Tidal deflection signal of a glacier indicates grounding line and hinge zone of the glacier which gives useful information on the geographic distribution of ice boundaries, glacial climate changes, and physical parameters of the glaciers such as thickness and modulus of ice [2]. DDInSAR-derived tidal deflection also plays an important role in evaluating the existing tide models and atmospheric data [3].

In this paper, we present our preliminary results on the tidal deflection of Ross Ice Shelf observed by applying DDInSAR techniques to a series of Sentinel-1A data and its comparison with the Ross-Inv tide model and subsequent inverse barometric effect (IBE) correction.

2. STUDY AREA AND DATASET

The study are is near the outlet of Ross Ice Shelf in Antarctica along the coastal region. Fig.1 shows the 'East' and the 'West' of the study area as well as the locations of automatic weather station (AWS) distributed over the ice shelf.

For the East, we retrieved three Sentinel-1A SLC data obtained in IW mode with 12-day interval (23 November, 5 and 17 October 2015), as shown in Table 1. For the West we obtained two SLCs on 16 and 28 June 2015, and the other two SLCs on 29 May and 10 June 2016. For the comparison with DDInSAR-derived tidal deflection, we used Ross_Inv tide model and barometric pressure data from AWSs.

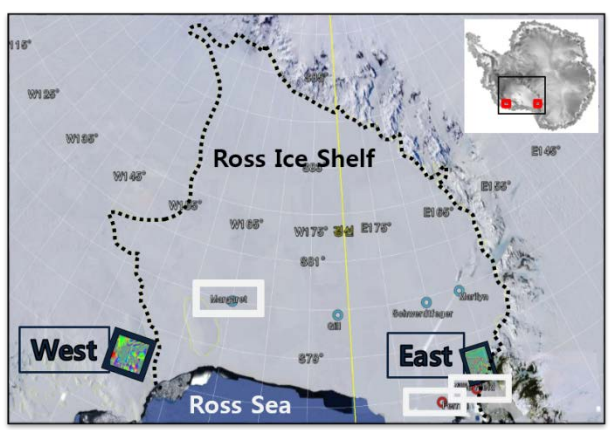

Fig. 1. The study area the locations of AWSs. Investigated images, the East and the West, are along the coast of Ross Ice Shelf. Note the inaccuracy of the Google Earth coast line in the West.

3. METHODS

Interferometric SAR processing was performed by using SNAP program provided freely by ESA. Firstly, a pair of SAR SLCs were matched together to generate initial earth-flattened interferogram. GETTASSE30 digital elevation model was then used to remove topographic fringes to obtain differential interferogram which was then exported to SNAPHU for phase unwrapping. The processed DInSAR data were then imported to SNAP and the phase of the two DInSAR data were subtracted to obtain DDInSAR image.

Each DDInSAR images of the East and the West of Ross Ice Shelf were visually investigated to find out tidal deflection signals under the assumption of steady gravitational ice flow. The observed tidal deflection values in radar line-of-sight (LOS) were then converted to the vertical tidal deflection by using local incidence angles.

For the comparison, we obtained the tide value of the Ross_Inv model and the barometric pressure from AWSs at the time of image acquisition. The load-tide values obtained from TPXO7.2 was used to correct Ross_Inv. AWS data were investigated to decide which data should be used, whether to use a specific location or to take average, in this sparsely distributed AWSs.

4. RESULTS AND DISCUSSIONS

Fig. 2 shows DDInSAR image of the East while Fig. 3 shows that of the West. Note that coast line of the Google Earth needs to be corrected as we found grounding line and hinge zone further west of the Ross Ice Shelf. The hinge zone of the East is ~1 km on average which is much narrower than those of the West that has 4~9km. Assuming similar ice properties, ice thickness of the East is assumed to be much thinner than that of the West.

Vertical component of the double-differential tide were obtained to be 65.43 cm for the East and -77.35 cm for the West, as shown in Table 2. The load-tide corrected Ross_Inv model (before IBE correction) has 0.5 cm for the East and -45.97 cm for the West, showing large differences between DDInSAR and tide model and provoking the necessity of IBE-correction.

Fig. 4 shows the double-differential barometric pressure data for a day from the selected AWS data near the study sites to be compared with the DDInSAR-derived tidal values. For the East, the two nearby stations (45 km from the Willie Field AWS and 108km from the Ferrell AWS) have very similar pattern in the barometric pressure data. Therefore, we decided to use the averaged value of the two stations to improve the accuracy. For the West, however, barometric pressure data from the four stations located hundreds kilometers apart from the study sites have quite different patterns so that we only used the Margaret AWS data 280 km away from the study site.

After IBE correction, the tide model was 51.16 cm for the East and -74.87 cm for the West, showing -14.27 cm and 2.48 cm of deviation from the DDInSAR values in the East and the West, respectively. Relatively large difference in the East is not easy to explain only with a single DDInSAR image. Large variation of topography in the East might be the cause of error in the estimation of barometric pressure.

Table 1. Sentinel-1A SAR data and DDInSAR processing.

Area	ID	yyyy/mm/dd hh:mm (UTC)	DInSAR (days)	DDInSAR
The East	T1	2015/09/23 00:47	T2-T1 (12) T3-T2 (12)	(T3-T2)-(T2-T1)
	T2	2015/10/05 00:47		
	T3	2015/10/17 00:47		
The West	T1	2015/06/16 10:40	T2-T1 (12)	(T4-T3)-(T2-T1)
	T2	2015/06/28 10:40		
	T3	2016/05/29 10:40	T4-T3 (12)	
	T4	2016/06/10 10:40		

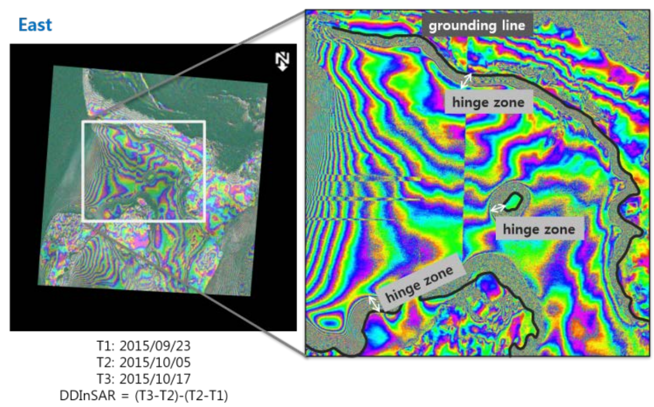

Fig. 2. DDInSAR image of the East showing grounding line (thick line) and hinge zone.

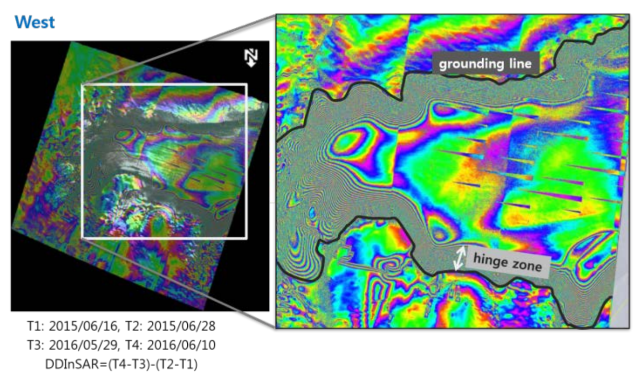

Fig. 3. DDInSAR image of the West showing grounding line (thick line) and hinge zone much thicker than the East.

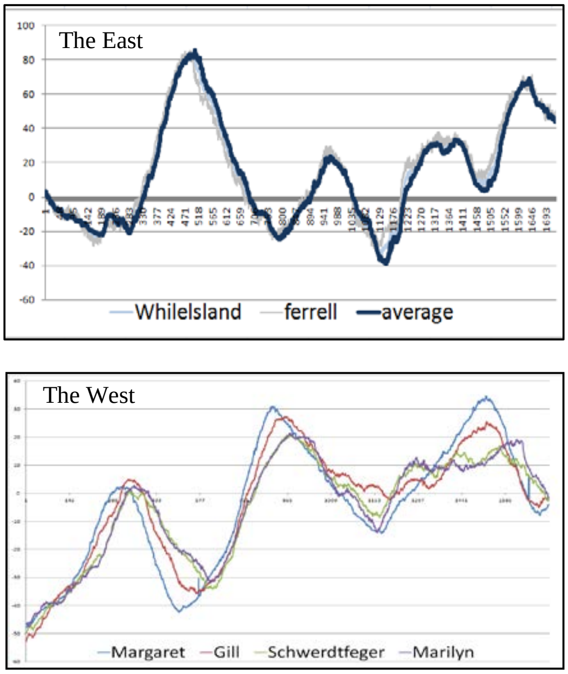

Fig. 4. Double-differential barometric pressure data (mbar) for a day obtained from the AWS data used for the East(top, averaged) and the West (bottom, Margaret only). The SAR acquisition time is at the end of the graph.

Table 2. Vertical tidal deflection measured from DDInSAR and tide model (cm).

	DDInSAR	Before IBE	After IBE	Deviation
The East	65.43	0.5	51.16	-14.27
The West	-77.35	-45.97	-74.87	2.48

5. CONCLUSIONS

This paper shows a successful application of DDInSAR technique using Sentinel-1A SAR data in finding grounding line and hinge zone of relatively slow-moving glaciers such as the coastal area of Ross Ice Shelf. Grounding line and hinge zone in the West shows that the coast line of the Google Earth should be corrected. Narrower hinge zone of the East than that of the West might indicate shallow ice in the East. The IBE-corrected Ross_Inv model is quite accurate in the West (2.48cm difference) while that of the East (14.27 cm) is large in comparison.

Continuous observation of Sentinel-1A data, together with more accurate tide model is necessary to verify the preliminary results derived from this study. Moreover, combination of newly launched Sentinel-1B with Sentinel-1A will provide 6-day revisit cycle which can extend the InSAR capability for faster glaciers.

6. ACKNOWLEDGEMENTS

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