VELOCITY ANOMALY OF DAVID GLACIER, EAST ANTARCTICA, OBSERVED BY DOUBLE-DIFFERENTIAL INSAR

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ABSTRACT

This research observed variation of flow velocity on the David Glacier, East Antarctica observed by using Sentinel-1A satellite. Because of the 12-day revisit cycle, relatively slow-flowing area was observed. Using double-differential InSAR (DDInSAR) technique, we could find the circular shaped velocity anomaly. We combined the ascending and descending DDInSAR images to figure out the direction of the true displacement over the anomaly. As a result, the circular anomaly appears mainly to be a vertical movement, not in the flow direction. This vertical movement in the David Glacier, where subglacial lakes are known to exist, can be thought of as a signal of water level change of a subglacial lake forming a subglacial channel system.

***Index Terms*—** DDInSAR, Subglaical lake, David Glacier

1. INTRODUCTION

Antarctic glaciers show changes in flow rates due to climate change and basal effects. There are various factors in the change of flow velocity, such as mass balance gradient of accumulation and ablation, deformation in glacier, and basal sliding. Among these factors, basal sliding is usually caused by the lubrication of the melt water and the resulting reduction in friction (Bennett and Glasser, 1996). The melt water flows through various paths from the point where it is generated. The melt water flows through a channel and forms a subglacial lake that was stored in basin or blocked by a cold glacier so that the melt water cannot penetrate. The drainage system of subglacial lakes forming the channel system affects the flow of glaciers over the subglacial lakes. Changes in the quantity of water in the subglacial lakes by the drainage system are also observed as vertical movements on the surface of the glacier (Fricker et al., 2007). Until now, most subglacial lakes have been found using optical satellite images, Radio Echo Sounding, and Laser Altimetry (Bell et al., 2007; Fricker et al., 2007; Smith et al., 2009). In this study, we used the DDInSAR (Double-Differential Interferometric Synthetic Aperture Radar) technique to identify the velocity changes between the two periods, which seemed to be caused by the drainage system of a subglacial lake. Among them, the DDInSAR signal, which appears as a circle and is difficult to think of as a signal due to a change in flow, may be a vertical movement due to a change in the water level of the subglacial lake. David glacier has already been known to have several subglacial lakes (Smith, 2009), and vertical surface changes can be attributed to drainage or flooding of the subglacial lake. To determine the direction of the actual displacement-change in DDInSAR images, the horizontal flow direction of the glacier was determined by combining Sentine-1A ascending and descending DInSAR images assuming no vertical motion. The direction of the actual displacement changes of the anomaly signal in the ascending and descending DDInSAR images was found assuming that the anomaly is either in flow direction or of vertical movement.

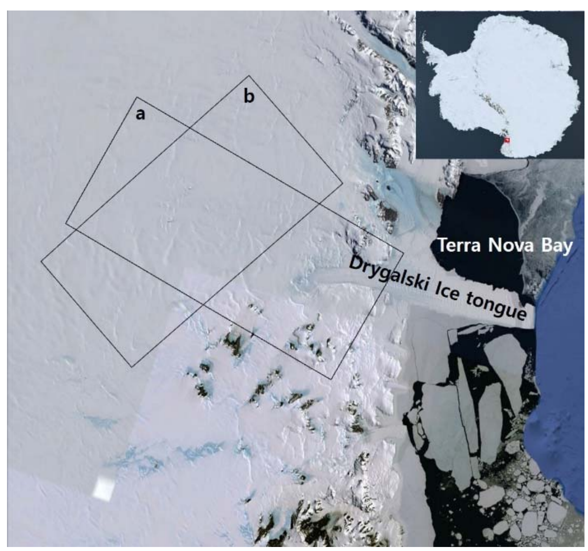

Fig 1. The study area is marked with a red box in the attached Antarctic map. a is the outline of ascending IW2 image and b is of descending IW1 image.

2. STUDY AREA AND DATA

The study area is David Glacier in Victoria land, East Antarctica, that forms the Drygalski Ice Tongue and the Nansen Ice Shelf toward Terra Nova Bay. It flows from Dome C and Talos Dome to form a drainage basin with an area of about 250,000 km^2(Frezzotti, 1993). Frezzotti et al. (2000) confirmed an ice discharge of 7.8±0.7 $km^3 a^{-1}$.

We used C-band SAR images from Sentinel-1A satellite which was launched by the European Space Agency(ESA) in 2014. It can take images in interferometric wide-swath mode that operates in TOPSAR, an advanced scansar mode that produces three subswaths. Thanks to this wide-swath mode, both ascending and descending images can be obtained in a same day, providing opportunity to find out true displacement vector of the surface motion. As the revisit cycle is 12 days, it is difficult to observe the rapidly flowing part of the glacier due to low coherence. In this study, we applied DDInSAR technique to relatively slow-flowing area using a total of 8 images consisting of ascending and descending images of each date (03 May 2017, 15 May 2017, 15 Jun 2018, and 27 Jun 2018). To make the DInSAR image, the GETASSE30 DEM was used to remove the topographic phase from the InSAR image.

3. METHODS

ESA's SNAP program was used to make a DInSAR image. We used GETASSE30 DEM to remove the topographic effect. Firstly, we made the two DInSAR images of 03 May 2017 and 15 May 2017, and of 15 June 2018 and 27 June 2018. Phase unwrapping was performed using the snaphu program. Two unwrapped DInSAR images was subtracted to get the DDInSAR image. By doing so, flows with no change between the two periods are removed and only signals with the changes are left. When rewrapping the DDInSAR image, patterns of channels and a circular shape appeared. The pattern of the circular is likely to be either a change in glacier flow or a signal due to vertical movement. Therefore, we need to find true displacement of DDInSAR circular pattern by combining ascending and descending DDInSAR image. When we consider the east-west (x), north-south (y), and up-down(z) coordinate systems at a target on the ground, the LOS vector from the satellite antenna to the target can be expressed as an incidence angle (i, the angle between the zaxis and the LOS vector, positive value) and the satellite heading angle (h, measured clockwise from the north).

$$\hat{l} = (\sin i \cos h, -\sin i \sin h, -\cos i).$$

The glacier flow vector $\vec{f} = (f_x, f_y, f_z)$ can be calculated as follows using the displacements obtained from the two DInSAR images (d_A and d_D for the ascending and the descending, respectively) and the LOS vectors ($\hat{l}_A$ and $\hat{l}_D$ for the ascending and the descending, respectively), assuming that the vertical component is close to zero and most of them are of horizontal components.

$$\begin{bmatrix} f_x \\ f_y \\ f_z \end{bmatrix} = \begin{bmatrix} \hat{l}_A \\ \hat{l}_D \\ \hat{z} \end{bmatrix}^{-1} \begin{bmatrix} d_A \\ d_D \\ 0 \end{bmatrix},$$

where $\hat{z}$ is the up unit vector. The DDInSAR signal is assumed to be either of flow direction or vertical direction. In this case, the normal vector of the DDInSAR true displacement plane is found by the cross product of the up vector and the flow vector, ($\hat{n} = \hat{z} \times \hat{f}$). The true displacement vector $\vec{\dot{f}} = (\dot{f}_x, \dot{f}_y, \dot{f}_z)$ of the DDInSAR signal ($\dot{d}_A$ and $\dot{d}_D$ for the ascending and the descending, respectively) can be found as,

$$\begin{bmatrix} \dot{f}_x \\ \dot{f}_y \\ \dot{f}_z \end{bmatrix} = \begin{bmatrix} \hat{l}_A \\ \hat{l}_D \\ \hat{n} \end{bmatrix}^{-1} \begin{bmatrix} \dot{d}_A \\ \dot{d}_D \\ 0 \end{bmatrix}.$$

4. RESULT

As a result of applying DDInSAR technique to the study area, the circular anomaly signal and multiple channel anomaly signals were observed. In the ascending and descending images, the circular anomaly appeared at the same position. As a result of finding the true displacement of the circular anomaly, the vertical displacement $\dot{f}_z$ showed a displacement difference of up to -5 cm, the horizontal displacement $\dot{f}_x$ showed almost zero movement and $\dot{f}_y$ about 3 cm. From this, it can be seen that the displacement change of the circular pattern is a combination of horizontal and vertical change. The channel-shaped signal and the circular signal are connected to each other, which is considered to be a signal due to the subglacial lakes that exchanges water through channels inside the glacier or the ice-bedrock interface.

5. SUMMARY

In the David glacier, DDInSAR images using Sentinel-1A were analyzed. Both ascending and descending images showed a circular anomaly at the same position. The vertical motion is dominant rather than the horizontal motion. The anomaly of this circular shape is assumed to be due to the water level change of the subglacial lake. For further studies, we will observe the research area in a time-series DDInSAR data to determine whether the vertical movement is continuous and the circular anomaly is rising or subsiding with time. Moreover, GPR (Ground Penetrating Radar) exploration will be implemented in the forthcoming field investigation.

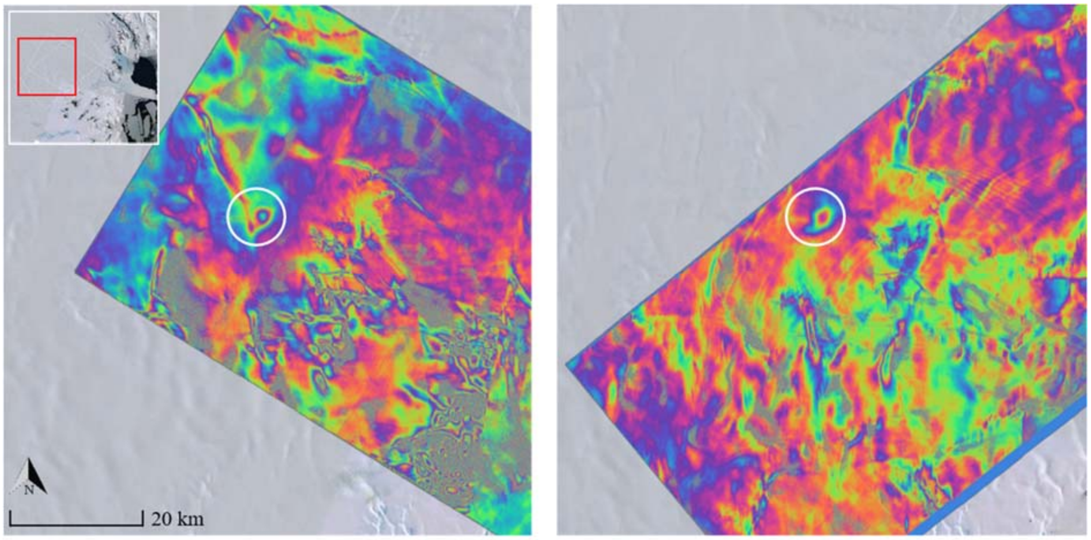

Fig 2. The ascending (left) and descending (right) DDInSAR images. White circles in both images are the same position that show the circular shaped anomaly. A channel pattern is also seen from north leading to the circular anomaly.

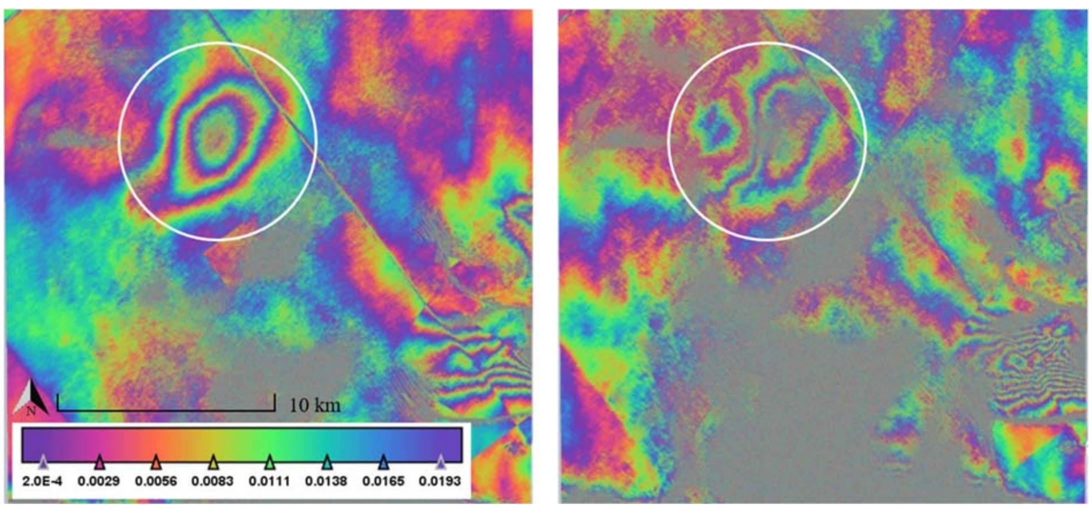

Fig 3. The vertical component of displacement change (left) and the horizontal component (right) were obtained (in meter scale). The white circles are the same as marked in Fig 2. The displacement is re-wrapped so that one color cycle indicates a displacement change of 2 cm.

6. ACKNOWLEDGEMENTS

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