Strain over landfast sea ice near Jangbogo Antarctic Station observed by InSAR

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Abstract : In this study, we identified strain over landfast sea ice and its annual variation in Terra Nova Bay (74°37′4"S, 164°13′7"E), East Antarctica, where Jangbogo Antarctic Station has recently been constructed in 2014, by using Interferometric Synthetic Aperture Radar (InSAR). We generated 38 interferograms having temporal baselines of 1-9 days out of 62 COSMO-SkyMed SAR images obtained from December 2010 to January 2012. No meaningful relationships were found between interferometric fringes and wind or current. Glacial strain (~67cm/day) caused by Campbell Glacier Tongue is similar to tidal strain (~40 cm) so that they appear similar in one-day InSAR. Glacial strain is cumulative and highlighted InSAR images with weekly temporal baselines (7~9 days) while tidal strain is oscillatory. Glacial strain is parallel to the glacier-sea ice contacts while tidal strain is parallel to the coastlines defined by sea shore and glacier tongue. Double-Differential InSAR (DDInSAR) operation removed the consistent glacial strain leaving tidal strain alone so that the response of fast ice to tide can be used to deduce physical properties of sea ice in various ice stages.

1. Introduction

Landfast sea ice, often called fast ice in short, is a type of sea ice adjacent to the coast and is immobile for a certain period of time. Temporal and spatial variation of fast ice significantly influences marine ecosystem and safe operation of icebreaker vessels. In 2014, Korea Polar Research Institute (KOPRI) has opened a new Antarctic research station, called Jangbogo Research Station, near Terra Nova Bay. During survey and construction of the station from 2011 to 2014, sea ice state near the route of Araon icebreaker research vessel has been major issue for logistics.

Previous study by Lee *et al.*(2015) have shown that fast ice in this region began to appear in March 2011, two month later after air temperature dropped below freezing point while it survived the summer melt in 2012. Large annual variation in sea ice extent and thickness exists in this region. However few studies have been attempted to investigate its annual variation and ice dynamics due to lack of high resolution satellite images.

Lee *et al.*(2015) have also reported that interferometric fringes exist over the fast ice field in this region with 20

COSMO-SkyMed one-day interferometric synthetic aperture radar (InSAR) pairs obtained from December 2010 to January 2012 (Fig. 1). Sea ice can be distorted by stress from many factors such as wind, current, Coriolis force, adjacent sea ice or glaciers, and sea surface tilt by tide or current. Among them, wind, current, and Coriolis forces play major role in strain over pack ice but their contribution is very little for most Antarctic fast ice with few ridges or keels. No meaningful correlation could be found so far between those factors and the temporal and spatial variations over the fast ice in this region.

In this study, we try to analyze the variation of strain over fast ice and its relationship with stresses from tidal ocean tilt and Campbell Glacier Tongue (CGT) by a series of InSAR pairs.

2. Methods

Using a total of 62 COSMO-SkyMed images (Han and Lee, 2014) obtained during December 2010 and January 2012, we generated 20 one-day InSAR images and 18 weekly InSAR images. We also have generated several Double-Differential InSAR (DDInSAR) images by using dataset when ice surface is stable between two InSAR

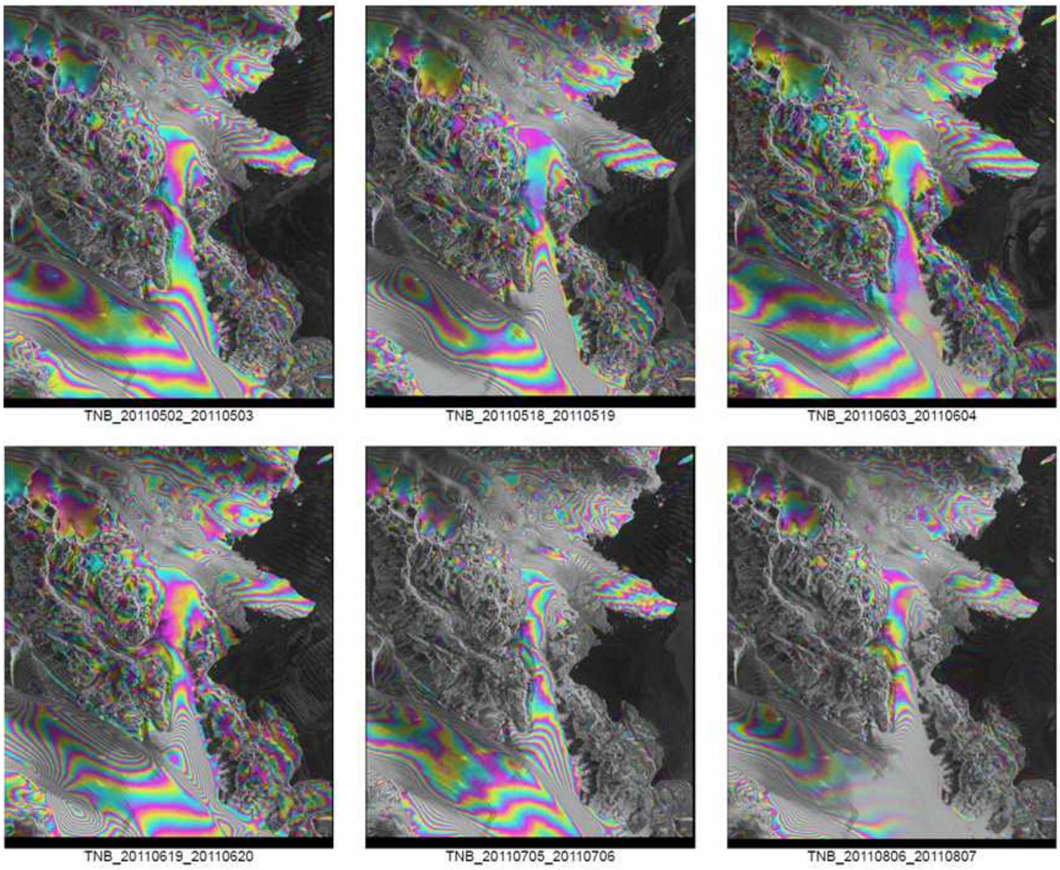

Fig. 1. Examples of one-day InSAR pairs showing strains from CGT and tide.

pairs. The rationale behind the generation of those images is that the magnitude of ocean surface tilt (~40 cm) and the steady flow of CGT (~67 cm/day), as found by Han and Lee (2015), are very similar so that they are mixed and hard to distinguish in one-day interferograms. However, the former is oscillatory while the latter is cumulative so that the effect of CGT (~469 cm/week) is dominant in weekly InSAR. Therefore, weekly InSAR can be used to identify the effect of CGT over fast ice. We also expect that the strain from the continuous and year-long steady motion of CGT can be eliminated by DDInSAR operation leaving strain from tidal ocean tilt alone.

3. Results and Discussions

Fig. 2 shows an example of weekly InSAR images obtained in 20110817 and 20110814. Very strong fringes appears over the fast ice field on the righthand side of the CGT. The magnitude and direction of those fringes are similar in all other weekly InSAR images. Equi-displacement lines of fringes are parallel to the boundaries between CGT and fast ice, which confirms that those fringes are caused by stress from the flow of CGT that are steady and continuous over the whole year (~67 cm/day maximum). The strain from the flow of CGT cumulative over time and reaches ~469 cm/week in this interferogram while that from tidal ocean surface tilt is oscillatory (~40 cm). Equi-displacement lines from tidal ocean tilt follows the coastline which are found near the cost where fast ice is broken and the CGT stress is not reachable. Therefore, weekly InSAR confirms that the amplitude of strain from CGT is similar to the flow of CGT and the equi-strain lines are parallel to the glacier and fast ice contacts.

Knowing that strain from glacial flow is steady over time, those fringes can be eliminated by DDInSAR operation under

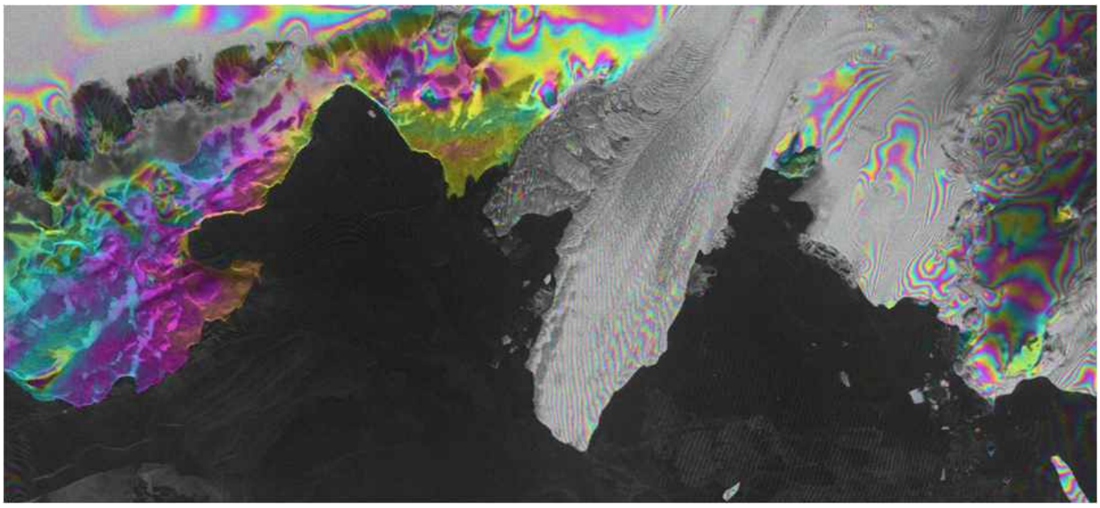

Fig. 2 An example of weekly InSAR images (20110807-20110814). Very narrow fringes over the fast ice on the righthand side of CGT show cumulative strain caused by the flow of CGT (~469 cm/week).

stable ice condition. Fig. 3 shows examples of DDInSAR images which positively states that fringes are from tidal ocean surface tilt which are parallel to the boundaries between coastline and glacier and their amplitudes are closely related to the tidal conditions predicted by tidal model.

Reconsidering one-day InSAR images in Fig. 1 also revealed that fast ice is not attached to CGT in the early ice formation stage while they began to couple with each other.

4. Conclusions

We confirmed that strain over fast ice near Jangbogo Antarctic Station is mainly caused by glacial stress from CGT and tidal stress. Weekly InSAR highlights consistent glacial strain while DDInSAR shows oscillatory tidal strain along the coastlines. Fringe rates and directions also coincide with the glacial flow rates and tide models. More quantitative investigation is expected to reveal the physical properties of fast ice and its seasonal variations.

Acknowledgement

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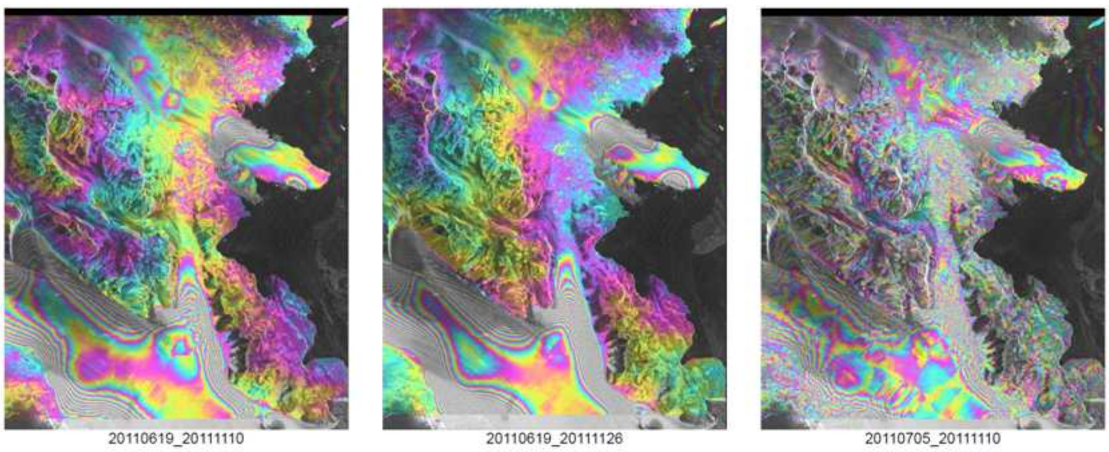

Fig. 3 Examples of DDInSAR image highlighting the strain caused by tidal ocean surface tilt over fast ice while the strain by CGT is cancelled out during DDInSAR operation.