SPATIAL-TEMPORAL INVESTIGATION OF ICE VELOCITY OVER PINE ISALND AND THWAITES GLACIERS, WEST ANTARCTICA

Simone Darji[1], Naveen Tripathi[2], Sandip Oza[2], Rajesh Shah[1], I. M. Bahuguna[2]

[1]M. G. Science Institute, Gujarat University, Navrangpura, Ahmedabad-380009, India
[2]Space Applications Centre, ISRO, Jodhpur Tekra, Ahmedabad-380015, India
Email: dsimone24@gmail.com

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ABSTRACT: Ice velocity is one of the important parameter in the glaciological studies. In the recent years the changes observed in glaciers in terms of its front's retreat, advances, elevation and the flow velocity are an important indicators of the climate changes. The Western part of Antarctica is constantly changing, the two important glaciers of Western Antarctica region are Pine Island glacier and Thwaites glacier. The paper presents the surface ice velocity of the Pine Island and Thwaites glacier using Moderate Resolution Image Spectroradiometer (MODIS) data between 2000 and 2017. The surface ice velocity is calculated using feature tracking method based on Normalised cross correlation method. The derived surface velocity of Pine Island glacier ranges between 2000 and 3000 meters/year, and that of Thwaites glacier ranges between 2500 and 3500 meters/year. The speed of glaciers keeps on accelerating since last 3 decades, which makes the glaciers important to study and monitor. There are many factors which are responsible for the high surface velocity of Pine Island and Thwaites glaciers.

1. INTRODUCTION

The Pine Island glacier is a major tributary of the Western Antarctica Ice Sheet, which contains enough ice to raise the eustatic sea level by over 3 meters (Bamber, et al., 2009) (Park, et al., 2013). The catchment area of WIAS ~175,000 sq. km, comprises two basins; one in southern side having more-inland and slower flowing basin and other in northern side, faster flowing basin feeding into the Amundsen Sea embayment (Vaughan & others, 2006). Thwaites glacier is second largest broadest ice stream in the Amundsen Sea Embayment in West Antarctica (Yu, et al., 2017). These two glaciers of West Antarctic ice sheet are assumed to be most unstable glacier system (Rignot, et al., 2002) There are few histrionic changes occurred on Pine Island glacier where the grounding line increased by 25% between 1974 and 2003 along the Amundsen Coast with major flucations with additional increase over 2008 (Joughin, et al., 2009) (Rignot, et al., 2002) (Joughin, et al., 2003b) (Rabus & Lang, 2003). The large numbers of ice calving activities observed on the floating section of Thwaites glacier, it has been losing mass and retreating rapidly in past few decades (MacGregor, et al., 2012) (Yu, et al., 2017).

These glaciers are most unstable as there grounding line retreats and they are considered as one of the potential sites for ice sheet collapse (Hughes, 1981) (Tinto & and Bell, 2011). The changes near the grounding line affects the glacier speed and force balance well inland, influence is determined by the properties at the base of ice sheet, the surface observations are routine, glaciers bed conditions are very difficult to observe, though seismic reflection techniques to measure subglacial conditions (Vaughan, et al., 2003) (Joughin, et al., 2009). The emergent indication that the changes occurred on the ice sheet caused by oceanographic changes, the Circumpolar Deep Water warms the continental shelf which increases melting beneath ice shelves (Jacobs, et al., 1996) (Rignot & and Jacobs, 2002) (Joughin, et al., 2009).

The satellite remote sensing data were used to examine glaciers velocity, that influence the climatic condition of Western Antarctica. The flucations in the speed of glaciers need to monitor as these glaciers hold enough ice to raise the global sea level by ~0.5 meters if it melts fully (Wilkens, et al., 2015). The surface ice velocity of Pine Island glacier and Thwaites glacier were measured using feature tracking method.

2. STUDY AREA AND DATA USED

The study area comprises two important glaciers of Western Antarctica region they are Pine Island glacier and Thwaites glacier. Pine Island glacier is one of the largest ice streams in Antarctica, flows together with Thwaites Ice Stream, into Amundsen Sea embayment. These two ice streams drains ~5% of the Antarctic Ice Sheet (Davies, 2014).

Pine Island Glacier drains much of the marine based West Antarctic Ice Sheet, and it has a configuration susceptible to rapid disintegration and recession. The ice sheet in this area is grounded up to 2000 m below sea level, which makes it intrinsically unstable and susceptible to rapid melting of its base and rapid migration of the grounding line (Davies, 2014). Thwaites glacier has also shown increasing instability and rates of seaward movement during recent years.

The estimate the ice velocity of Pine Island and Thwaites glacier using MODIS (Moderate Resolution Image Spectroradiometer) data between years 2001 and 2017. From 2001 to 2017, the change observed in the region of Western Antarctica becomes very important to monitored due to its instability and critical dynamics. Both the glaciers had found to have high velocity, which makes than even more important to study.

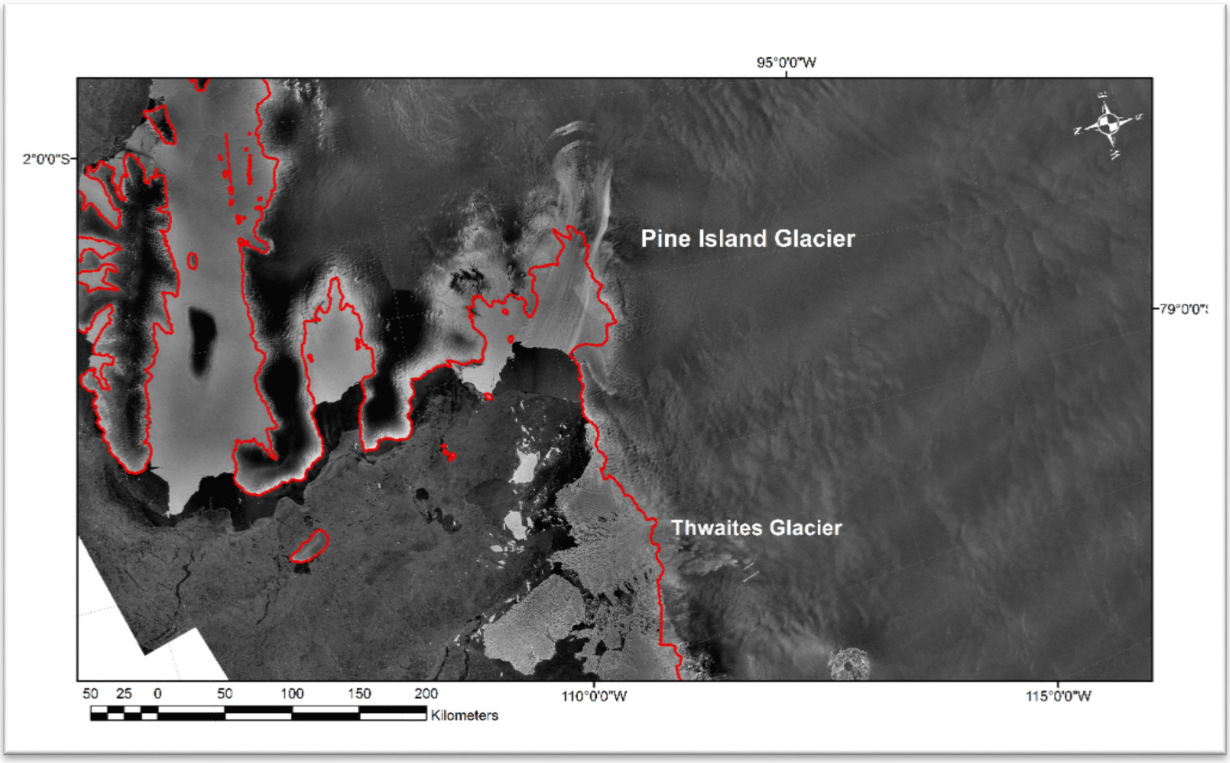

Figure 1: Pine Island glacier and Thwaites glacier with grounding line (red colour) using RADARSAT data.

3. METHODOLOGY

To estimate glacial ice velocity there are various methods which includes feature tracking method, offset tracking method and differential Interferometry SAR method. To measured glacial ice velocity in Western Antarctic region, feature tracking method is used in the study area. The feature tracking methods generally divided into two types which includes automatic feature tracking and manual feature tracking. The automatic feature tracking method based on software whereas the manual feature tracking depends upon manual identification of the features manually in the images. Before image matching there are few pre-processing steps includes co-registration, orthorectification, and both the images should be at the same scale.

The velocity produced using feature tracking method, whereby features such as crevasses through are tracked through time in a sequences of the image pair, in order to track the features minimum two images are required. The first image is the template image where features were identified and the second image is known as the search image. Further, the search image was scanned within a defined search window to find the best match of those features from the template image (Messerli, et al., 2014). The feature tracking methods depends upon image matching techniques which includes software's like CIAS (Correlation Imaging Analysis Software), ImGRAFT (Image Georectification and Feature Tracking Toolbox) ImCORR (Image Correlation). All this software's depends upon Normalised cross-correlation techniques and this technique was first established to derive glacier ice velocity done by Bindschadler and Scambos (Bindschadler & and Scambos, 1991). ImGRAFT is a feature tracking toolbox and is based on the Matlab programming suite, it is easy to use and freely available (Messerli, et al., 2014). In the present study area, the ImGRAFT toolbox had used, as it provides the best and appropriate results.

4. RESULTS AND DISCUSSION

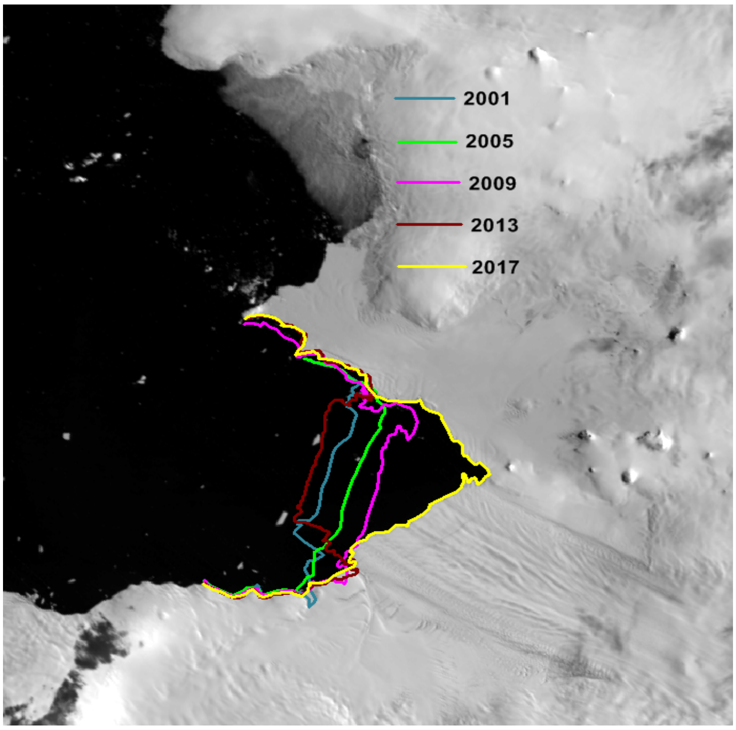

Figure 2: The advance and retreat of frontal portion of Pine Island glacier between 2001 and 2017.

The two major processes that removes mass from the glaciers and ice shelf are basal melting and iceberg calving, the large ice calving event tends to occur as a part of natural cycle where the front advances by the ice flow and it retreats when it reaches beyond its embayment wall. (Bassis, et al., 2007). The Pine Island glacier is prone to basal melting and iceberg calving, hence after certain the advancement in the glacier, it eventually leads to calving. This process commonly observed at Pine Island glacier. Hence maximum amount of mass released in Amundsen sea through Pine Island and Thwaites glacier.

The maximum advancement of Pine Island glacier was observed in year 2013, whereas minimum observed in year 2017 during our study period (Fig: 2). The advancement and retreat of the glacier was continuous process that observed in the Pine Island glacier, eventually leads to great mass loss which results into global sea level rise.

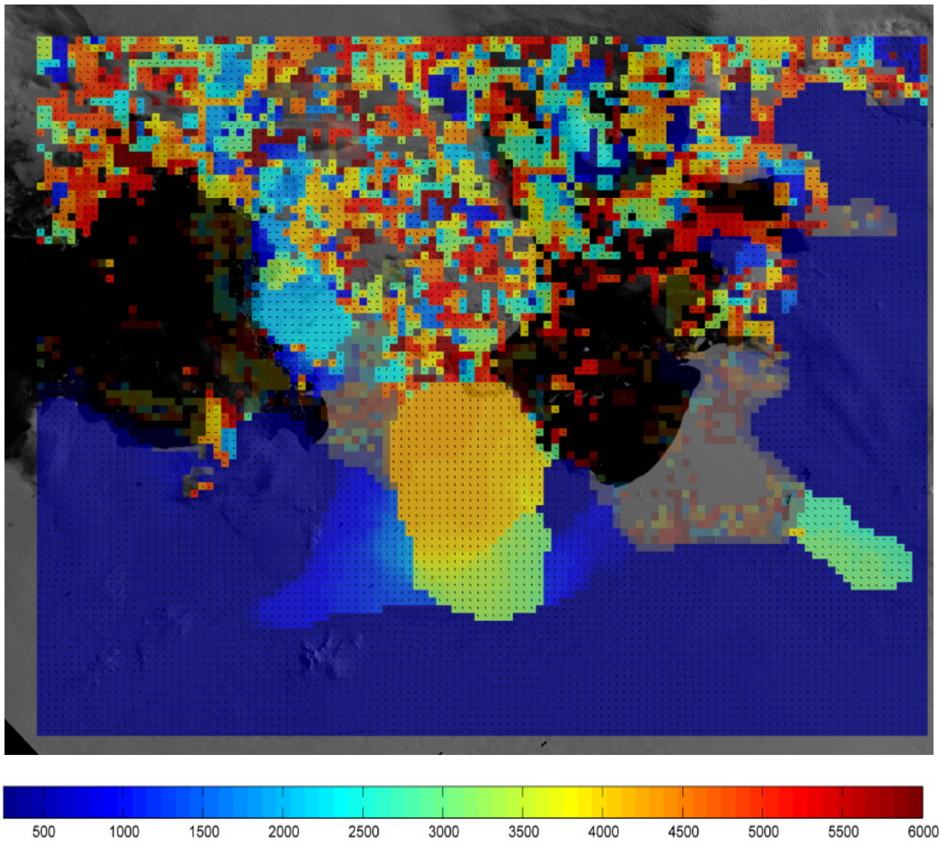

Fig: 3 Velocity of Pine Island and Thwaites glacier in the year 2001-02

The interaction of tides and ocean-waves has a significant impact on the ice shelf, *Holdsworth and Glynn [1978, 1981]* investigate that the short-period sea swell (10-100 s) contributes to the formation of icebergs by exciting eigenmode vibrations of floating tongue. (Holdsworth & Glynn, 1978). The sea-swell frequencies are resonant with the corresponding eigenfrequencies of floating tongue, (MacAyeal & al, 2006) (Cathles, et al., 2009) (Brunt & and MacAyeal, 2014) (Bromirski, et al., 2015).

The advancement of Pine Island glaciers was found in various years, the frontal portion of the Pine Island glacier is affected by major activities which includes calving and deformation of the glacier tongue. The tongue of pine island glacier is affected by the ocean swelling, currents and many other oceanic activities taking place in the ocean due to circum-polar currents. Huge amount of ice mass is released from the frontal portion of the glacier through calving and deformation.

Whereas on the other hand the Thwaites glacier has comparatively less velocity measured at it, this might be due to the large iceberg in the vicinity of the Thwaites glacier. The large icebergs were in the circumference of the Thwaites glacier since 2003.

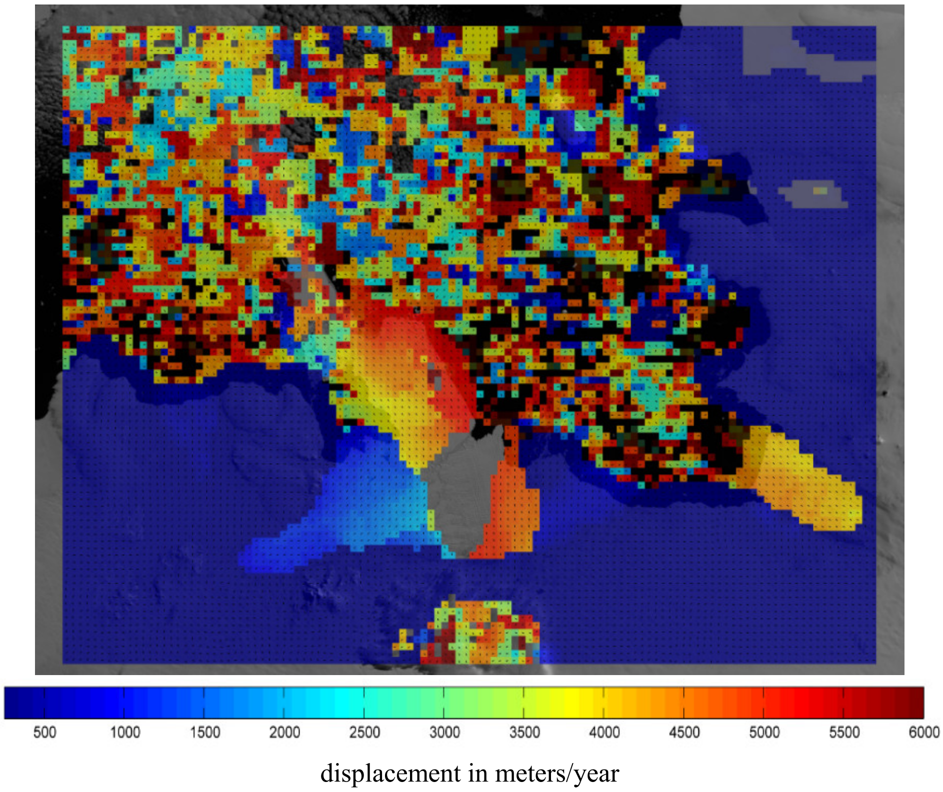

Fig: 4 Velocity of Pine Island and Thwaites glacier in the year 2010-01

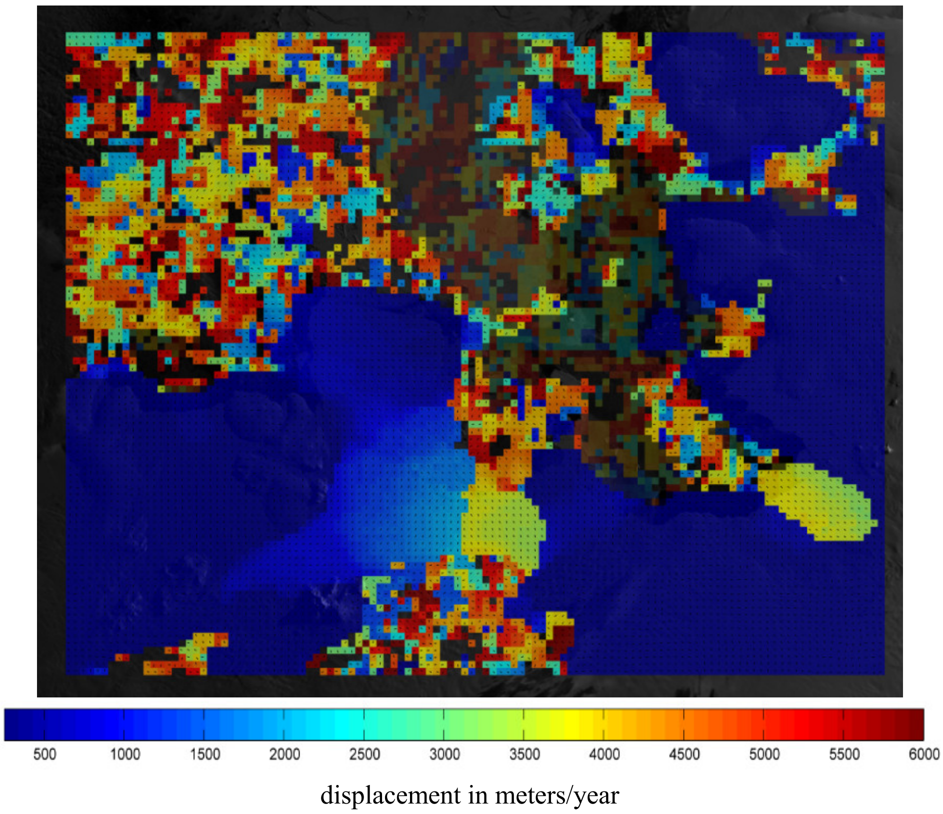

Figure 5: Velocity of Pine Island and Thwaites glacier in the year 2016-17

The maximum velocity observed in year 2008-09, 2010-11 and 2014-15 for Pine Island glacier was ~4500 meters, ~4200 meters and ~4500 meters respectively. whereas minimum velocity observed in years. The Figure 3, 4 and 5 shows the ice velocity of Pine Island and Thwaites glacier.

The observed velocity of Pine Island glaciers keeps on fluctuating between 2000 and 4500 meters/years. The Thwaites glaciers fluctuating between 2000 and 4500 meters/years. After 2008 the values

5. CONCLUSION:

Less variation in velocity observed at Thwaites glacier as compare to Pine Island glacier. The measured velocity at Pine Island glacier were in the range from 2000 meters/year to 4800 meters/year, which seems that it is highly instable glacier. The maximum velocity of Pine Island glacier was measured in year 2014-15, whereas the minimum velocity observed in the year 2000-01. On the other hand, the velocity of Thwaites glacier shows variation in the values. The maximum velocity observed in year 2014-15 and 2015-16, and the minimum velocity was observed in year 2005-06.

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