GEOSPATIAL STUDY ON ICEBERG CALVING EVENTS IN ANTARCTICA USING MULTISPECTRAL REMOTE SENSING DATA

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ABSTRACT

Iceberg calving is the sudden release and breaking away of a mass of ice from ice shelves, glaciers or ice fronts. It starts with the formation of crevasses and rifts. In Antarctica, various ice shelves are witnessing major and minor iceberg calving at the coast. Calving is the major cause of ice mass loss in Antarctic ice shelves. These calving events give us an idea about what is going on in ice shelves and what could be the factors triggering the increasing rate of rifts. Remote Sensing technique has been playing a significant role in tracking these calving events. In this study, three calving events have been studied. Two of them have already been calved and one event is about to calve in future. The first event is reported in the Leopoid and Astrid Coast and calved an iceberg of area 6.09 km^2. The second event took place along Sabrina Coast which calved a total area of 33.06 km^2. The third event is along Luitpoid Coast where various rifts are going to calve an iceberg. This study tracks calving events through optical remote sensing along the coast of Antarctica.

1. INTRODUCTION

Remote Sensing (RS) technique has been playing a significant role in monitoring phenomena on surfaces where access of human beings is difficult. This has made monitoring of ocean and polar areas more easy. Antarctica is the continent that is around the south pole of the Earth and is always covered with ice. The mean annual temperature of Antarctica is -57°C while the coast is warmer than interior. RS can help in monitoring the phenomena taking place in Antarctica as the climate of this continent is hard to survive for humans and multi-temporal information is available through RS. The Landsat program is the longest running enterprise for acquisition of satellite imagery on Earth. On July 23, 1972, first Landsat satellite was launched. Most recently, Landsat 8 was launched on February 11, 2013. Landsat data is used in agriculture, cartography, forestry, geology, regional planning, surveillance and education. Iceberg calving is the breaking of ice chunks from the edges of glaciers or ice shelf. It is mainly caused by glacier expanding. SAR data has been used to analyze iceberg calving in the past (Jawak and Luis, 2014; Jawak and Luis, 2015a; Jawak and Luis, 2015b). Waterline, tidal and seismic events, buoyant forces and melt water wedging also affects calving events. It is the sudden release and breaking away of a mass of ice from glacier, ice shelves or ice fronts. The ice that breaks away can be classified as an iceberg. Calving glaciers can undergo very rapid retreat following an initial climate signal (Post et al., 1975; Meier, 1997), and thereby have the potential to contribute disproportionately to global sea level rise (Meier and Post, 1987; Rignot et al., 2003). An understanding of calving processes is crucial for the accurate prediction of cryospheric response to future climate forcing, and consequent sea level change. The effect of calving events on the ocean system is also important. This helps in the study of ice shelf mass budgets, drift patterns and ocean currents as well as life history of bergs. (Elliott et al., 2014) Calving events are naturally occurring phenomena but it should also occur at a natural rate. High rate of calving events can be a threat to ice shelves. Various calving events have been taking place in Antarctica since ages. Some calved icebergs were so huge that one single iceberg is able to raise sea level up to few millimeter. The most recent reported calving from Antarctica was Larsen C and it took place in July 2017. It weighs about 1.1 trillion tons and measures 2200 square miles. The iceberg is name A68 and it has reduced the area of Larsen C ice shelf by about 12%. In 1988, a large iceberg calved from Filchner Ronne Ice shelf which was approx. 150×50 km^2. Again, in 2000 a larger iceberg was calved (area= 167×32 km^2) from this ice shelf. In year 1995, an ice shelf of area 3250 km^2 was calved from Larsen Ice Shelf.

Along with these large calving events there are hundreds of minor calving events are also there that are taking place over the coast of Antarctic. Study of calving can help in understanding the Polar Regions and their unseen processes in a better way. Optical remote sensing (Jawak and Luis, 2017a; Jawak and Luis, 2017b; Sandeep et al., 2017c) enables us to study these phenomena in detail. Even though calving is a natural phenomenon, but it is very important to understand that the rate at which they are calving in the present time is a very serious issue relating to the health of the Polar Regions.

2. STUDY AREA & DATA

The present study focuses on three calving events on Antarctica. Antarctica is Earth's southernmost continent. Southern Pacific, Atlantic, and Indian Oceans surround it. It has an area of more than 14 million km^2. The Antarctic ice sheet covers 98% of Antarctica. It is the world's largest ice sheet and the largest reservoir of fresh water. Averaging at least 1.6 km thick, the ice is so massive that it has depressed the continental bedrock in some areas more than 2.5 km below sea level. Physically, Antarctica is divided i by Transantarctic Mountains, Western Antarctica and Eastern Antarctica correspond roughly to the eastern and western hemispheres relative to the Greenwich Meridian. The climate of Antarctic is the coldest in Earth. The mean annual temperature of the interior is -57˚C (-70˚F). The coast is warmer. Monthly means range from −26 °C (−14.8 °F) in August to −3 °C (26.6 °F) in January. The total precipitation on Antarctica, averaged over the entire continent, is about 166 millimeters (6.5 inches) per year. Almost all Antarctic precipitation falls as snow. Figure 1 shows the map of Antarctica and name of ice shelves. Iceberg calving takes place in ice shelves. In the present study, Landsat data is used as it provides multi-temporal data from 1970's to date. Data from Landsat 8, Landsat 7, Landsat 4 and Landsat 5 are used in this study. The true color composition is used to study crevasses, rifts and icebergs. Information about the location of calving events is taken from Google Earth.

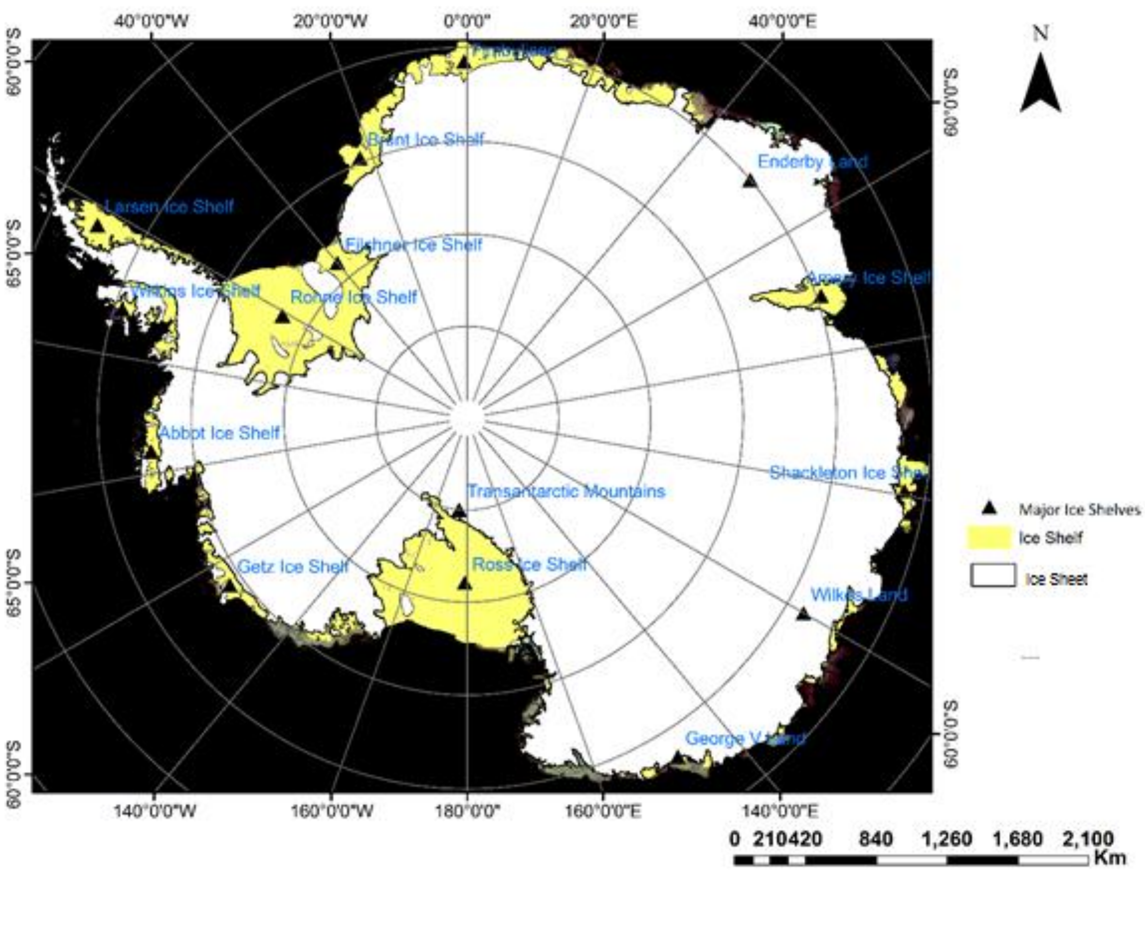

Figure 1. Major Ice Shelves of Antarctica

3. METHODOLOGY

The methodology utilized for carrying out this study consisted of three major steps: (1) Marking points & data download, (2) Preprocessing, (3) Digitization & Analysis. Figure 2 depicts the methodology flow chart that includes all the steps followed.

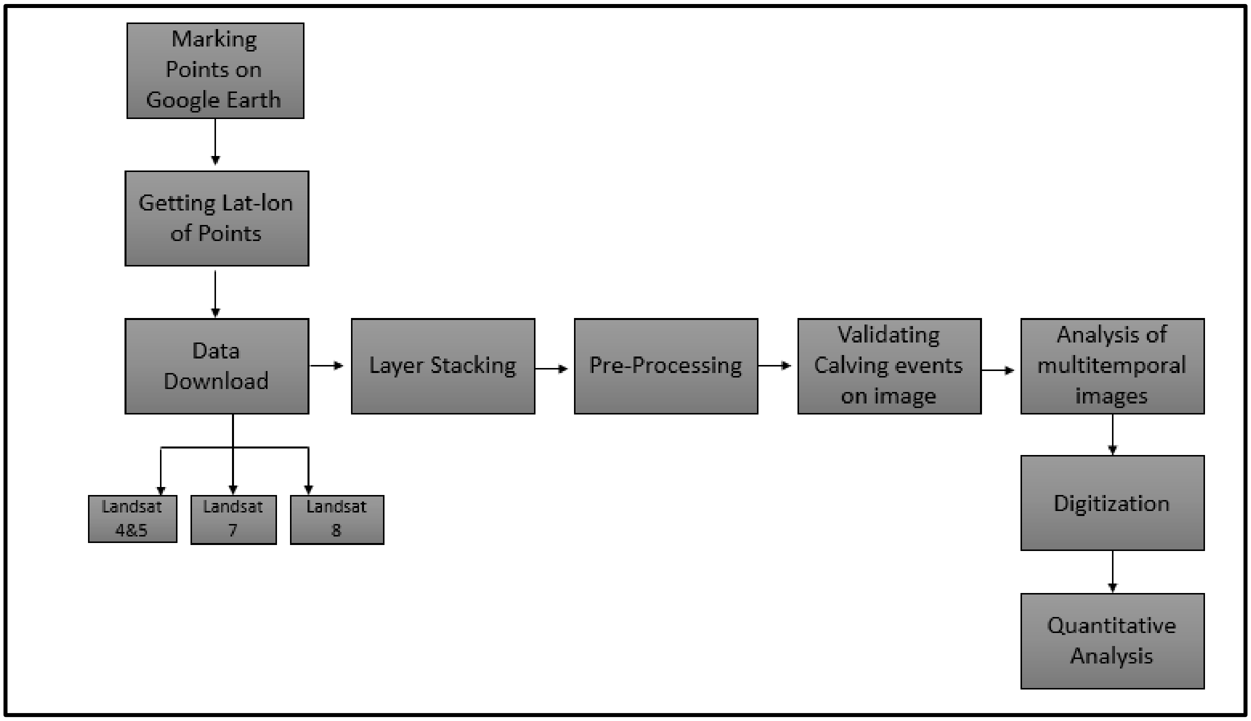

Figure 2. Methodology Flow Chart

3.1 Marking points & Data download

Google Earth was used for marking calving events. The Historical imagery feature of the Google Earth proved very helpful in performing the task. It consists of global mosaics LANDSAT and Sentinel-2. Depending upon the temporal images available for that place, the feature would show the changes occurring in that region at that time upon sliding the Timeline bar. This is just like time lapse. This has been very helpful in differentiating fast ice and ice shelf. The year where significant changes were there were noted. After detecting the events in a particular region, they were place marked. The Google Earth images were of low resolution. It was difficult to differentiate between Fast Ice and Icebergs. Using the Latitude-Longitude information of the placemarks; LANDSAT data for the corresponding events was searched using USGS Earth Explorer. This helped us to differentiate between the fast ice and ice shelf, iceberg further cutting down the non-required placemarks from the list. The Level-1 Geo-TIFF data of the confirmed images was then downloaded.

3.2 Pre-processing

The stacking of the images followed the extraction of information from data. The features present in each event were Seawater and Ice which are clearly visible in TCC. The dataset being multi-temporal it also included the Landsat 7 imageries, which consisted of the images with gaps due to SLC failure. On May 31 2003, the Scan Line Corrector (SLC) failed. This was a permanent failure. After processing the Level-1 data, there was generation of gaps in the image, which lead to the loss of 22% pixels from the original image. The data is still geometrically and radiometrically accurate. The downloaded data is pre-processed so that information from them can be extracted from the satellite images. As there was no scientific calculation of pixel required, the objective was only to digitize the features present in the image, Focal Analysis tool in ERDAS was used to fill the gaps. This is one of the method prescribed on USGS website regarding filling gaps. This method computes the values of neighboring pixels and fills in the gaps based on those calculations for a single Landsat 7 scene. The method was repeated until the time the gap present over area of interest was filled.

3.3 Digitization & Analysis

The latter part consisted of manual digitization of the features that included calving ice front, icebergs, crevasses of the multi-temporal data. Digitization is the process of converting information from images into computer readable format. The result is the digital representation of the image. This was used for the final qualitative and quantitative analysis of the data. The length and width of the crevasses were measured. These measurements were used to determine a trend line for these events.

4. RESULT AND DISCUSSION

Analysis of calving/calved events was performed on multi-temporal Landsat images. Satellite images helped in tracking the events and their progress with their direction and the possible shape of iceberg that will be calved. Analysis of three different calving events at three different coasts of Antarctica: The first event took place in Leopoid and Astrid Coast. In this place, an iceberg of 6.09 km^2 got calved in year 2016. The event is monitored from 2012. Even after removing the strips the satellite imagery of year 2012 looks striped and hazy as the algorithm calculates mean of neighboring pixels. A rift formed of area 1.324 km in 2012, then increased up to 1.68 km in 2014. From 2012 to 2014 the average rate of increase in rift area was 0.18 km^2/year. The iceberg finally got calved in year late 2016. Fig. 3 shows the gradual increse in the width and length of rift which finally lead to calving of an iceberg of 6.09 km^2.

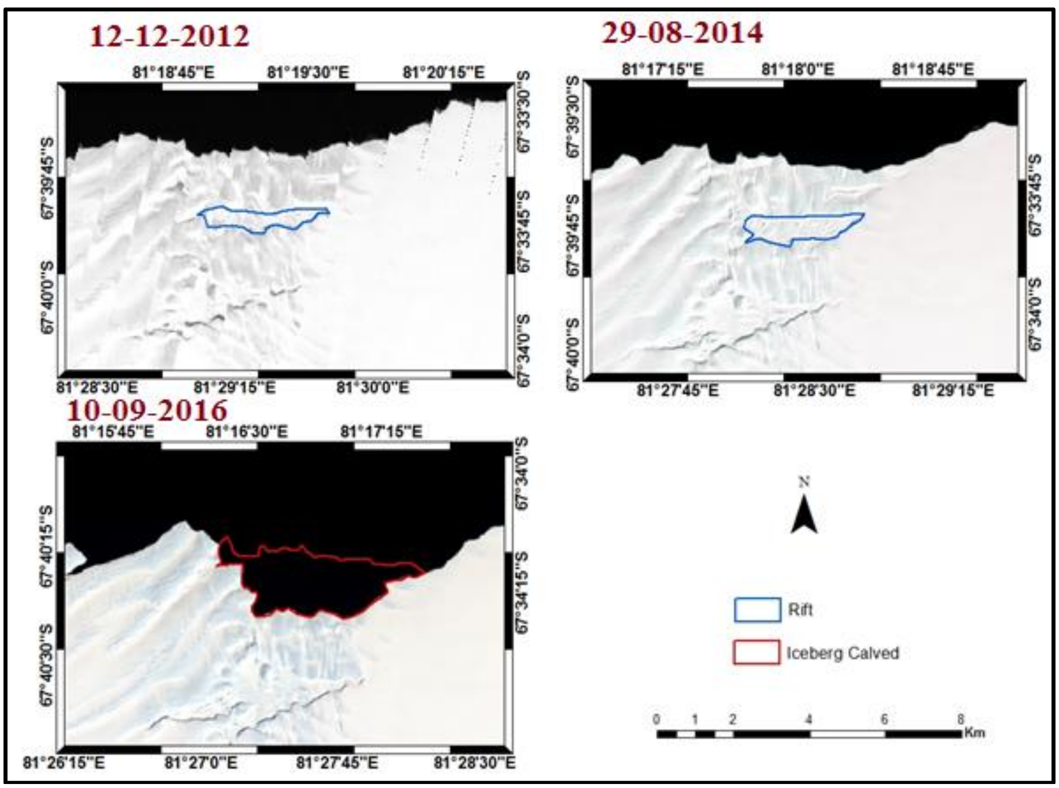

Figure 3. Process of calving event 1

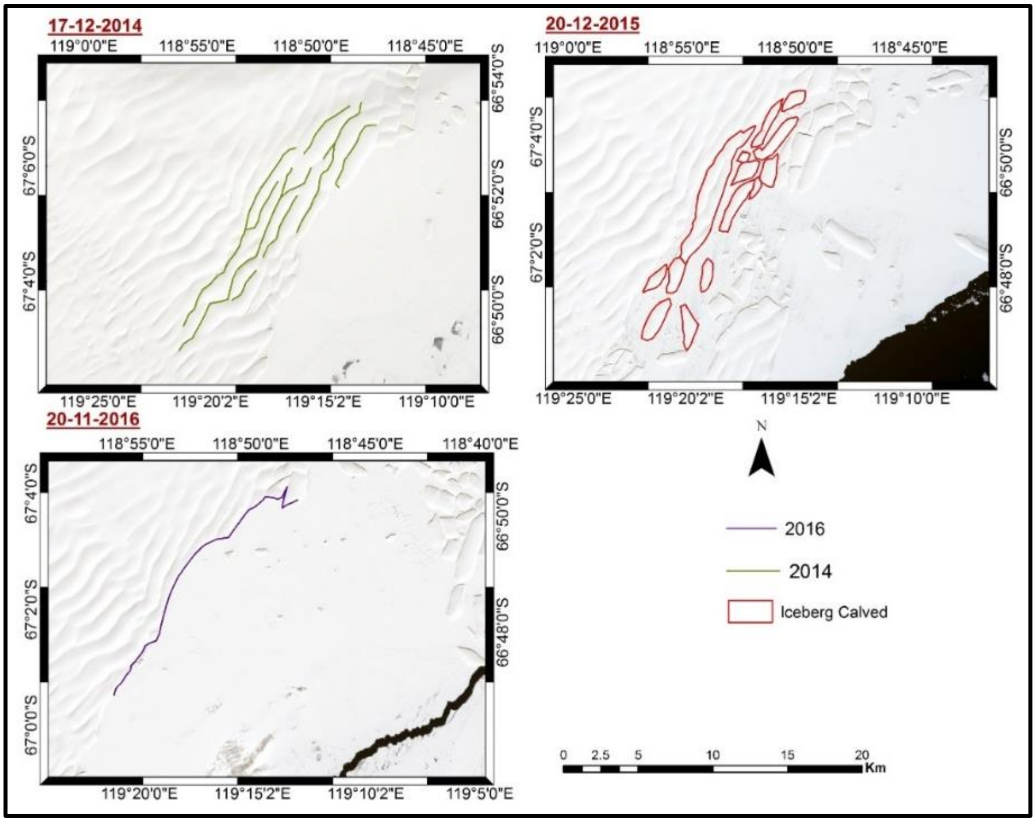

Figure 4. Process of Calved event 2

Second event took place in Sabrina Coast. Here, various small icebergs of area 33.06 km^2 got calved in year 2015.The event is monitored from 2014 when only crevasses were there. In year 2015, the icebergs calved from the ice shelf and broke into smaller pieces. In 2016, the icebergs do not even appear anywhere. The rate of calving is very high in this coast. Large icebergs are not there but various small icebergs have been calved. The surface structures present in this place shows that more area will be calved. Fig. 4 shows the process of calved event 2. Various crevasses appear in the image of 2014 few of them got calved in 2015. The third calving event took place in in Luitpoid Coast. In this place, three rifts are increasing with passing years and will lead to calving of two icebergs in future. The Rift is monitored from year 2007 along with one more rift.

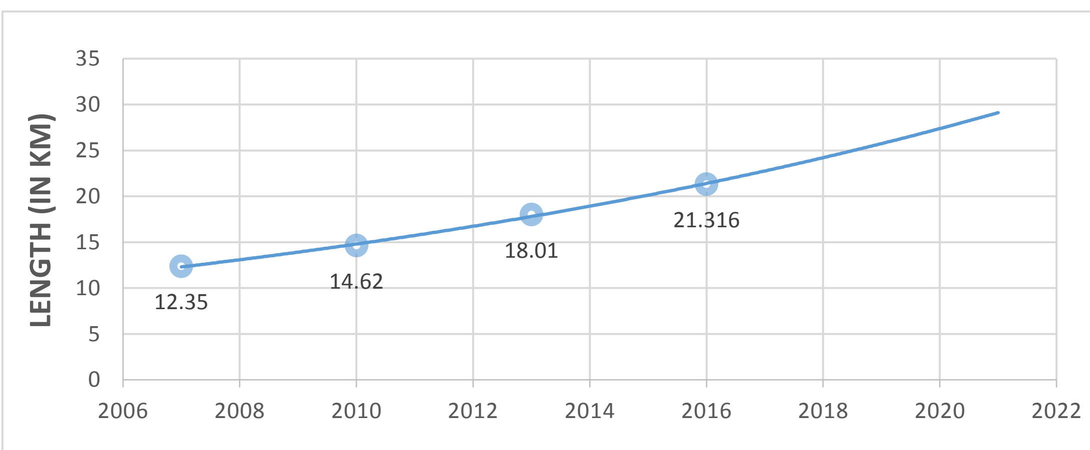

Figure 5. Trend of increase in length of rift 1

In year 2012, another rift came into existence along with these two rifts. In year 2016, two rifts are connected with each other. These 3 rifts are going to calve an iceberg of approx. 300 km^2. Another rift appearing in the satellite image parallel to rift 1, this rift can calve an iceberg of about 200 km^2 if it increases in near future due to any triggering factor. Fig. 8 shows the process of third calving event and increase in rifts. The length of rift 1 was 12.35 km in 2007 whereas width was 1.72 km. In 2010, the rate of increase in length of rift 1 was 0.75 km/year, which increased up to 1.13 km/year. In year 2016, the length becomes 21.316 with a rate of 1.1 km/year. The width also increased to 4.73 km from 1.71 km in 2016. Fig 5 shows the trend line of rift 1.

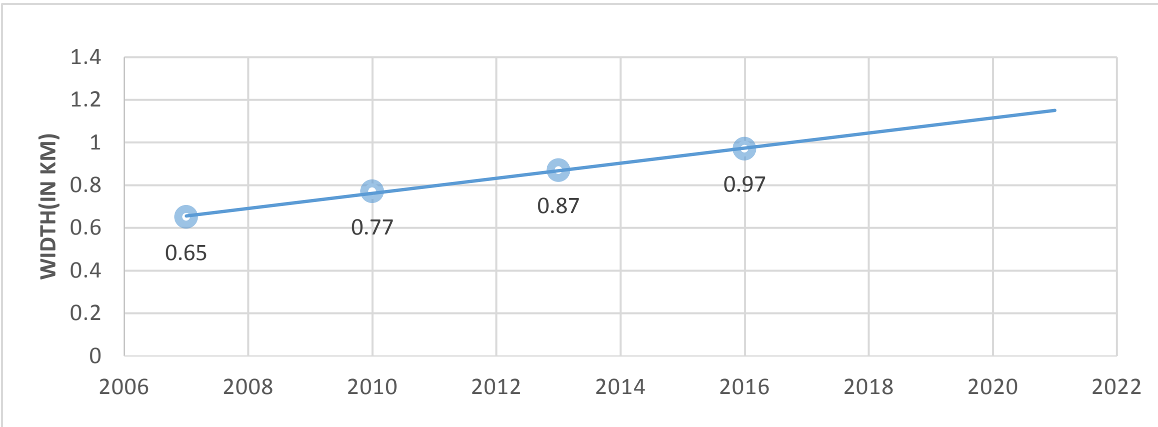

Figure 6. Trend of increase in width of rift 2

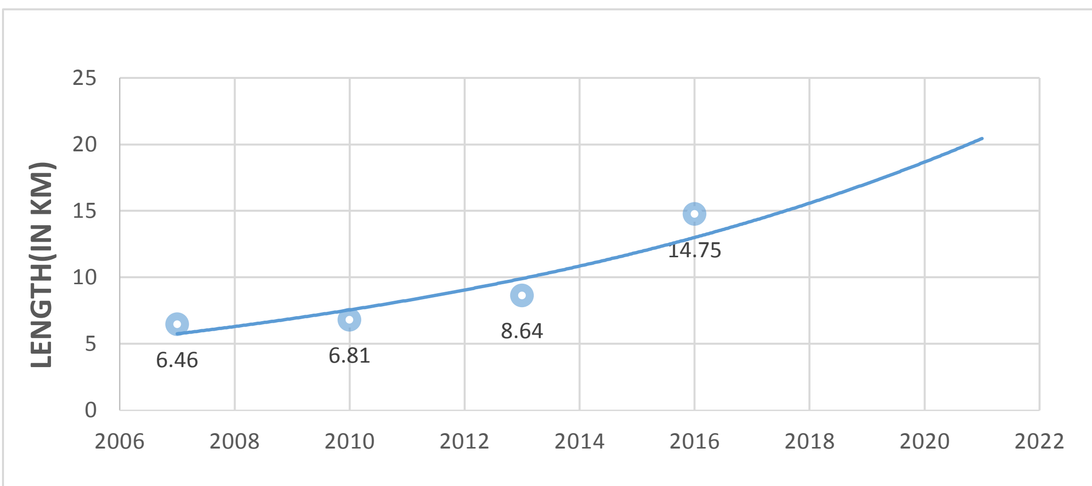

Figure 7. Trend of increase in length of rift 2

The rift 2 is monitored from 2007, when the length was 6.46 km, and maximum width was 0.65 km. Until 2010, the rate of increase in length was 0.12 km/year, which increased to 0.61 km/year in 2013. Until 2016, the rate increased up to 2.04km/year. From 0.65 km width in 2007, the width of rift 1 increased up to 0.97 km in 2016. Fig. 7 shows the trend line of increase in length of rift 2. Fig 6 shows the trend of increase in width of rift 2. The third rift appeared on the imagery of 2013 and was of length 1.99, which increased up to 3.21 in 2016. The overall rate of increase in length of rift 1 was 0.99 km/year. From 2007 to 2010, the rate was 0.75 km/year, which increased to 1.13km/year till 2013. The overall increase rate of width of this rift is 0.33 km/year. The initial rate of increase in length of rift 2 from 2007 to 2010 was just 0.11km/year, which increased to 0.611 km/year until 2013 and 2.04 km/year until 2016. The increased rate of its length has become every high while the increased rate of its width is 0.035 km/year. These rifts are going to calve a large area of around 300 km^2.

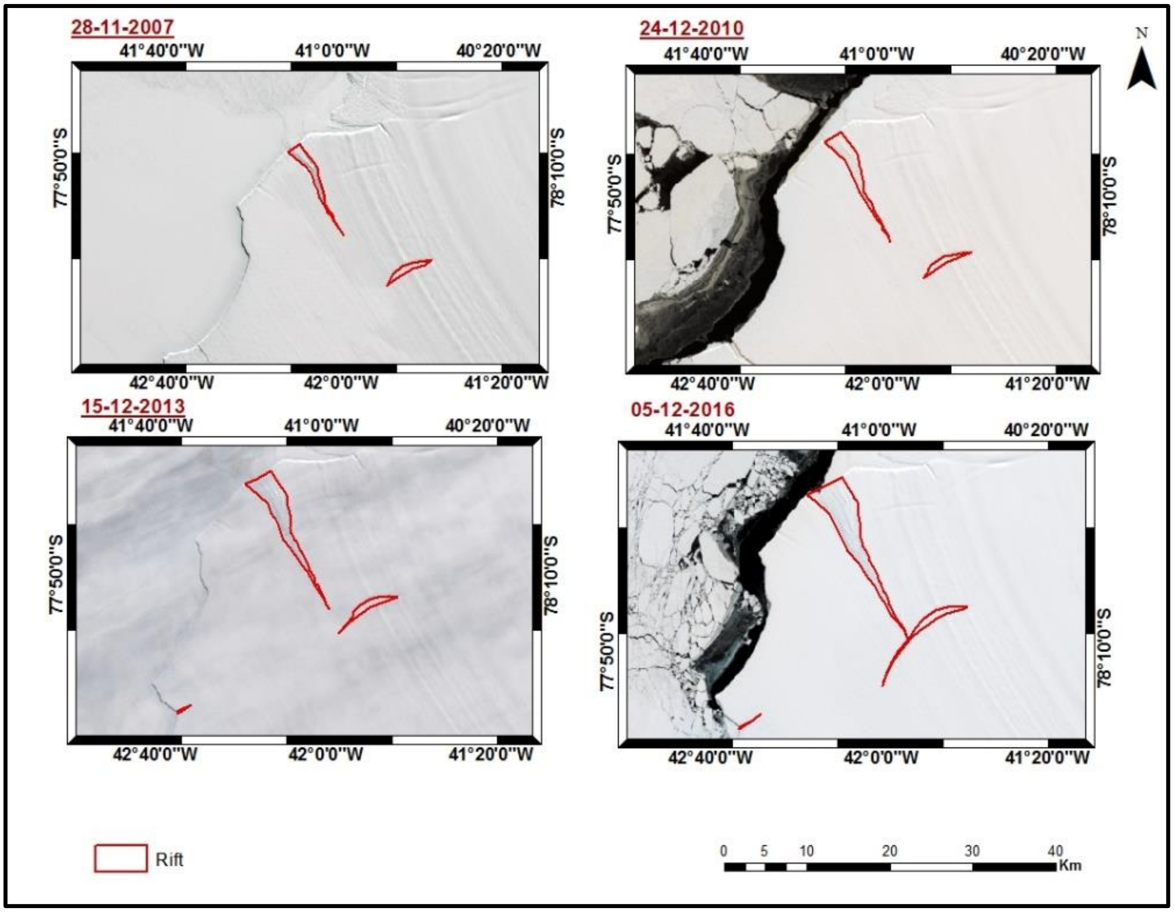

Figure 8. Process of calving event 3

5. CONCLUSION

The calving Events are taking place all over the Antarctica. Most of the events are minor and not much attention is given towards them. However, these events also have impact on environment and they tell us about the local phenomenon. In this study, 3 events have been studied, that has not been reported. Two of them have already been calved and one will be calved in future. The first event is on Leopoid & Astrid coast and an iceberg of 6.09 km^2 was calved in year 2016. It lies within Shackleton Ice Shelf, the area of which is 33820 km2. The second event is on Sabrina Coast and an iceberg of 33.06 km^2 was calved in 2015. This lies within Amery Ice Shelf, the area of which is 62,620 km^2. The third event is to be calved potential event, in which a total of 331.54 km^2 area will be calved in future. This event is on Luitpoit coast of Antarctica. This event lies on Filchner Ronne Ice shelf the area of which is 4, 22,420 km^2. This ice shelf has already witnessed various major iceberg calving events.

In this study, calving of minor icebergs has been observed that are not reported. This study of monitoring calving in Antarctica shows that calving process initiates with crevasses, which become rifts and then the iceberg gets calved. Most of the attention is given to the major icebergs but it is very important to give attention to minor ones also. These will give us idea about the local phenomenon that is triggering the calving. Even though calving is a natural phenomenon, but it is very important to understand that the rate at which they are calving in the present time is a very serious issue regarding to the health of the Polar Regions. The major problem was to differentiate between fast ice and ice shelf. Presence of ice over the decades and presence of physical structures are the signs that differentiate between ice shelf and fast ice. Study of calving can help us understanding the Polar Regions and their unseen processes in a better way.

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