Volumetric change estimation by generating Point Cloud data of Polar Ice Front.

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Abstract- The Polar cryosphere is more sensitive to the change in the regional climate. The loss of ice from Antarctica is considered one of the most important indicators of climate change. The loss of ice at the margin of the ice sheet constitutes an important part of ice loss, besides ablation during the summer. Hence the precise measurement of the recession becomes most vital part of the study results and inputs for the models. The present study is used first of its kind methodology to presents result on the estimation of volumetric loss at the ice sheet margin by means of point cloud data generation technique using semi-automatic Total Station (TS) in reflector-less (RL) mode. This technique is used to estimate the ice loss more precisely than the older methods, in which area of vacation is calculated by ice loss from the ice wall. For demonstration of this method an area has been selected near Maitri station at eastern part of the Schirmacher Oasis. The length of the ice wall is about 500m and height is about 23m. After reflection of lesser beam point cloud data have been generated using semi-automatic total station before and after collapse of large part of the ice wall. The volumetric change in two virtual surfaces derived from point cloud of pre & post-event data used to estimate the ice loss due to collapse and melting of the ice wall. The estimated ice loss of the observed ice wall was measured 64.87 metric ton water equivalent. This method may use to estimate the volumetric change of the ice surface with higher accuracy.

Keywords –Point cloud, Ice wall, Volumetric change, TIN, Antarctica.

I. INTRODUCTION

The Antarctic Polar ice sheet is the largest and most significant part of Earth's cryosphere. The frontal zone of polar ice sheet near the Schirmacher Oasis is freely standing like an ice wall. The position of the ice wall retreats every year due to recession as a consequence of calving and melting. (Kumar et al., 2018, unpublished GSI Report). The monitoring of the recession is continued since the inception of Indian Antarctic Expedition as integrated glaciological studies in the region by Geological Survey of India. The monitoring of the recessional pattern is assessed by calculating change in vacated area due to glacier wall melting and calving by fixing the observation points over ground in discreet manner. There are extrapolations involved between the observation points to calculate the vacated area on the ground. The proposed methodology in this study fixed the position of the wall surface by creating virtual mesh with three-degree angular interval (may go up to one-degree interval) in three dimensional space. Hence all the curves of the ice wall larger than the observation point interval have been detected and recorded todetectthechangeintemporaldomainduetomeltingandcalvingoftheglaciericewall.Alargepartoftheicewall collapsed from upper-east side of ice wall and spread at the base of the ice wall during the observations period 2017-18. The recession/ice loss from ice wall using older method could not be estimated because of wall base was filled with collapsed ice chunks and retreat could be calculated using the proposed methodology using semi- automatic Total Station. This technique is more accurate procedure of computing Polar ice front ice loss as very large number of data points have been utilized using a precise Semiautomatic Total Station. Besides, the observations have been taken through automatic technique, thus reducing the possibility of humanerrors.

II. STUDY AREA ANDMETHODOLOGY

The study area is bound by the Longitude 11° 44' 4" N to 11° 44' 18"N and Latitude 70°46'19" S to 70°46'21"S (Fig. 1). The frontal part of the ice sheet is present in the form of ice wall at the north-eastern part of the Schirmacher Oasis. The average thickness of the north-east facing ice wall is about 23 m and width is about 500m. The meltwaterfrom the ice wall feeds to the Priyadarshini Lake which is main source of water for Indian Research Base, Maitri. During the reconnaissance of the ice wall in January 2018, one large fracture was observed which was slowly growing. During the period of observation, the fracture continued to grow and finally one large ice chunk of the wall fell from the top portion of the ice wall (Fig. 2).

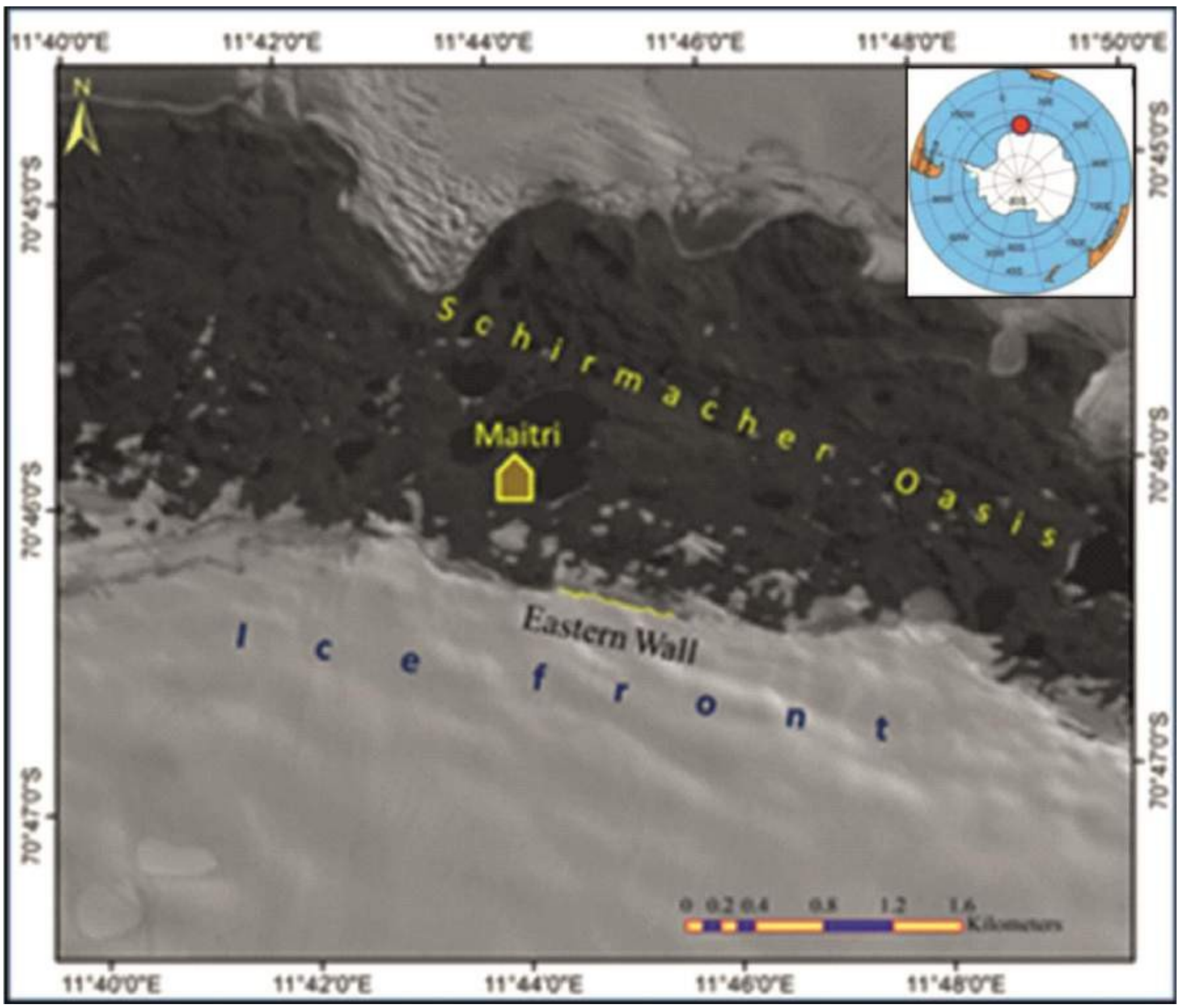

Figure 1. Location of the ice wall (Eastern ice wall) near Indian Antarctic Research Base Maitri, East Antarctica.

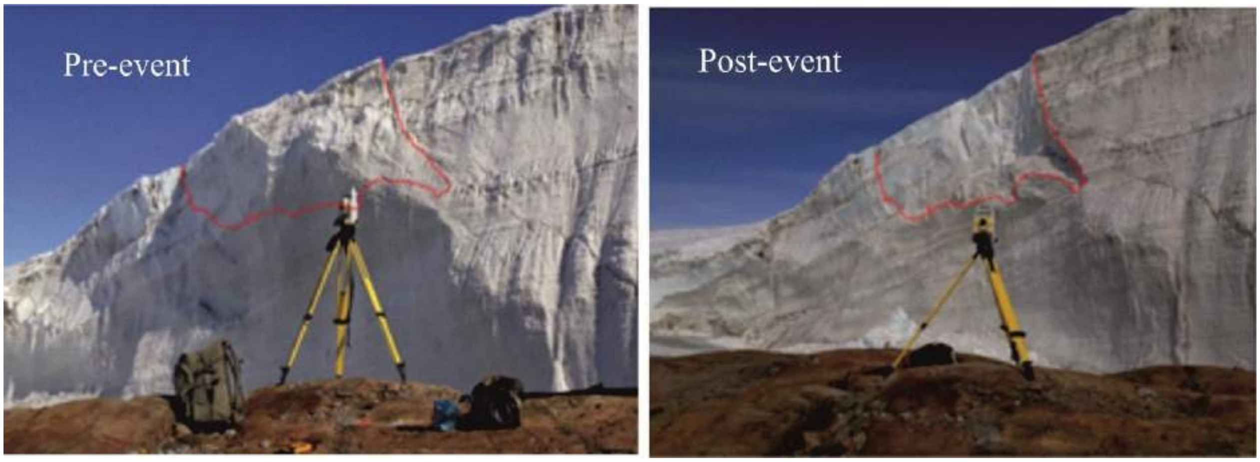

Figure 2. Field photograph of the ice wall before and after the calving (Pre and post-event).

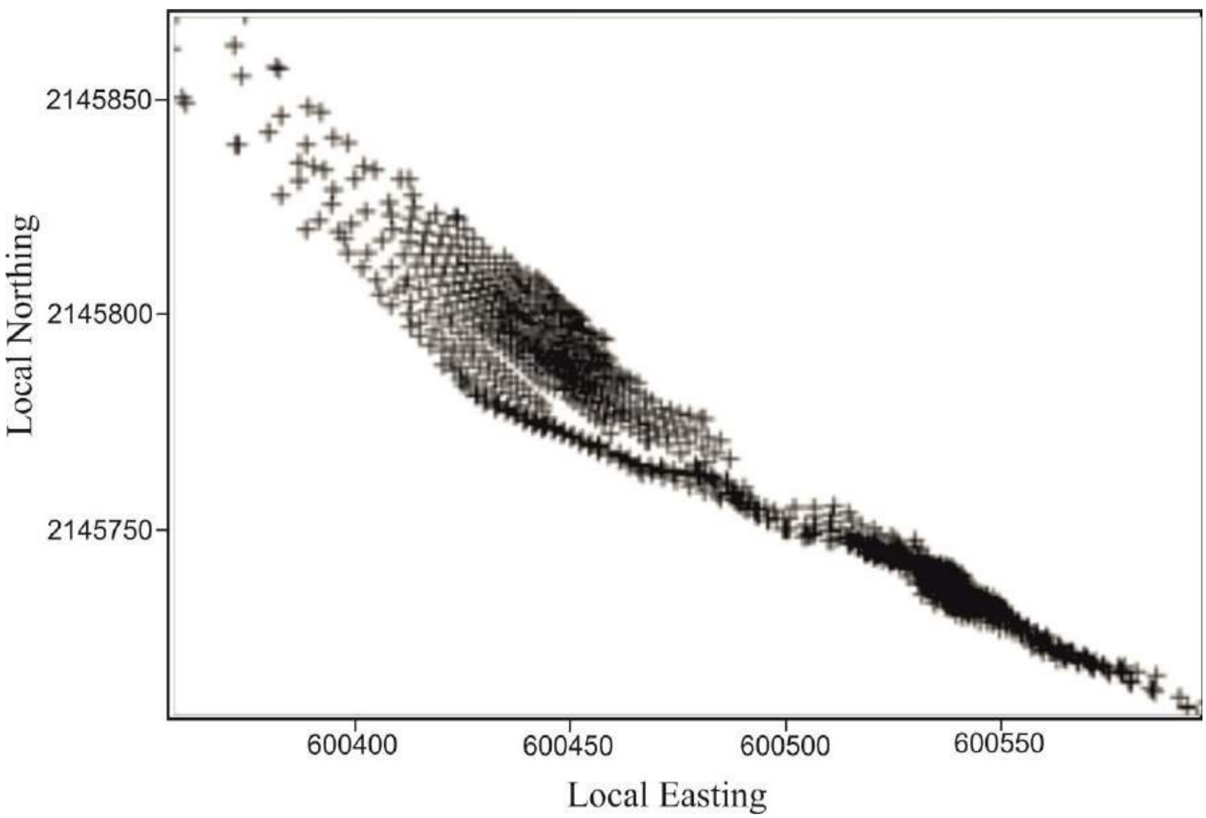

Figure 3.   Point clouds of 1326 observation points of the ice wall.

The selected part of the ice wall was surveyed and point cloud data generated with the help of Semi-automatic Geomax Total Station (Zoom80) with positional accuracy 5 cm at 100 m in reflector-less (RL) mode of the TS from the survey stations positioned using DGPS in static mode. The upper and lower boundary of the ice wall was also mapped. The surveying was undertaken twice, one pre-event while another post-event. At the middle part of both upperandlowerboundary,pointcloudshavebeengeneratedatthetwoDegreeangularintervalforpreciseestimation oftheiceloss(Fig.3).Theupperandlowerboundarydemarcationhelpedindelineatingrockmasslayingatthebase oftheicewallwhichwasdiscardedwhilecalculatingthemasschangeoftheicewall.

The two sets of point clouds have been used to generate two raster surfaces (pre-event and post-event) of wall with the help of ArcGIS 10.3 (Fig. 4) which were used to generate the Triangular Irregular Networks (TIN) surfaces. Surfer 8.0 software has been used to visualize the data in 3-D mode (Fig. 5).

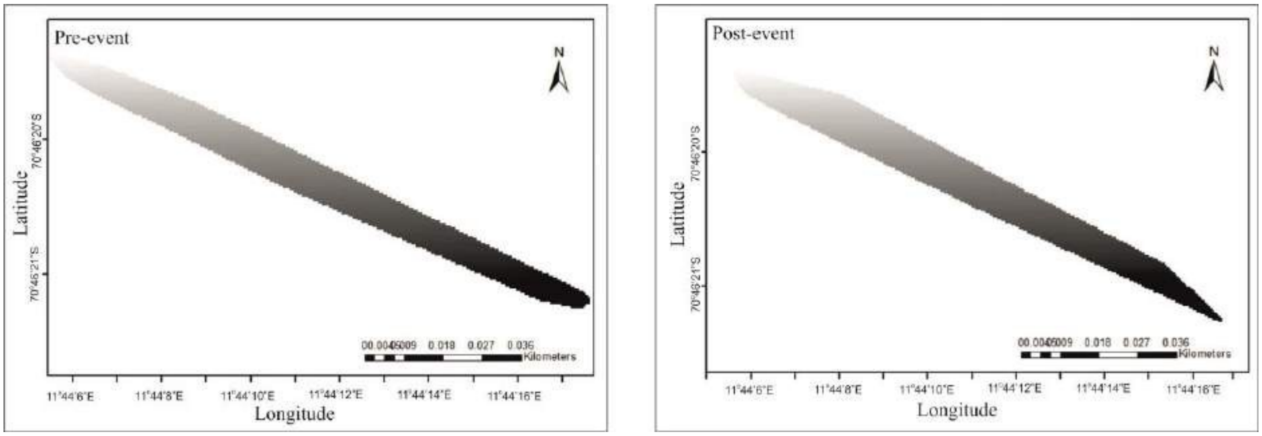

Figure 4. Pre and Post-event raster image generated by point clouds using ArcGIS.

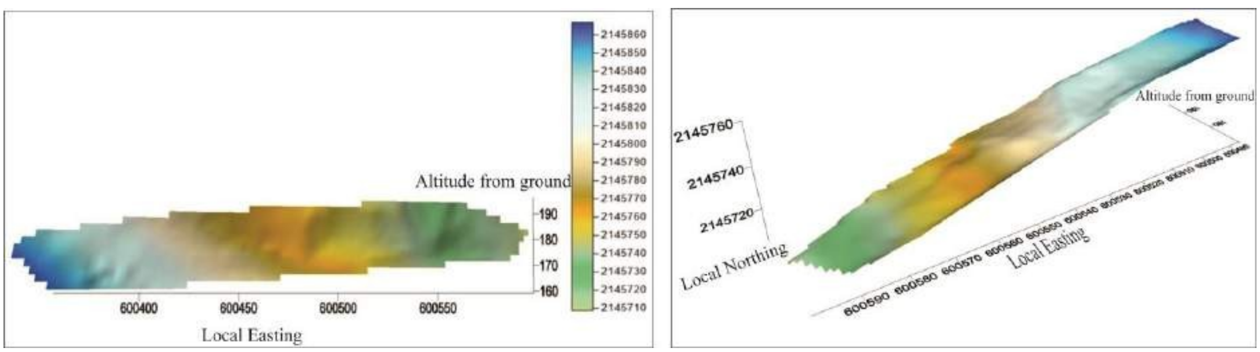

Figure 5. 3-Dimensional visualization of the ice wall generated surface by using point clouds with the help of Surfer 8.0.

With the help of Surface Difference tool of the ArcGIS, one vector file has been generated which has above, below and same area marked in terms of volume difference. The pre-event raster image (data collected on 11 January) was virtuallylaiddownbelowthepost-eventrasterimagetocalculatethevolumeofthesurfacechange.Hence,theabove volume shows the advancement of the surface during the observation period whereas below volume indicates recession of the surface. Each area is attributed with the knowledge as to its "above", "below", or "same" status respectively as well as the cubic area between the surfaces on its location. Areas where the surfaces are coincident, taggedas"same",haveanovolumechangeandmarkedas0.0intheattributetable(Fig.6).

Sincethesurfaceisaverticalwall,EastingwasplottedonX-axis,HeightwasonY-axisandNorthingwasplottedon Z-axis using Cartesian projection (Northing, Easting and height in meters). In order to compute, net mass loss of the polar ice front during the observation period, the volume above the surface has been subtracted from the below volume.

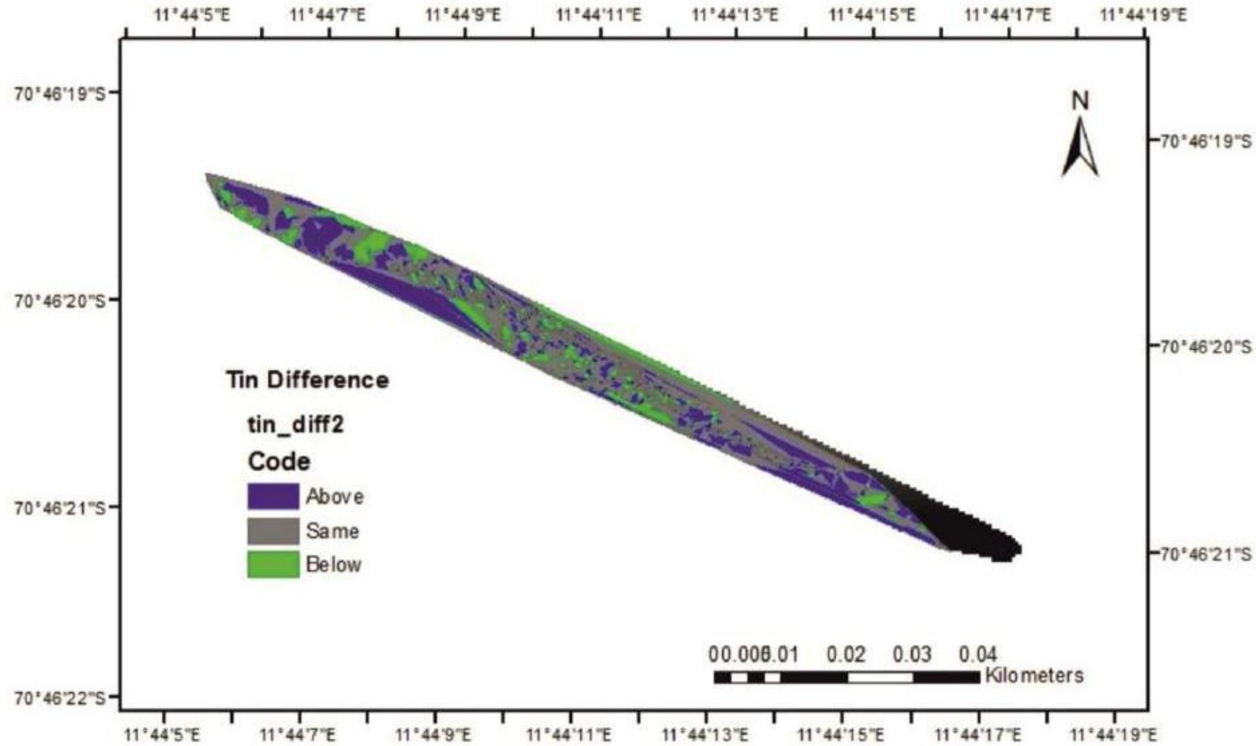

Figure 6. Surface difference feature class polygons in shape format.

III. Discussion

Differentrecentgeo-informaticstechniqueshavebeenusedtoprepare2D/3Ddigitalmapsofglacialterrain(Buckley et al., 2004; Bolch, 2008). Glaciologists have used these techniques to achieve parameters of glacier variability (Hall et al., 2003), mass balance estimation (Østrem and Haakensen, 1999; Andreassen, 1999), understanding of morphometryofglacialterrain(Sangwaretal.,2004),estimationoficevolumechange(SurazakovandAizen,2006; Bauder et al., 2007; Bolch et al., 2008), and fixation of the equilibrium line (Leonard and Fountain, 2003). These techniques depend primarily on the accuracy of the data collected, availability of old original map resource, besides generation glacierdata.

Geological Survey of India is monitoring the DakshinGangotri glacier snout front since 1983 and western wall since 2010. Initially, DG snoutandwesternwallweremonitoredusingsurveyingPlainTabletechniqueandbytakingobservationsfromfixing points on rocky ground. Both type of the measurements are 2-Dimensional measurements which fix the location of exposed ice-land interface of the ice wall on interpolation basis. This method could measure the recession or advancement of the interface in cm/meter. The exposed area has also been measured and inferred for assessment of longtermrecessionandadvancementpatternoftheicewall.Recessionalpatterwasalsoobservedintermsofaverage linear shift of the ice wall due to surficial melting and calving of the ice wall during the 2017-18, the DG snout and western (ice) wall shown average recession 0.25m and 2.36m per annum. During these observations, the gap areas were extrapolated while computing area vacation i.e. about 17700sq.m. (Kumar and Habib 2018). In contrast, the presentstudyusingSemiautomaticTotalStationprovideprecisedelineationofthePolaricefrontsurfaceleavingvery little scope ofinaccuracy.

TheNetvolumelossis72.07cubicmeter(roundedoff)consideringthedensityoftheiceas0.9gm/cm^3.

ThevolumelossinWaterEquivalent=VolumeoftheiceXDensityoftheice.

$$= (72.07*1000000) X (0.9)$$

= 64867142.7 gm (WEQ) or

= 64.8671427 metric ton

IV. Result

During the observation period (Between 11 January 2018 and 20 January 2018) the ice wall lost 64.87 metric ton ice in terms of W. Eq. The loss of the ice was occurred due to calving, melting of the surface ice, besides sublimation of exposed ice surface. This technique is more accurate procedure of computing Polar ice front ice loss as very large numberofdatapointshavebeenutilizedusingapreciseSemiautomaticTotalStation.Besides,theobservationshave been taken through automatic technique, thus reducing the possibility of humanerrors.

V. Acknowledgement

AuthorsareindebtedtotheDirectorGeneral,AdditionalDirectorGeneral& NMH-IV, Geological Survey of India for providing opportunity to work in the Antarctic terrain. We extend our gratitude to DeputyDirectorGeneral,NCEGR, Faridabadtheirco-operation and regular support. Authors are grateful to Director, Polar Studies Division, GSI, Faridabad for invaluable help and technical guidance during the course of the work. We are also obliged to all the officers of Polar Studies Division, GSI, Faridabad for providing necessary help and motivation. A Sincere thanks are also due to NCAOR, Goa and all other expedition members for providing logistic support during the37thIndianScientificExpeditiontoAntarctica.

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