ICE THICKNESS USING GROUND PENETRATING RADAR AT ZNOSKO GLACIER ON KING GEORGE ISLAND

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KEY WORDS: Ground penetrating radar, ice thickness, Znosko glacier, Antarctic Peninsula, electromagnetic waves, glaciology.

ABSTRACT:

Ground Penetrating Radar (GPR) survey was carried out to estimate the ice thickness and mapping the bedrock topography at Znosko glacier on King George Island, Antarctic Peninsula during 25th Peruvian Antarctic Expedition (2018). GPR surveying did at 5.2 MHz frequency with a 16 m antenna gap (transmitter and receiver). The mean ice thickness profiles vary from 7 to 123 m across the 350 m profile length. This high-resolution survey also identified a different type of ices and glaciological features which will help in modelling the nature of the glaciers in the future.

1. INTRODUCTION

Around 71% of the earth's water stored in oceans and glaciers. Polar regions (Antarctic and Arctic) are crucial for regulating the world climate, but they are vulnerable to the impacts of global warming (Teleti, Luis, 2013).

The Special Report on the Ocean and Cryosphere in a Changing Climate published by the Intergovernmental Panel on Climate Change reveals that recent studies detected that Antarctic Peninsula (AP) and West Antarctic Ice Sheet (WAIS) had lost ice mass since 1992, and the rate of retreat has been increasing since 2006 (IPCC, 2019). Suck phenomena in AP caused the disintegration of ice shelves, retreat and thinning of glaciers (Friedl et al, 2018) particular on King George Island.

Knowledge on ice volume and ice thickness distribution are essential parameters for glaciological applications especially for simulate glacier dynamics (Farinotti et al, 2009) and may provide information to understand the effect of global warming (Singh et al., 2011; Farinotti et al, 2019). Direct (ice drilling and excavations) and indirect (gravimetry, radio-echo and seismic soundings) explorations techniques have used to quantify glacier thickness (Gärtner-Roer et al, 2014; Farinotti et al, 2009). Besides, recent advances in remote sensing technology have made to obtain data with an excellent spatial resolution (Gärtner-Roer et al, 2014).

Ground Penetrating Radar (GPR) is a non-destructive technique, based on the propagation and reflection of electromagnetic waves to acquire information from the subsurface materials (air, water, sediment, ice) and the interfaces between them (Gärtner-Roer et al, 2014; Oberreuter et al, 2014, Singh et al, 2011). Electromagnetic waves propagation depends on the electric permittivity, electrical conductivity and magnetic permeability (Oberreuter et al, 2014). In glaciology, low frequency GPR (approx. 2–220 MHz) is useful for ice thickness observations (Oberreuter et al, 2014).

Preliminary results of the GPR survey carried out to estimate the ice thickness at Znosko glacier on King George Island, Antarctic Peninsula reported.

The present work shows the initial stage of a broader action that seeks to know the changes in the ice masses located on King George Island, through the use of GPR, picture by drone and mass balance measurements from monitoring the glacier Znosko.

2. STUDY AREA

King George Island (KGI) is the largest of the South Shetland Islands situated at 130 km from the northwestern tip of the Antarctic Peninsula and has an area of 1250 km^2 (Simões et al., 1999). The humid and warm air masses from the South Pacific Ocean influenced the west coast of the AP, while cold and dry air masses from the Weddell Sea affected the east coast (Falk et al, 2018). The highest elevation reaches more than 700 m in the central ice dome. Almost 90% of the island covered by a polythermal ice cap and influenced by maritime climate conditions (Falk et al, 2018, Ruckamp et al, 2010, Simões et al, 1999).

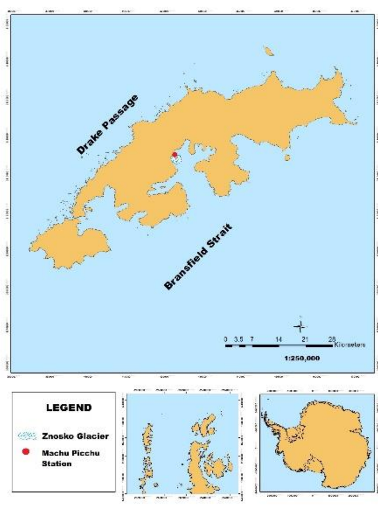

Figure 1. Location map

In recent decades, the glaciers on KGI have shown retreat and loss of thickness associated with rising air temperatures. Znosko

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glacier is located (Figure 1) in King George Island South Shetland Islands of the Antarctic Peninsula, has an area of 2.4 km^2 with an elevation range from 2 to 256 m with an average slope of 15%.

3. METHODS

Since 2013 the National Service of Meteorology and Hydrology of Peru (SENAMHI) and the National Water Authority (ANA) participate in the Peruvian Antarctic Expeditions with a project that intends to study the ice volume changes and mass balance at Znosko glacier on KGI.

During the 25th (2018) and 26th (2019) Peruvian Antarctic Expedition, a GPR survey was carried out, and a total of 19 stakes located in the ablation zone of the Znosko glacier, respectively. Also, a topographic survey was conducted by photogrammetry method by the National Geographic Institute (IGN).

For the present study, GPR profiles were performed for three days during the 25th Peruvian Antarctic Expedition in February 2018. The GPR system consists of a transmitter and a receiver, with corresponding antennae (bistatic arrangement). We use a radar HF unit made by Unmanned Industrial with antennas at a central frequency of 5.2 MHz (16 m antenna length). The radar survey was performed by two operators (transmitter and receiver) on foot with a 25 m of the separation distance between them. 8 profiles measured with a length of approximately 350 m. Post-processing and data analyses carried out using Reflexw V7.5.5 (Sandmeier Scientific Software).

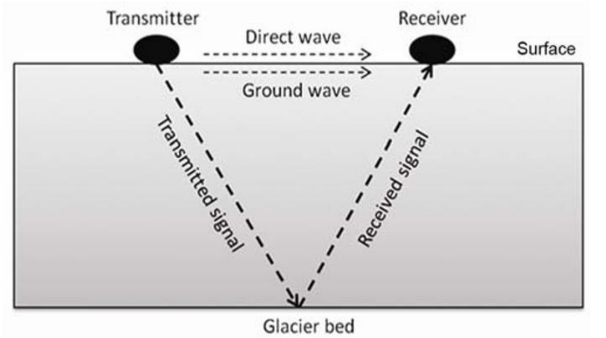

Figure 2. GPR operational principles. Figure is from Singh, 2012.

Unmanned Aerial Vehicle (UAV) photogrammetry has emerged as an on-demand method to generate high-resolution datasets, including DEMs and orthorectified images (orthophotos). During the 26th Peruvian Antarctic Expedition, we used a self-assembled UAV platform equipped with a Sony Alfa 500/RGB digital camera which has a 16 mm focal length and a 23-megapixel resolution. The Quadcopter has an onboard navigation system, and the whole platform weighs approximately 3 kg. DEM composed with 5 m of exceptional resolution and accuracy of 0.7 cm (X) and (Y) in the horizontal directions and 2 cm (Z) in the vertical direction.

4. RESULTS

Figure 3 shows the colour-coded ice thickness along with all acquired GPR profiles, indicating that the subglacial topography has a minimal roughness.

During the radar survey, data collected over 350 m. GPR sections at Znosko Glacier show the ice thickness distribution varies at different parts in the tongue of the glacier. Ice thickness ranges from around 7 m at the eastern margin to a maximum ice thickness of 123 m on the western part of the central flat area (Figure 4). A contribution to the difference between ice thickness and surface elevation change could result from basal melting related to the thermal regime and ice flow conditions of the ice cap in KGI (Ruckamp et al, 2010, Simões et al, 1999).

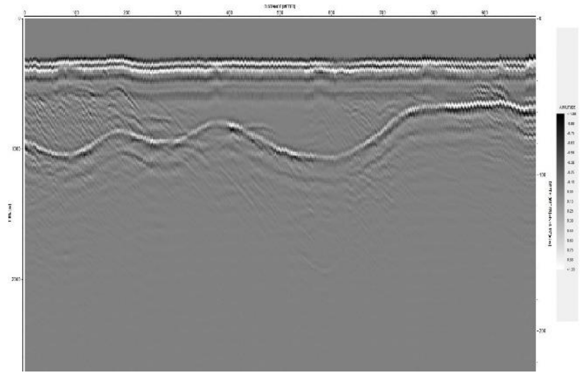

Figure 3: GPR reflection.

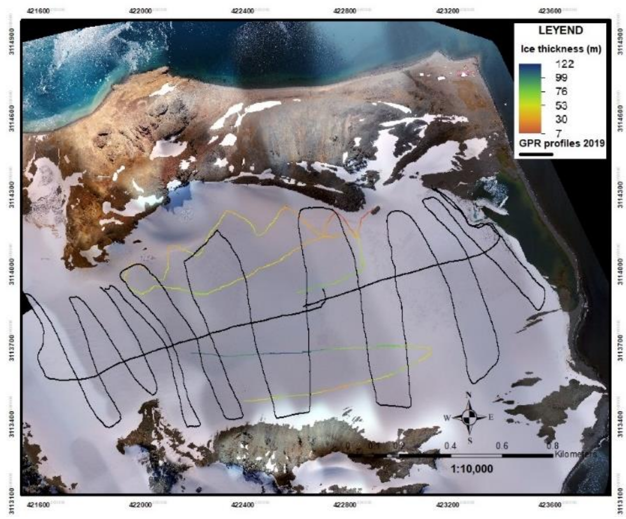

Figure 4. Ice thickness distribution Znosko glacier.

5. CONCLUSIONS

GPR is a non-destructive technique with the potential to estimate the ice thickness directly and identify englacial subsurface features. However, in many cases, additional information from different sources is required to interpret the radar data. A low-frequency antenna used for the GPR survey carried out in the 2018 summer. The study has shown that Znosko glacier thickness changed from 7 to 123 m across the 350 m profile length. The mass balance loss for Znosko glacier was around 2.41 m/per year (until 80 m above sea level). The next step will be the comparison between mass changes obtained from glaciological measurements and the geodetic method to assess the temporal evolution of glacier mass balance in recent years. Also, through atmosphere-ocean general circulation models (AOGCMs) simulate the effect of climate change on the mass balance of Znosko glacier.

6. ACKNOWLEDGEMENTS

The National Antarctic Program of Peru supported this study. Fieldwork in Antarctica was carried out in cooperation with the National Geographic Institute (IGN) and Glaciar + project (CARE and Zurich University) the Swiss cooperation in Peru for the training in the GPR system. This study is part of a PhD research from the Water Resources Graduate Program - National Agrarian University.

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This contribution has been peer-reviewed.
https://doi.org/10.5194/isprs-archives-XLII-3-W12-2020-437-2020 | © Authors 2020. CC BY 4.0 License.
Primary publication at IEEE Xplore: https://doi.org/10.1109/LAGIRS48042.2020.9165584