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Ponencias



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44. FIRST GROUND PENETRATING RADAR SURVEY ON MONTE PERDIDO GLACIER (PYRENEES)

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ABSTRACT

The project “The Monte Perdido Glacier: Monitoring the glacial dynamic and the associated cryospheric processes as indicators of global change” (National Park’s 2013 Fund) aims to study the recent dynamic and degradation of this ice mass, using geomatic and geophysical techniques in order to estimate thickness and potential volumetric variations. We present the first ground penetrating radar survey, carried out on the northwest section of the lower Monte Perdido Glacier. The survey was conducted along a 270 m transect, using three antennas of different frequencies -500, 200 and 50 MHz- that enabled us to study the glacier’s structure at various maximum depths and spatial resolutions. The results show a first section composed by several seasonal snow layers (2015-2016 winter and spring), a clear snow/ice transition layer, an ice layer and a final basal zone characterised by typical sub-glacial till sediments.

We infer a maximum ice-depth of 25.2 ± 1.6 m, constituting the first and unprecedented estimation of thickness on the Monte Perdido Glacier.

INTRODUCTION

This work is part of the project “The Monte Perdido Glacier: Monitoring the glacial dynamic and the associated cryospheric processes as indicators of global change” (Ordesa and Monte Perdido National Park, PNOMP). This glacier has shown a dramatic retreat over the last years [Del Río and Serrano, 2014]. In order to estimate its current depth, annual volumetric changes and ice-flow, geomatic (Terrestrial Laser Scanning - TLS - and interferometry) and geophysical (Ground Penetrating Radar -GPR) techniques have been applied. This project aims to establish a long term monitoring strategy, framed by the recent adscription of the PNOMP to the LTER-Spain network (Long Term Ecological Research Sites).

This framework was the basis for a GPR survey of the glacier. Despite the existence of geophysical studies about the Pyrenean glaciers [ERHIN 2008, Del Río et al., 2014], Monte Perdido Glacier had never been surveyed from a geophysical perspective, potentially due to the difficult access, treacherous terrain, steep slopes, rock and snow falls and abundant crevasses in its central part.

Fieldwork was carried out during the 30th of April and 1st of May 2016 with the aim to apply GPR techniques in order to estimate the internal structure and depth, in an area particularly sensitive to changes such as the northwest zone of the lowest Monte Perdido Glacier [Lopez-Moreno et al., 2016].

METHODS

In order to conduct this survey we used a MALÅ GEOSCIENCE set up, formed by a PROEX control unit and three 50, 200 and 500 MHz antennas, the first two were un-shielded and the latter shielded.

Additionally, the survey has been supported by extra batteries and a generator to guarantee energy supply for two days of work. The obtained radargrams have been processed using the software Reflexw 8.1 (<http://www.sandmeier-geo.de/reflex.html>).



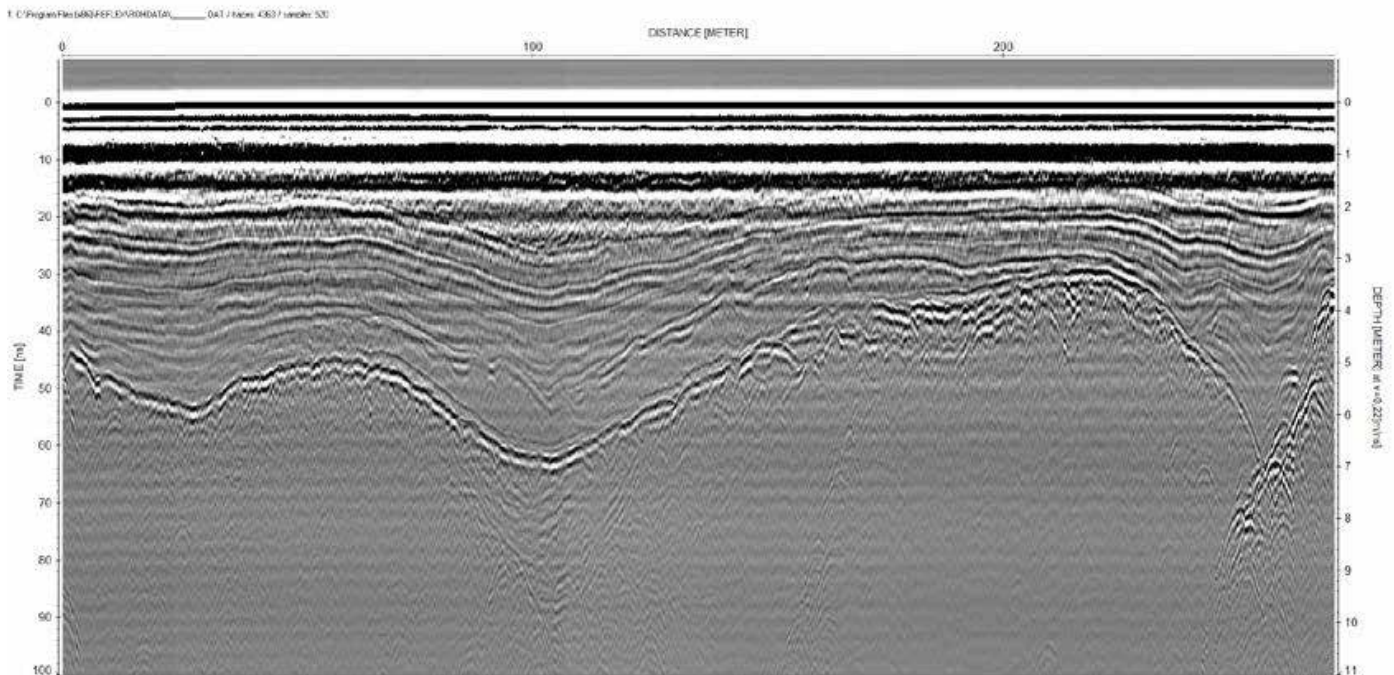
DATA

The field work campaign was carried out under unexpected extreme high-mountain meteorological conditions; gale force winds and snow precipitation that combined with the substantial steepness of the glacier made the development of the fieldwork remarkably difficult, being only possible to perform the GPR survey during a short window on the first day. Nevertheless, it was possible to complete three useful transects of the same profile (Figure 1). The 270 m profile was measured downwards with each of the three 50, 200 and 500 MHz antennas. Transects were named T50, T200 and T500 with regard to the aforementioned antennas.



Figure 1.- Photographs of the study area in Monte Perdido Glacier (above) and data acquisition with 200 MHz GPR (below).

The starting point of the profile is located at coordinates 42° 40.870' N / 0° 2.078' E (altitude 2825 m) and the lower end at 42° 40.987' N / 0° 2.179' E (altitude 2740 m), showing a 85 m descent along 216 longitudinal meters and therefore implying an averaged slope of 39%.





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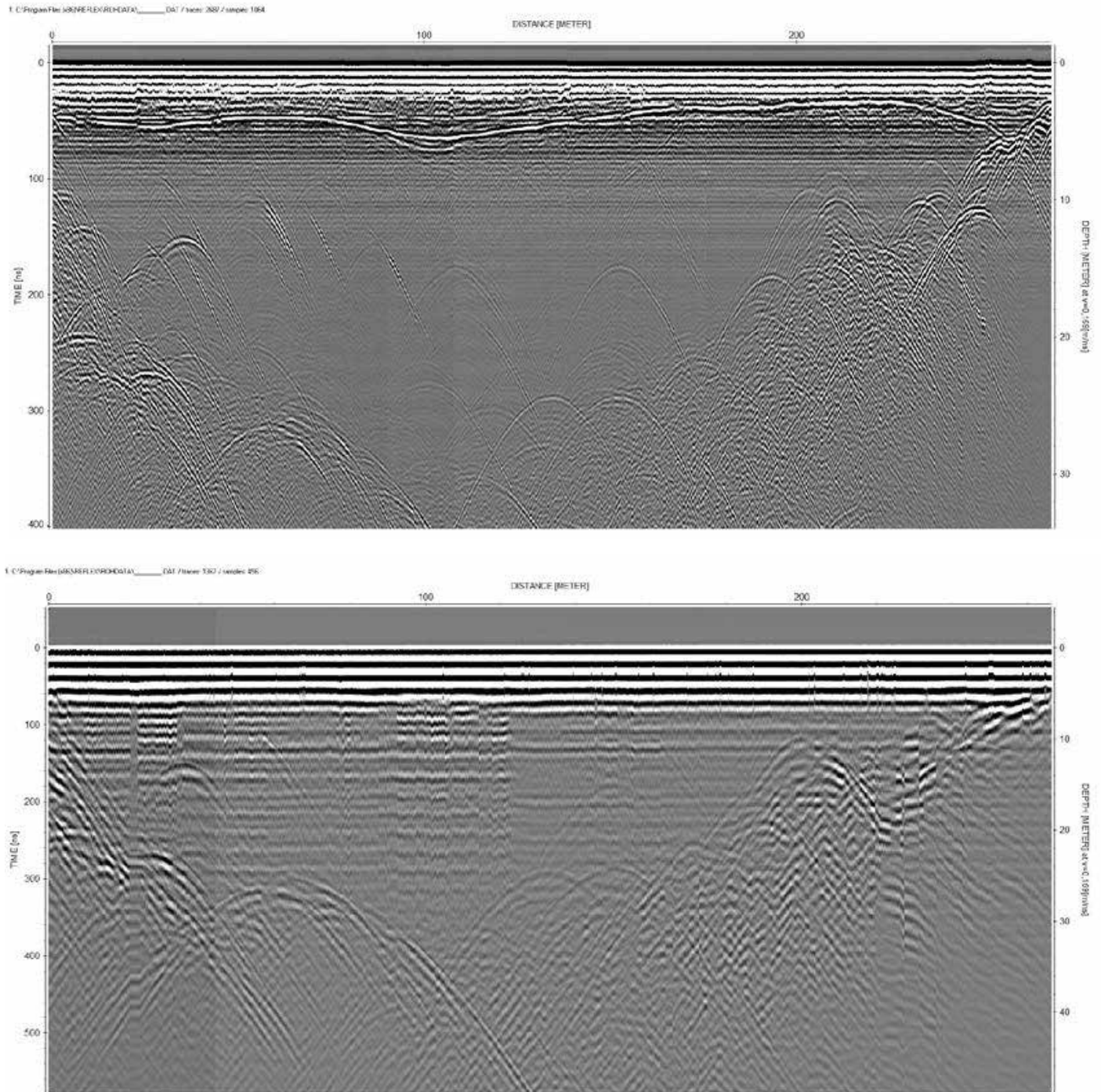


Figure 2.- Radargrams of the three GPR transects obtained with 500 MHz (T500) and 200 MHz (T200) and 50 MHz (T50) antennas. The upper part of the transects are at the left of the radargrams.



RESULTS

Figure 2 shows transects obtained with each of the three antennas, showing both their spatial resolution and reached depth. The different radargrams are coherent with each other, resulting on a homogeneous pattern over the same profile. The T500 transect shows a very clear snow/ice transition (at ca. 30-65 ns) as well as various recently deposited snow layers from the previous 2015-2016 winter. T200 transect equally presents the mentioned snow/ice layer and several seasonal snow layers. However, the latter antenna allows further penetration across the entire ice-mass, up to the underlying bedrock.

As reflected on the radargrams, along the first 50 m (from the left) there is a section where the depth grows fast, followed by a section of more homogeneous depth, where the maximum depth is recorded (at ca. 100 m from the beginning of the profile). The bedrock then rises up the snow surface, marking the end of the collected profile. On the other hand, it is also possible to observe several hyperbolic diffractions, which could be explained by the potential presence of rocks and drainage channels distributed across the ice-mass. Finally, the T50 confirms the pattern obtained with the 200 MHz antenna, but giving lower resolution. However, the stronger penetration capacity allows to distinguish more clearly the layer of rocks and sediments at the glacier bottom in this area. We cannot exclude totally the presence of water and drainage system at the bottom. In fact, it is possible that within the glacial till accumulations may exist with some moisture retention. It is unlikely that there were deposits of water retained in the base of the glacier, due to the following reasons: the steep slope; the dates; the specific weather conditions of development of fieldwork; and the karstic domain circus where the glacier is located, which would percolate the substrate water.

In order to estimate a depth-scale for each of transects, we have inferred the average propagation velocity of electromagnetic waves in the snow+ice from the hyperbolas produced in T200, obtaining an estimated value of $0,169 \pm 0.004$ m/ns. With this RWV the maximum depth value appears to be located around 100 m away from the beginning of the profile, but it's not possible to determine its position more accurately as the maximum depth point would be located beyond the maximum penetration threshold obtained with the radargram (at 417 ns). Nevertheless, applying the Kirchhoff migration to T200 radargram (Figure 3), we can estimate a maximum depth of 31.7 ± 1.3 m at about 93m from the beginning of the profile.

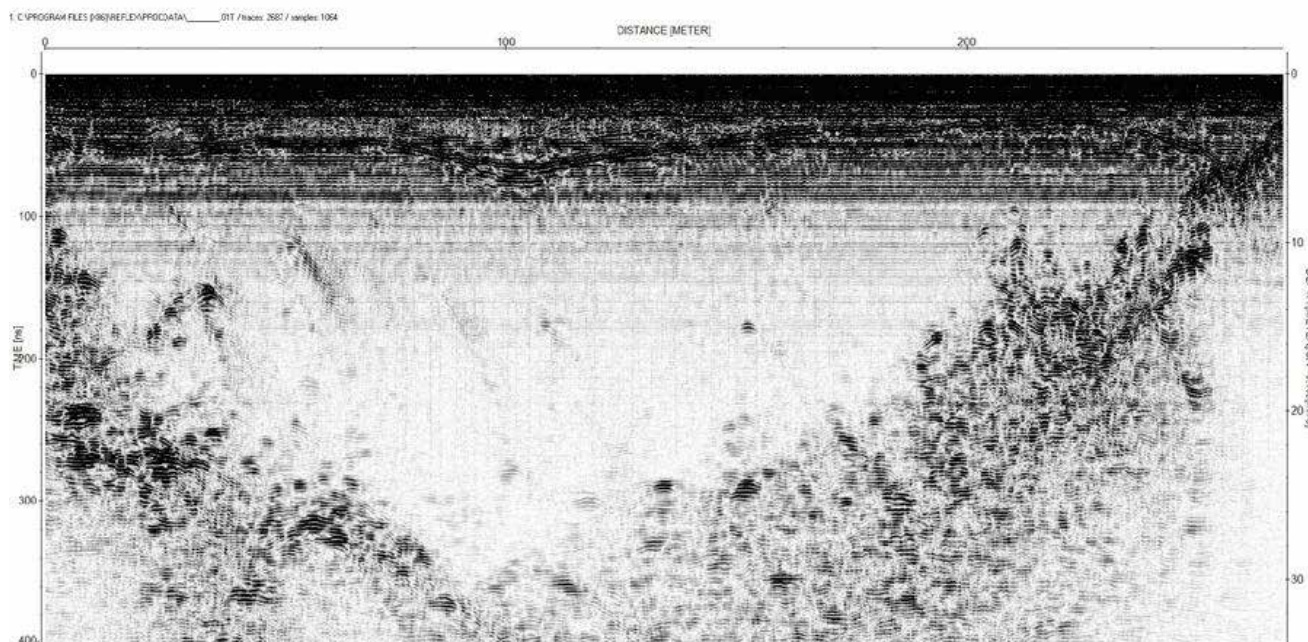


Figure 3.- Kirchhoff migrated T200 radargram.

In order to estimate the thickness of the ice-mass, it's necessary to disentangle the snow from the ice layers. Therefore, we analyse transect obtained with the 500 MHz, T500. Looking at the hyperbolas at the end of the transect – snow/ice transition area – we infer an average velocity of $0,220 \pm 0.005$ m/ns that is coherent with snow propagation velocity reference values (0.212-0.245 m/ns) [Brandt et al., 2007]. Using this value, we calculate that the thickness of the snow layer at 93 m point is 6.5 ± 0.3 m, obtaining around 25.2 ± 1.6 m of maximum ice-mass thickness in the studied area.



CONCLUSIONS

We have conducted the first GPR survey on the Monte Perdido Glacier allowing a first detailed observation of its internal morphology, thickness and structure. The underlying topography is characterised by a sequence of rock basins and thresholds where the ice-mass adapts and flows over.

From the obtained radargrams we have determined the average snow+ice and snow velocities of the glacier - respectively ca. 0.169 and 0.220 m/ns – allowing us to estimate a maximum ice-mass thickness of around 25 m in the studied area.

AKNOWLEDGMENTS

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