Universidad de Granada

**MASTER’S DEGREE IN GEOPHYSICS AND METEOROLOGY**

**MASTER’S THESIS**

# DETERMINATION OF ICE THICKNESS AND VOLUME OF HURD GLACIER, HURD PENINSULA, LIVINGSTONE ISLAND, ANTARCTICA

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**Abstract.**The present work is the result of several radio-echo sounding (RES) surveys carried out on Hurd Glacier, Hurd Peninsula, Livingston Island, Antarctica, during the austral summer season 2001/2002 campaign, which included radar profiling and common-midpoint measurements with low (20-25 MHz) and high (100-200MHz)frequency using a ground penetrating radar (GPR), allowing to estimate the radio-wave velocities (RWV) and determine the subglacial relief, thickness and volume of the glacier, topographical surface, and to study the global flux of the ice mass. Theprofiles reached a total length of 77.5 km, with 3922 radio-echo sounding measurements and estimating an average ice volume of 0.35 $km^3$ and a maximum ice thickness of 200 m.

**Keywords:** Hurd Glacier, radio- echo sounding (RES), ground penetrating radar (GPR), radio- wave velocities (RWV).

## INTRODUCCIÓN

Hurd Peninsula ice cap (62°39-42'S, 60°19-25'W; Fig. 1) is based in Livingston Island, South Shetland Islands, Antarctica, covering an area of nearly 10 $km^2$. The main ice cap is drained by several outlet glaciers: Argentina, flowing northwestwards; Las Palmas, flowing westwards; Sally Rocks tongue, flowing southwestwards; an unnamed tongue flowing southwards (where the authors refer to as McGregor glacier); and Johnsons

Glacier, flowing northwestwards, which is additionally fed by ice draining not from the main ice cap but from the east and northeast. For the latter reason, Hurd Peninsula ice cap is often subdivided into two main glacier units: Johnsons Glacier, a tidewater glacier; and Hurd Glacier, the remainingice mass, mostly ending on land. The local ice boundary separating Johnsons and Hurd has altitudes between 250 and 330 m a.s.l. The main body of Hurd Glacier has an average surface slope up to 3°, though its westward-flowing side lobes, Argentina and Las Palmas, have much steeper slopes (around 13°). These are even higher in McGregor glacier, which is entirely a heavily crevassed icefall. Typical slopes for Johnsons Glacier range between 10° in its northern sector and 6° in the southern sector.

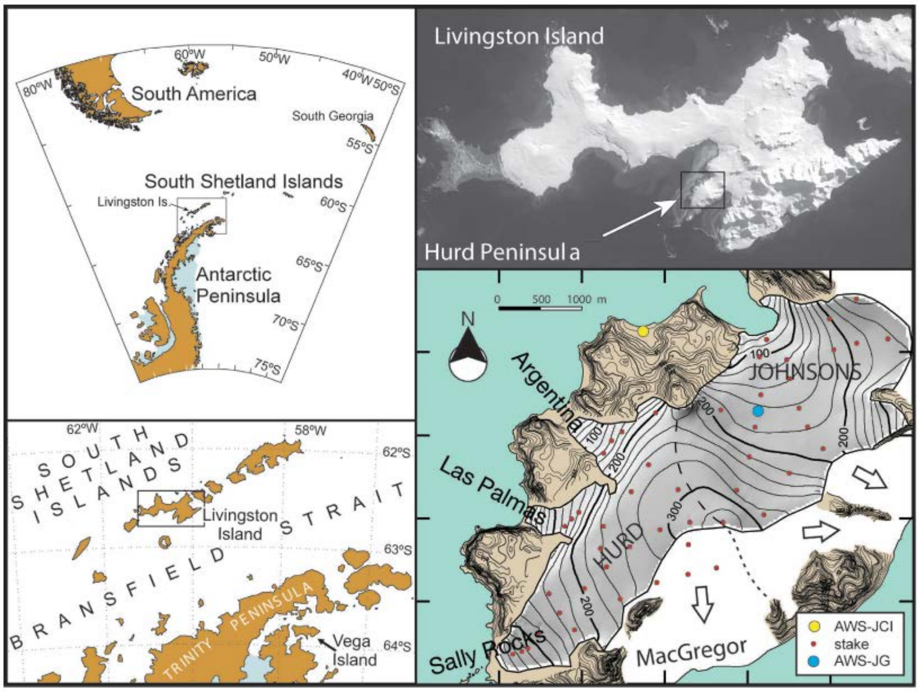


**Fig. 1.** Location and surface elevation map of Hurd and Johnsons Glaciers, Hurd Peninsula, Livingston Island. The dashed line indicates the divide between Hurd and Johnsons Glaciers meanwhile the dotted line indicates the divide between McGregor and the unnamed tongue. The arrows indicate the approximate flow directions in the South on the basins. The positions of the automatic weather stations (AWSs) at Juan Carlos Istation (JCI) and Johnsons Glacier (JG) are also shown (Modified from Francisco J. Navarro et al., 2013).

## METHODOLOGY

The objective was to set the appropriate number of transects all over the glacierdrawing a grid over Hurd glacier, covering an important area (figure 2).The researchers used differential GPS (DGPS) to position the starting and ending of the profiles. RWV were determined with common-mid points (CMP) in order to calculate the depth of the glacier. A total of 3922 measurements were taken. Radar data have been used for multiple purposes: defining the glacier geometry for numerical modelling experiments (Martín and others, 2004; Otero, 2008), estimating the water content from radio-wave velocities retrieved from diffraction hyperbolae recorded during radar profiling (Benjumea at al., 2003), comparing the capabilities of radar and seismic methods for the study of glaciers (Navarro and others, 2005) and estimating the total volume of ice stored by Hurd Peninsula ice cap (Molina et al., 2007).

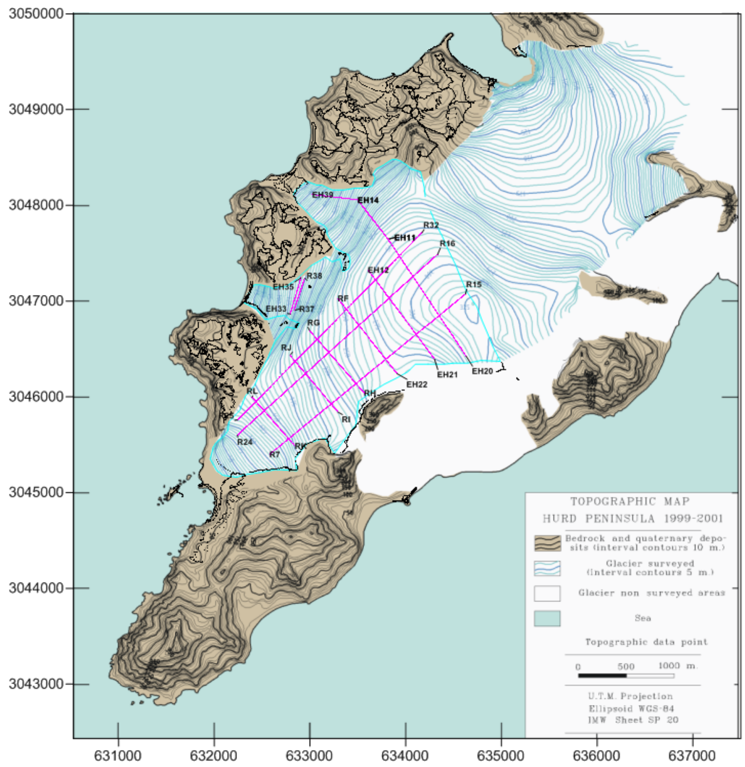


**Fig. 2**. Radar profiles (100 MHz) covering Hurd glacier. They correspond to surveys of December 1999, 2000 and 2001. Note the divisory line between Hurd and Johnson icecaps. The transects are positioned on Hurd glacier.

They took 417 topographical waypoints necessary to cover the glacier, using common-offset geometry at a 1 s time interval between records, keeping a constant speed of about 3 m/s or, alternatively, a record for each odometer wheel rotation, the latter implying a distance between adjacent records of 1.55 m.The equipment is transported with the aid of a convoy composed of snowmobile and sleds (figure 3).

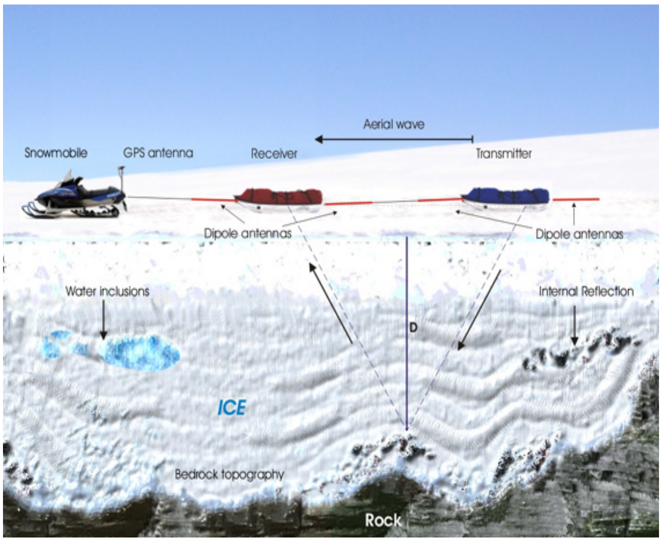


**Fig. 3.** Set of snowmobile, sleds, transmitter and receiver.

## RESULTS

With RWV and CMP, it has been determined the ice thickness reaching up to 200 m, the bedrock topography, and to study the global flux of the ice mass,(figure 5.a).Additionally, total volume of ice was also calculated with a total volume of 0.35 $km^3$, (figure 5.b).

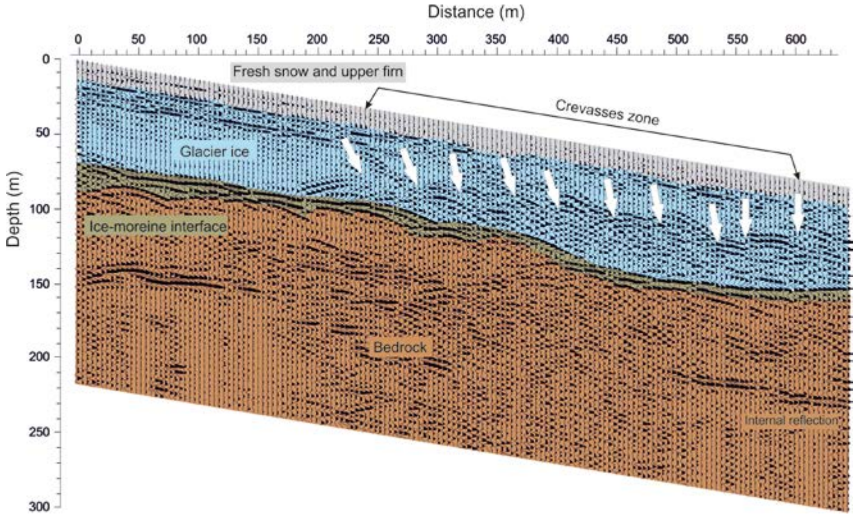


**Fig. 4.** Transversal (NW- SE) radargram correspondig at the EH-14- EH39 GPR profile.

Radargram showing most important contacts and topography. Main crevassed, upper firn and glacial ice is represented. Note strong diffraction between bedrock and ice.

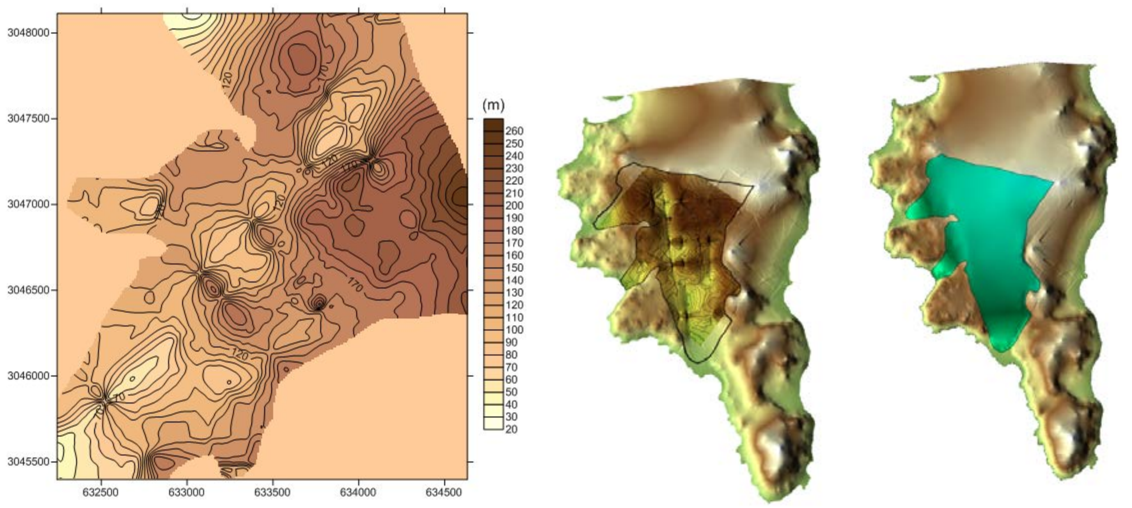


**Fig. 5.** (a) Contour levels of top bedrock. (b) Below image shows the flux of the glacier leaving the footprint on the bedrock. The arrows represent the direction and main movement of ice (orange arrow means a lower flux). The image on the right represents the surface mass ice on the terrain.

## CONCLUSIONS

The GPR method is a useful geophysical technique for prospecting the ice mass. With a 100 MHz antenna, we can to reach until 5 µs with a good signal/noise rate (s/n). It means around about 300 m depth.

The contact between the ice-moreines interface is described with a strong double/triple reflection produced by the heterogeneous bed; mainly composed by ice-mourraines-water and cavities. So GPR is an excellent method for detecting this level.

The individual interpretation of the GPR profiles has highlighted the good detection characteristics of the ice mass; given by: i) a transparent signature for the homogenous ice, ii) strong diffractions associated to crevasses, iii) scattering plumes in ice zones with water content and (iv) secondary reflectors corresponding to the contact between different ice flows or ash layers from the neighboring volcanic Deception island.Due to a good s/n rate, we also detected internal reflections in the roc basement.

In conclusion, the radio- echo sounding geophysical method has been proved to be reliable and giving excellent results on glaciers.

## REFERENCES

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