Control and monitoring of the Znosko Glacier in Antarctica

by Fabian Brondi Rueda, Gabriele Garnero, Giovanni Righetti, Stefano Serafini

Fig. 1 - Location of the area (φ=62° 06' S, λ= 58° 28' W)

Since the 1990s, Peru's IGN (*Instituto Geográfico Nacional*) has carried out intensive documentation and monitoring activities in the Antarctic territories. During the last few years, these activities have focused on the Znosko glacier. The importance of this project is based on the generation of correct digital elevation models (DEM). In fact, a correct geodesic setting allows to obtain high resolution geospatial products. These inputs represent the fundamental support for the study of the glacial mass balance by institutions such as ANA (*Autoridad Nacional del Agua*) and INAIGEN (*Instituto Nacional de Investigación en Glaciares y Ecosistemas de Montaña*). This paper clarifies survey activities carried out so far, analysis and results achieved, and perspectives for next missions. Monitoring activities were carried out in an international cooperation context, involving the Instituto Geográfico Nacional (PE) and MEDS AMSTERDAM BV Society (NE) under the scientific supervision of Politecnico di Torino (ITA).

The Instituto Geográfico Nacional activity in Antarctica

The Instituto Geografico Nacional, as head of geospatial information in Peru, collaborated with the other participating institutions, providing them technical-cartographic support during the development of research projects. During this collaboration, topographic maps were generated in the areas adjacent to the Machu Picchu Science Station.

The missions covered various scientific aspects, such as:

- environmental factors regulating the distribution of bentonite organisms;
- sampling of ice coring for the measurement of environmental isotopes;
- study of the potential of Antarctic lichens as indicators of climate change;
- geomorphology and glacial assessment of Punta Crepín;
- macro-algae acquisition and their dehydration.

Fig. 2 - The environment of Znosko Glacier.

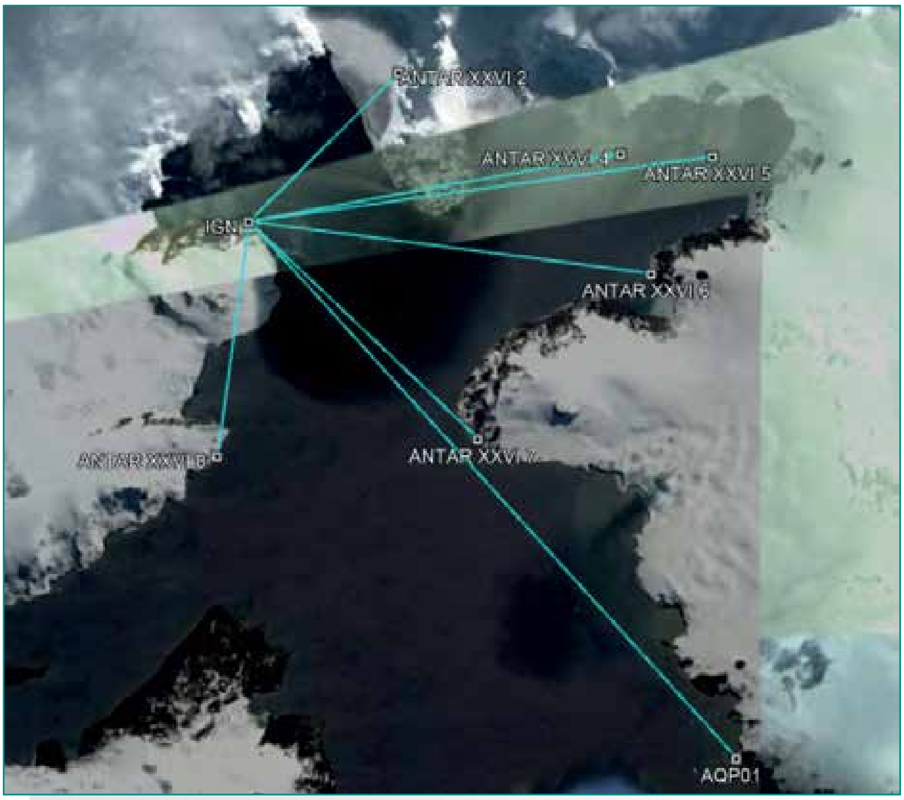

Fig. 3 - Passive geodesic network of the IGN in Antarctica.

Area	Sup. ha
Znosko	900
Langer	400
Wiracocha	1000
Monte Flora	200
Petrel gigante	135

Tab. 1 – Survey areas and extensions

The ongoing climate changes have pushed research groups, such as ANA and the Servicio Nacional de Meteorología and Hidrología del Perú; to generate geospatial information on the Znosko glacier.

Znosko Glacier

Znosko glacier is located in the southern Shetland Islands, in territories claimed by Argentina, Chile and UK.
Located at an average altitude of 22 m above sea level, the terrain around the glacier is hilly: highest nearby point is Admiral Peak, 305 meters above sea level, located 1.3 kilometers south the glacier.
This territory is not anthropized, in fact the nearest inhabited locality is the Brazilian station Commandante Ferraz, about 5 kilometers east of the glacier, and the Peruvian station Machu Picchu.

	Gen-19			Feb-20			Difference			Displacement	
NAME	East	North	ELEV. GEOID	East	North	ELEV. GEOID	East	North	ELEV. GEOID	DIST.	DIREC.
ANTAR XXVI 1	423421.479	3116628.701	4.098	423421.485	3116628.684	4.092	-0.006	0.017	0.006	0.018	SE
ANTAR XXVI 2	425890.704	3117550.113	10.061	425890.700	3117550.118	10.102	0.004	-0.005	-0.041	0.006	NW
ANTAR XXVI 3	425656.967	3115914.359	40.038	425656.967	3115914.351	40.032	0.000	0.008	0.006	0.008	S
ANTAR XXVI 4	430017.689	3116142.604	17.882	430017.693	3116142.609	17.898	-0.004	-0.005	-0.016	0.006	NE
ANTAR XXVI 5	431716.898	3116130.278	2.504	431716.882	3116130.282	2.503	0.016	-0.004	0.001	0.016	NE
ANTAR XXVI 6	430628.472	3113947.196	11.212	430628.470	3113947.203	11.213	0.002	-0.007	-0.001	0.007	NW
ANTAR XXVI 7	427494.726	3110835.728	37.729	427494.739	3110835.725	37.734	-0.013	0.003	-0.005	0.013	SE
ANTAR XXVI 8	422688.250	3110417.789	9.988	422688.264	3110417.784	9.981	-0.014	0.005	0.007	0.018	SE
TUM01	423494.774	3113442.19	41.393	423494.698	3113442.2	41.47	0.076	-0.007	-0.077	**0.076**	**NW**

Tab. 2 – The IGN passive network

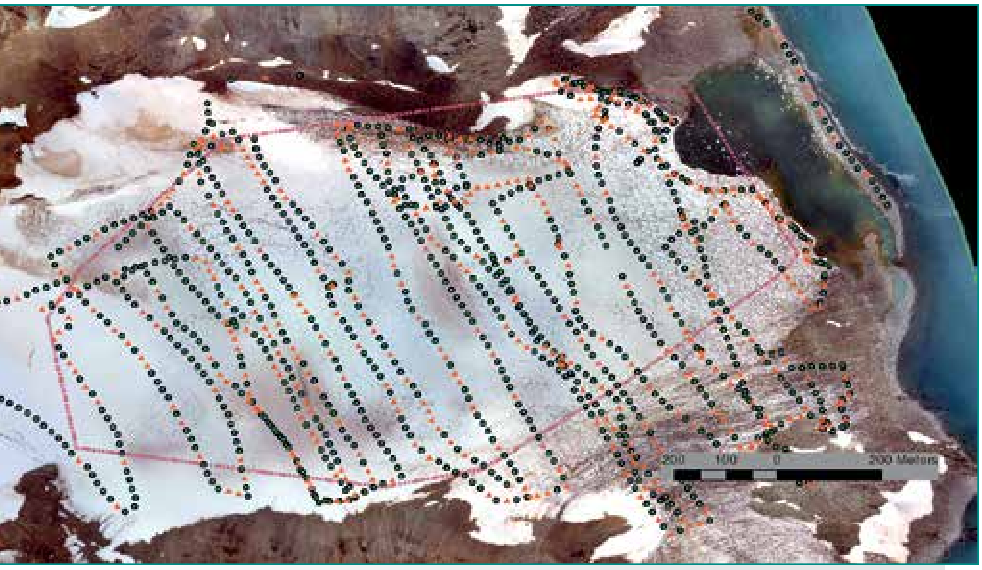

Fig. 4 – RTK Survey Antar XXVII - Training set (green dots, 70%) and Test set (red triangles, 30%).

tions depending on the tectonic micro-plates.
The interest so far aroused by the evidence of these movements suggests rescheduling the execution of the measures for the next five years, in order to evaluate with increased accuracy detected data. Eventually new coordinates will be included into the global reference system IGS14.

Monitoring of the Znosko glacier: Missions XXVI and XXVII

Missions XXVI and XXVII were carried out respectively in January 2019 and February 2020. They involved, in addition to the Znosko glacier, also other areas subject to photogrammetric survey to create a digital model and orthoimages (Table 1).

Overall stability check

In the last 2 years, a passive monitoring network has been set up covering 9 points, among which were measured with static geodetic measurements some baselines with observations of the order of 2.5-3 hours each, useful for evaluating the overall stability of the area and the tectonic movements of these plates.
Interpretation of data in this table, currently drafted in UTM SIRGAS-ROU98 zone 21E coordinates, reveals a significant movement of all points; among these, the TUM01 summit in particular has a translation of over 7 cm in one year only.
For example, Italy has a global movement of the order of 3 cm/year in the direction N-NE, which decreases to 2-3 mm/year if assessed with European references, with different orientations depending on the tectonic micro-plates.

Glaciers geometries evaluation

To evaluate the geometry of the glacier and therefore estimate the involved volumes, it was considered appropriate to use only the basic data obtained from GNSS measurements in RTK mode.
In fact, there are reliability problems, in using autocorrelation of images mostly occupied by ice, and therefore devoid of recognizable textures and elements.
Altitude profiles with an average wheelbase of around seventy meters were used, these were obtained in the 2019 (Antar XXVI) and 2020 (Antar XXVII) campaigns.
Differential corrections were performed, using a pair of points near the detection area, resting on the ASTA reference vertex positioned near the flagpole of the Machu Picchu base.

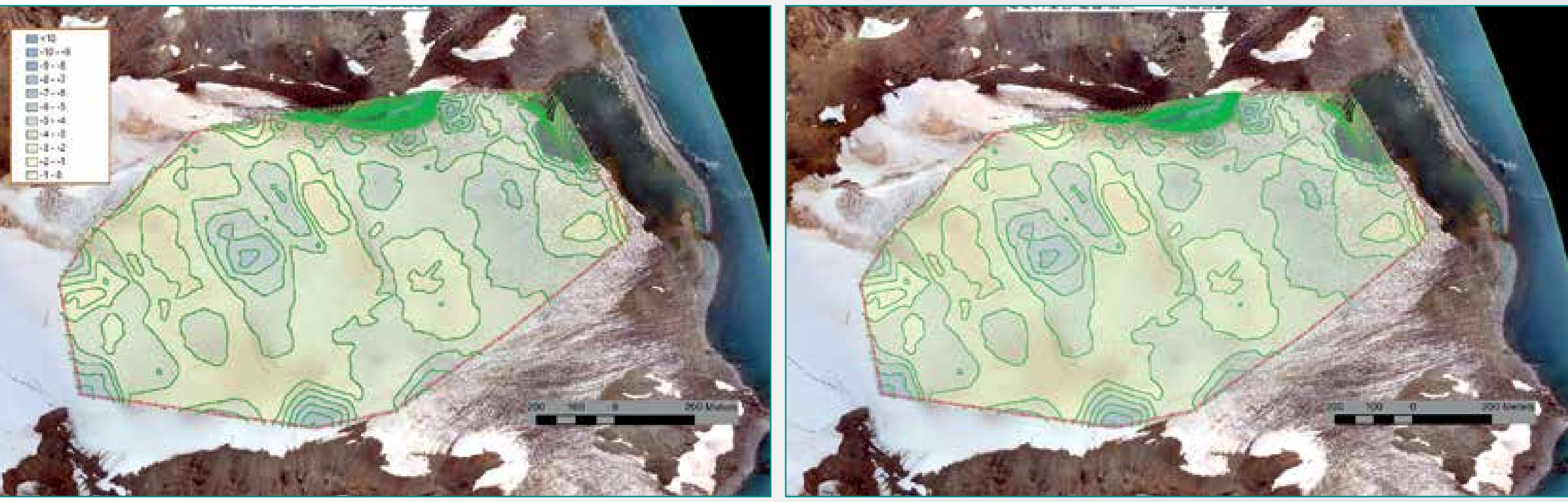

Fig. 5 - Digital model and altimetric contour lines variations between the XXVI and XXVII campaigns.

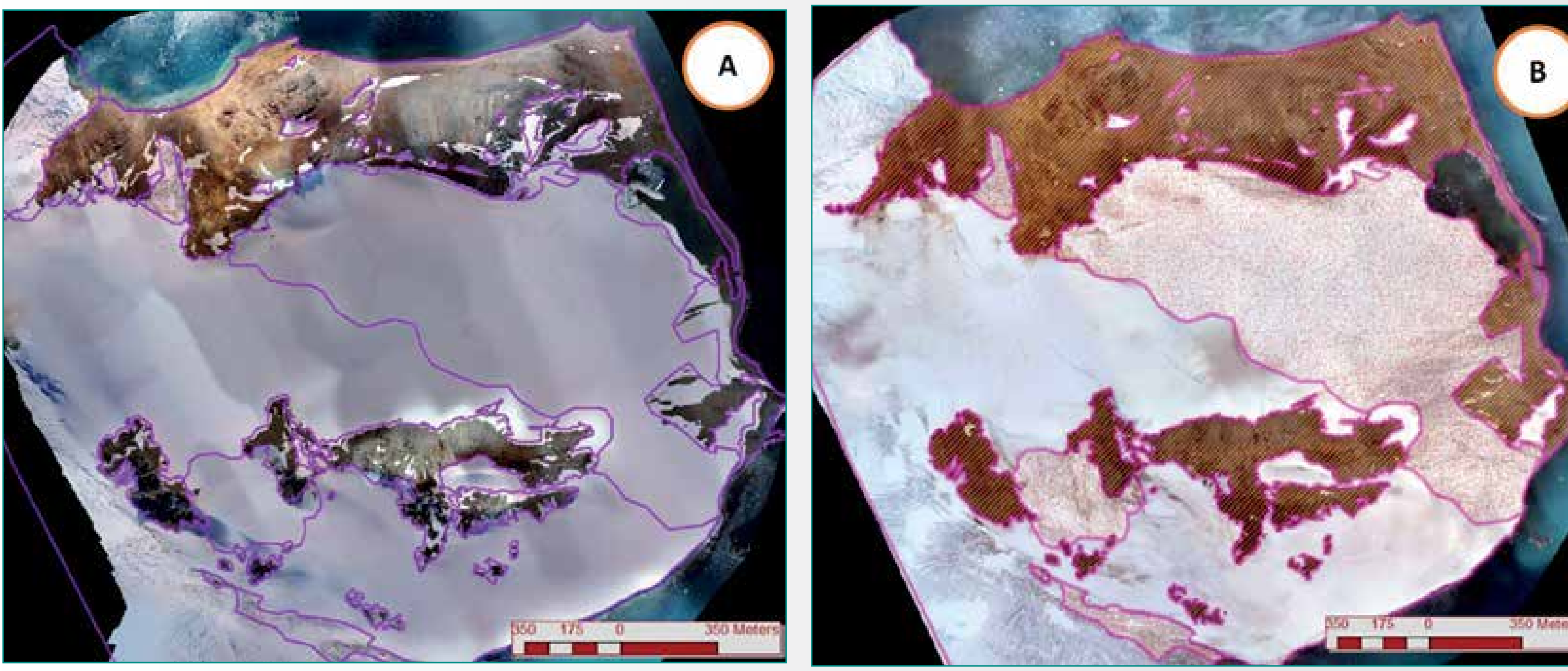

Fig. 6 - Comparisons between the situations 2019 (A) and 2020 (B).

Interpolator model estimating

In order to identify the optimal interpolator model based on distribution of points and conformation of soil, it was decided to proceed with an estimate of the residues derived from the application of different interpolating models, based on previous research experiences.

A subset of data training (70% of the total) -only for the dataset constituted by RTK points, obtained in February 2020 for a total of 1406- was selected, while the remaining part was considered as a test.

The models used were the following:

- IDW with exponent 2;
- Kriging with spherical semivariogram;
- Spline with smoothing of both the surface and the first derivative, all with a minimum number of 12 points. Synthetic results are reported in Table 3.

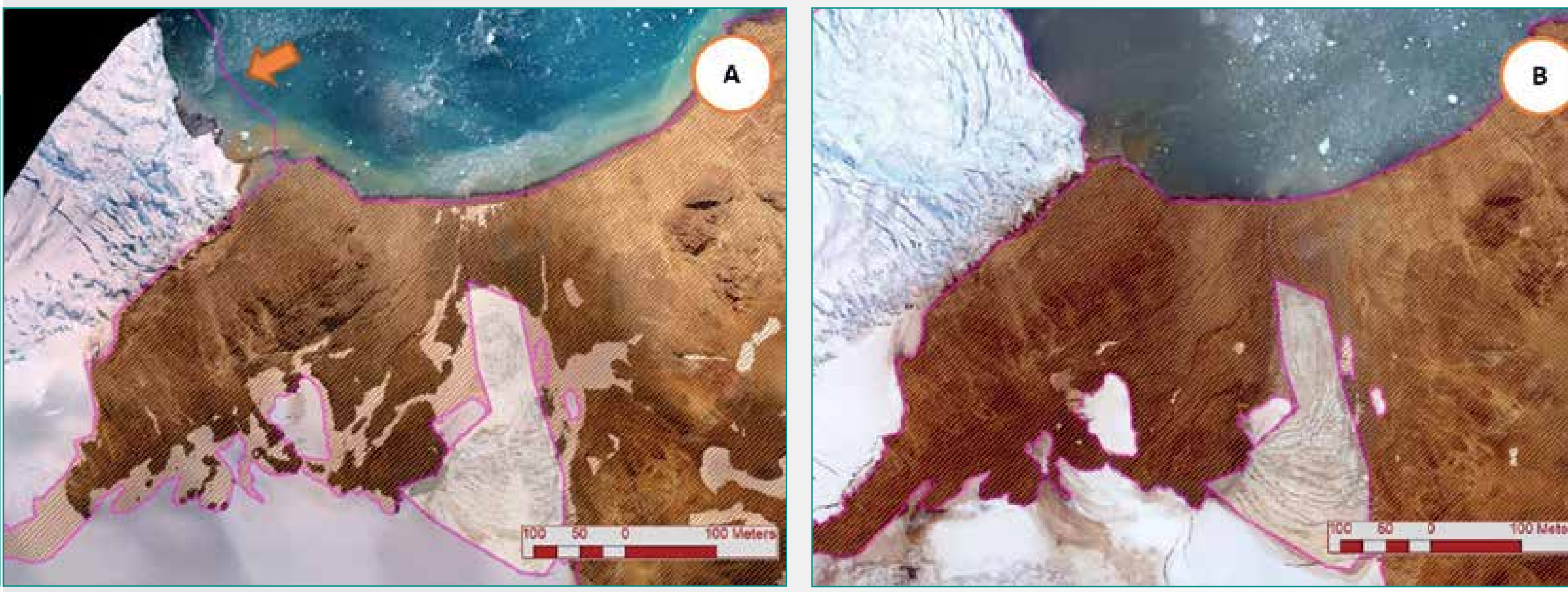

Fig. 7 - Comparisons between the situations 2019 (A) and 2020 (B) for the NE zone of Figure 6.

	IDW	Kriging	Spline
Media	-0.291	-0.135	0.048
Varianza	2.530	0.459	0.632
Max_Ass	3.032	1.065	5.464

Tab. 3 – Residuals on the different interpolator models.

Based on the evaluated residues, it was preferred to operate using the Kriging algorithm on all available datasets.

Ablation analysis (2020 vs 2019)

The altimetric differences estimation, highlights a discrete variability of the snow surface. This variable becomes important if assessed in relation to the short period of time elapsed between the two findings (13 months). The ablation is significant on the whole area subject to RTK investigations, with average values in the order of 4-5 meters.
Significant area variations were also found.
Fig. 6 shows the variation between the ortho-image of the 2019 and 2020 campaigns:
In this, the digitization performed on the basis of the orthophoto of the year 2020 (B), is compared with the orthophoto of the year 2019 (A).
This simple analysis highlights the retreat of the ice (the mixed land-ice areas are highlighted with a dotted background).
The difference mentioned above, in linear terms, in various cases reaches hundreds of meters.
When considering the uncovered terrain, less significant differences are observed, especially when compared with the phenomenon previously described.
An interesting detail is easily appreciated in the North-West area (Fig. 7), in this, the limits of the frozen area, (highlighted by the arrow), show an advance of the surface towards the sea, a sign of an evident spillage phenomenon.
This collapse affects a large area with an advancement of the front of about 70 m.

Future projections

This surfaces study, highlights a huge decrease in the ice mass during the year 2020 compared to the year 2019, and in the same period a significant process of the transfer into the sea, probable consequence of a glacial collapse.
As mentioned above, given the obvious limitations of the DEM models derived from photogrammetry, only the RTK survey was used for model generation.

While representing a robust methodology, going through glaciers by foot with geodesic tools has at least three critical issues:

- not adequate for the analysis of large extensions;
- difficult to repeat due to the hostility of the surrounding environment;
- high risk for the safety of the personnel involved in the execution of the survey.

The hope is to overcome the limitations and problems mentioned above in the coming campaigns, through the integration of LiDAR systems to be used in the analysis of larger surfaces.

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KEYWORDS

Antarctica; survey; geodesic network; geospatial; DEM; glacial mass balance

ABSTRACT

The study and analysis of climate change is a global challenge against which environmental, but also economic and social changes, will be measured.
This memorandum illustrates the recent activities carried out by the IGN Peru in collaboration with European institutions.

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