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TOPCART REVISTA DEL COLEGIO OFICIAL DE
INGENIERÍA GEOMÁTICA Y TOPOGRÁFICA

TOPCART XI

CONGRESO INTERNACIONAL
DE GEOMÁTICA Y CIENCIAS
DE LA TIERRA.

Criosfera y Cambio Climático

Ponencias

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26. STUDY OF THE RECENT EVOLUTION OF MONTE PERDIDO GLACIER FROM TERRESTRIAL LASER SCANNER DATA

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ABSTRACT.

In this work we use a long range terrestrial laser scanner to study the evolution of the Monte Perdido Glacier, the third largest glacier in the Pyrenees, from 2011 to the present. Scans were performed annually in late September. From 2011 to 2016, ice thinning has been obvious (-3.71 meters in average) but subjected to a marked spatial and interannual variability. Thus, to two consecutive anomalously wet winters and cool summers (2012-13 and 2013-14), counteracted to some degree the intense thinning that occurred during the dry and warm 2011-2012 period, but glacier thinned again strongly in 2015, a year characterized by heavy accumulation but very warm summer conditions.

INTRODUCTION.

The glaciers in the Pyrenees, which are among the southernmost in Europe, have undergone significant retreat. In 1850, these glaciers had an estimated area of 2060 hectares, but this had decreased to 321 hectares by 2008 (René, 2013). The annual air temperature in the massif has increased by a minimum of 0.9ºC since the culmination of the LIA. More recently, Deaux et al., (2014) reported an increase of 0.2ºC decade-1 for the 1951-2010 period. This air temperature increase explains the ~255 m increase in the elevation of the ELA of the glaciers of the Maladeta Massif since the culmination of the LIA, which is currently close to 2950 m a.s.l. (Chueca et al., 2005). The decreased accumulation of snow and the increase in air temperature during the ablation season are thought to be the principal causes of recent glacier decline on the southern (Spanish) side of the Pyrenees (Chueca et al., 2005). This paper focuses on the recent evolution of the Monte Perdido Glacier, the third largest glacier in the Pyrenees. During 1981-2010 the surface elevation of the glacier lowered 17 meters in average (López-Moreno et al., 2016). This work provides an update of these numbers from 2011 to 2016 thanks to the availability of terrestrial LIDAR data.

STUDY AREA.

The Monte Perdido Glacier (42°40′50″N 0°02′15″E) is located in the Ordesa and Monte Perdido National Park (OMPNP) in the Central Spanish Pyrenees. The ice masses are north-facing, lie on structural flats beneath the main summit of the Monte Perdido Peak (3355 m), and are surrounded by vertical cliffs of 500-800 m in height (García-Ruiz and Martí-Bono, 2002). In this part of the pyrenees annual 0ºC isotherm was estimated to lie between 2950 and 3150 m a.s.l (López-Moreno et al., 2016).

METHODS.

We used six DEMs derived from annual Terrestrial Laser scanner (TLS) surveys to estimate the surface elevation changes in the Monte Perdido Glacier from 2011 to 2016. The device employed in the present study is a long-range TLS (RIEGL LPM321) that uses time-of-flight technology to measure the time between the emission and detection of a light pulse to produce a three-dimensional point cloud from real topography. The TLS used in this study employed light pulses at 905 nm (nearinfrared), which is ideal for acquiring data from snow and ice cover, a minimum angular step of 0.0188º, a laser beam divergence of 0.0468º, and a maximum working distance of 6000 m. We used an almost frontal view of the glacier with minimal shadow zones in the glacier and a scanning distance of 1500 to 2500 m. We also used indirect registration, also called target-based registration (Revuelto et al., 2014), so that scans from different dates (September of 2011 to 2016) could be compared. Indirect registration uses fixed reference points (targets) that are located in the study area. Eleven reflective targets of known shape and dimensions (cylinders of 10x10 cm for targets located closer than 200 m, and 50x50 cm squares for longer distances) were placed at reference points on rocks situated 200 to 500 m from the scan station. Using standard topographic methods, we obtained accurate global coordinates for the targets by use of a differential global positioning system (DGPS) with post-processing. The global coordinates were acquired in the UTM 30 coordinate system in the ETRS89 datum. The final precision for the set of target coordinates was ±0.05 m in planimetry and ±0.10 m in altimetry. A total of 65 reference points around the ice bodies (identifiable sections of rocks and cliffs) were used to assess measurement accuracy. Ninety percent of the reference points had an error of less than 0.40 m. Thus 0.4 m was taken as the uncertainty (error bars) when calculating the ice thinning.

RESULTS.

Figure 1 shows the spatial distribution of changes in glacier surface elevation during the period 2011-2016, whereas Table 1 shows the average annual and total values of ice surface changes. As overall, during the five analysed years the surface of the ice has lowered almost 4 meters (-3.71 meters). The changes have a heterogeneous distribution of the glacier with very reduced areas were accumulation still dominates (above 3000 m a.s.l.), and wide areas with a net lowering, that in some sector exceed 10 meters of ice depth losses. Annually, the evolution of the glacier exhibited a very contrasted behaviour, with years characterised by stationary or slight increases in ice depth (2013-2014 and 2012-13 respectively). Both years were characterized by high snow accumulation in winter and spring and relatively cool or mild summers. Oppositely, there are years in which glacier wastage is more pronounced with average ice losses of -1.81 and -1.70 meters for 2011-12 and 2014-15 respectively. These years exhibited relatively dry conditions during accumulation period and warm or very warm summers. The last year (2015-2016) exhibited a relatively small loss of ice (average of ice surface lowering= -0.39) associated to high snow accumulation, mainly during spring months and a warm summer.

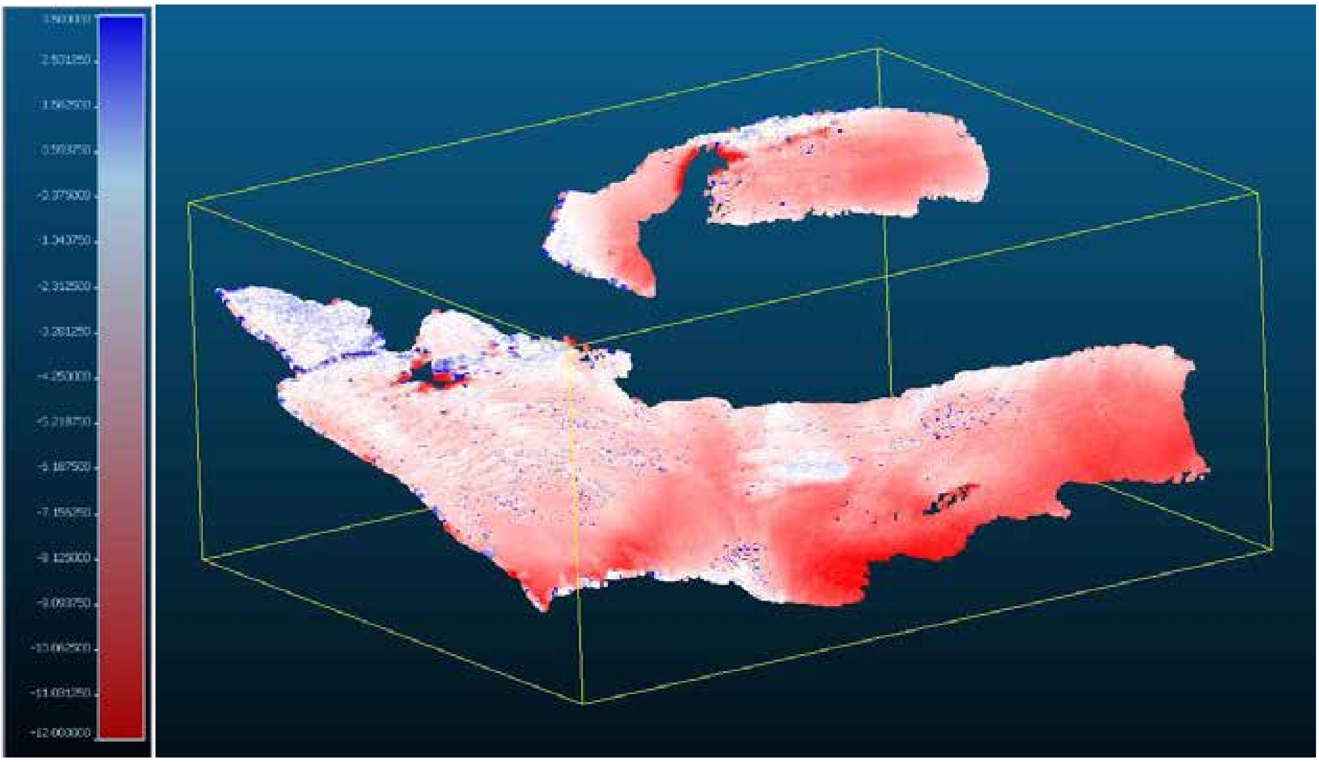

Figure 1.- Spatial distribution of ice surface changes for the period 2011-2016.

CONCLUSIONS.

Terrestrial Laser Scanner technique has been proved as a useful technique to monitor the annual evolution of Monte Perdido Glacier. During the last five years, the glacier has lost 4 meters of ice depth, what represents a similar rate of glacier wastage than exhibited during 2081-2010. Nonetheless, it is necessary to take into account that snow accumulation three out the five analysed years have presented clear positive anomalies compared to the long-term available records in the Pyrenees. The intense wastage observed in some parts of the glacier inform that wide sectors of the current glacier are seriously threatened, and they could disappear in the next few decades, remaining only the best sheltered and elevated portions of the glacier.

Period	Average surface lowering (m)
2011-2012	-1.81
2012-2013	0.35
2013-2014	-0.08
2014-2015	-1.70
2015-2016	-0.36
2011-2016	-3.71

Table 1.- Annual and total ice surface changes for the period 2011-2016

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