MONITORING OF A MELTING ICE PATCH FROM GEOMATIC TECHNIQUES: THE JOU NEGRO

Alan D.J. Atkinson
atkinson@unex.es

José Juan de Sanjosé Blasco
jjblasco@unex.es

Departamento de Expresión Gráfica
Escuela Politécnica de Cáceres
Universidad de Extremadura
Av. de la Universidad, s/n. 10071 Cáceres. España.

Enrique Serrano Cañadas
serranoe@fyl.uva.es
Juan José González Trueba
jjgtrueba@hotmail.com

Departamento de Geografía
Facultad de Filosofía y Letras. Universidad de Valladolid
Plaza del Campus, s/n. 47011 Valladolid. España.

Abstract

Introduction

Glaciers are receding all over the world and the loss of ice mass is a common fact in all mountains of the Earth.

Nowadays, glaciers suffer significant recession and they become an ice patch, that is to say, residual ice masses without motion but with melting mechanisms which imply adjustments and small movements.

Ice patches can be found in the Pyrenees and in the Cantabrian Mountains, which are situated in the north of the Iberian Peninsula. The processes related to the definitive deglaciation of mountains and the study of small glaciers and marginal ice bodies is nowadays an open research field of burgeoning interest. The Jou Negro is a glaciokarstic cirque located in the north-west of the Central Massif , on the north face of Torre Cerredo (2648 m), the highest summit of the Cantabrian Mountains.

Objectives

The aim of the study was to use geomatic techniques (GPS, Topographical survey, terrestrial photogrammetry) in order to determine the main features and the annual changes on the ice mass and around it.
This would provide information on possible changes in area, volume and melting in response to climate variations. Together with the geomatic techniques, climatic data analysis and geomorphological observations, it provides information on the present day evolution and variations of the ice mass related to geomorphogenic processes and climatic changes.

Methodology

Geomorphologic analysis: a geomorphologic map has been made with morphoclimatic characteristics of the glacier cirque of the Jou Negro, throughout which the geomorphologic framework can be known, in which the current ice patch is registered.

Climate Analysis: there had been no climatic data about Picos de Europa until last year (2008). On the cirque and moraines soil temperature dataloggers have been located. The Oviedo, Leon and Santander climatic record was examined for mean annual and mean summer temperatures in order to know the deviation between the mean summer temperature (June/July/August) from the summer annual mean temperatures (1973-2008). The results have been used to determine the climatic conditions of melting and geomorphological processes during the 2007/2008 period.

Geomatic analysis: the use of this technique is used in mountain environments, but not on ice patches in marginal environments where the morphology of the terrain on which the Jou Negro ice patch is situated, i.e. in a narrow and deep glaciokarstic depression, make it impossible to use of GPS. However, it is a potential site to use other geomatic techniques like Photogrammetry and Topographical surveys. Using topographic measuring, the ice patch perimeter has been measured and two transversal cross sections had been taken (NW-SE) during the years 2007 and 2008 and at an average attitude of 2264 and 2243 m.

Results

Although nowadays we only have topographic measuring from a very short period of time (2007-2008), we have detected a decrease in the ice patches' surface of 7% and a differentiated altimetric movement.

The highest cross section/profile shows subsidence of the ice (-0.68m), while in the lowest section it shows a rise (+0.51m). This is due to a movement in the ice patch by melting as a block in the rocky bottom.

Conclusions

Nowadays, the only thing we can say is that changes are being produced in the ice patch of Jou Negro due to the possible melting and slide of the ice. Although it is too soon to confirm the precise causes, it is true that the use of geomatic techniques such as topographical surveys is efficient in the quantification of the variation of the ice patches.

The works are developed in the field of an investigation project which has been financed by the Environmental Ministry, National Parks, (ref: 007/2007) and for this reason, we will have data from a new study and analysis in the next few years.

Keywords
Cartography, geomatic techniques, ice patch, Picos de Europa.

1.- Introduction

Glaciers are receding all over the world (many of them have even disappeared) during the 20th century and the loss of ice mass is a common fact in all mountains of the Earth, especially in the Iberian Peninsula (González Trueba et al. 2008). Nowadays, glaciers suffer significant recession and they become an ice patch, that is to say, residual ice masses without motion but with melting mechanisms which imply adjustments and small movements. Ice patches can be found in the Pyrenees and in the Cantabrian Mountains, which are situated in the north of the Iberian Peninsula. The processes related to the definitive deglaciation of mountains and the study of small glaciers and marginal ice bodies is today an open research field of burgeoning interest. Several authors (Grudd, 1983; Harris and Murton, 2005) have point out the important to know the processes of change between the last ice mass and the new non-glaciated morphonetic systems. Firstly, it is necessary to know the ice surface, the extension and the processes on the ice and around by means of the most accurate measurements. The study of marginal glaciated and periglacial areas provides knowledge of the last changes from a glaciated to a periglacial or unglaciated environment, and the processes involved are sensitive indicators of environmental change and climate fluctuations.

2.- Study area: the Jou Negro ice patch.

The Jou Negro ice patch is located in The Cantabrian Mountain where are located the Picos de Europa Masssif. The Picos de Europa massif is an Atlantic mountain system located in the North of the Iberian Peninsula, at 20 km from the Atlantic seaboard, and reaching 2648 m a.s.l. (the Torre Cerredo peak). The rugged relief of the Picos de Europa is characterized by great differences in altitude (over 1500–2300 m), and it is the first orographic barrier facing the rain-bearing winds from the Atlantic Ocean. These geographic features of an oceanic high mountain environment make it highly sensitive to recent climate changes. The Picos de Europa range consists of a succession of fault thrusts of northern dipping, calcareous rocks where the predominant rocks are

the Mountain Limestone Facies of Carboniferous age. The relief is the result of its geological background (stratigraphy and tectonics) and Quaternary geomorphological processes – mainly glacial, karstic, and periglacial and it is characterized by calcareous, steep and rugged relief, with altitude differences of over 2300 m. It was the only glaciated massif of the Cantabrian Mountains during the Little Ice Age (LIA) between the 14th and 19th centuries. The last ice bodies in the Cantabrian Mountains are located high on this massif.

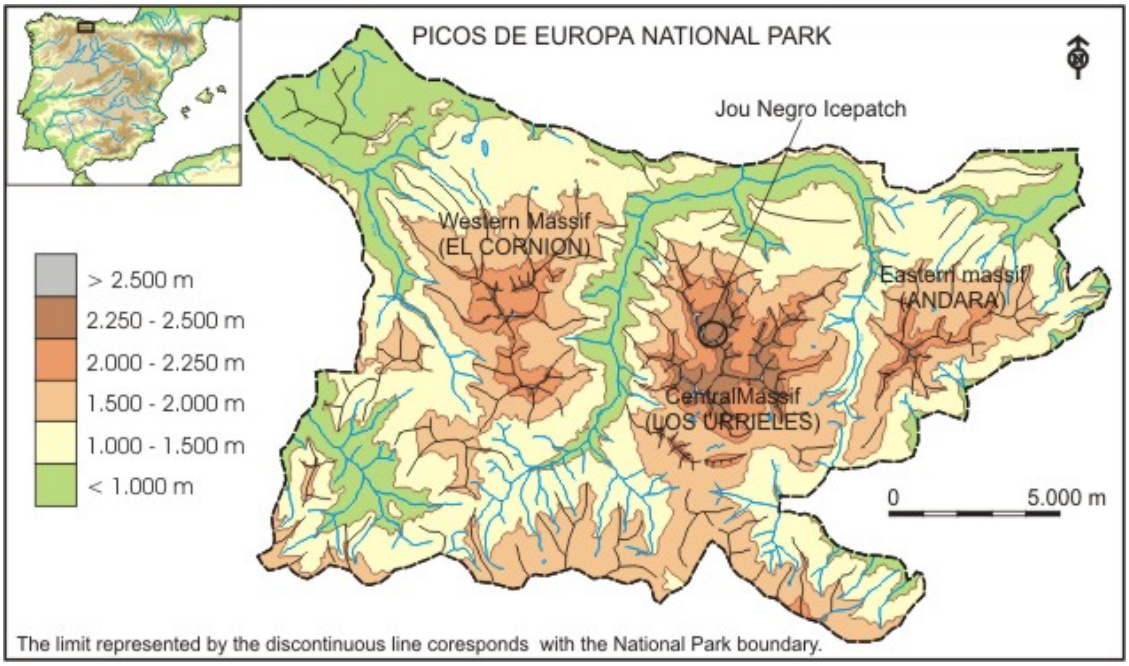

Figure 1: Location of the Picos de Europa and the Jou Negro ice-patch.

The Jou Negro is a glaciokarstic cirque located in the north-west of the Central Massif, on the north face of Torre Cerredo, that is the highest summit of the Cantabrian Mountains (Fig. 1). The cirque contains the most interesting glacial and periglacial features and the most extensive ice body of the Cantabrian high mountains, both of which are uncommon in the Picos de Europa. During the LIA a very small glacier of 52 ha (easily reconstructed from the well conserved terminal moraine) occupied the Jou Negro cirque. It was a low altitude glacier favoured by topoclimatic factors and its oceanic environment (González Trueba, 2006, 2007).

Different studies have pointed to the presence of an ice-patch inherited from the LIA in the Jou Negro cirque, and recent work has focused on the last historical advance (Frochoso y Castañón, 1995; Alonso y González, 1998; González Trueba, 2006). The key factors for the development of the Jou Negro glacier during the LIA were orientation and exposure (a north-facing cirque), the cirque's steepness with 400 m high walls protecting it from solar radiation, and the glacier's being fed by avalanches off the

walls. In these conditions, the moderate altitude was enough to generate a small glacier at 2235 m.

Today, the glacial dynamics has ended, and the glacier has shrunk into a debris-covered ice-patch ("glacieret"). This ice-patch is in a phase of regression, having undergone a loss of around 65% of its previous area [5],[8] and a major decrease in volume. Indeed, melting has been rapid for over 70 years, and a morphology typical of melting has developed – a bevelled snout where the ice structures are visible. There exist no crevasses to denote any present day movement.

On the Jou Negro slopes, the commonest processes are rockfall by gelifraction forming a talus of debris at the bottom of the cirque. Other processes being generated in the cirque are debris flow and moraine slides. This all implies the feed of debris onto the ice body, with the abundant presence of clasts within the ice, banding of white and black layers of ice, and a progressive mantling of the surface of the ice-patch with clastic material. The surface presents several vertical ice sink-holes or "moulins" produced by water melting down into the endokarstic system.

3.- Objectives and Methodology

The aim of the study was to use geomatic techniques (DGPS, Topographical survey, terrestrial photogrammetry) to know the main features and the annual changes on the ice mass and around. This would provide information on possible changes in area, volume and melting in response to climate variations. Joint to the geomatic techniques, climatic data analysis and geomorphological observations add information on the present day evolution and variations of the ice mass related to geomorphogenic processes and climatic changes. In this context, geomatic survey was implemented as a complement to the other techniques that are being used in the ongoing study: GPR sounding and temperature monitoring. The use of this technique is used in mountain environments, but not on ice patch in marginal environments where the morphology of the terrain on which the Jou Negro ice-patch is situated, in a narrow and depth glaciokarstic depression, make it impossible the use of DGPS but it is a potential place to use other geomatic techniques.

3.1.- Geomorphologic analysis

A geomorphologic map has been made with morphoclimatic characteristics of the glacier cirque of the Jou Negro, throughout which the geomorphologic framework can be known, in which the current ice patch is located. 30 geomorphologic elements have been represented throughout the fieldwork of the ice patch environment (Fig. 2). Also, a more detailed scale and geomorphologic map with morph dynamic character has been realized in which is shown the forms and the active processes about the glacier and the immediate environment, walls, moraines of the LIA and deglaciated canals. In it, is

represented 10 elements, forms and geomorphologic processes which explain the current dynamics and the spatial relations between the different processes.

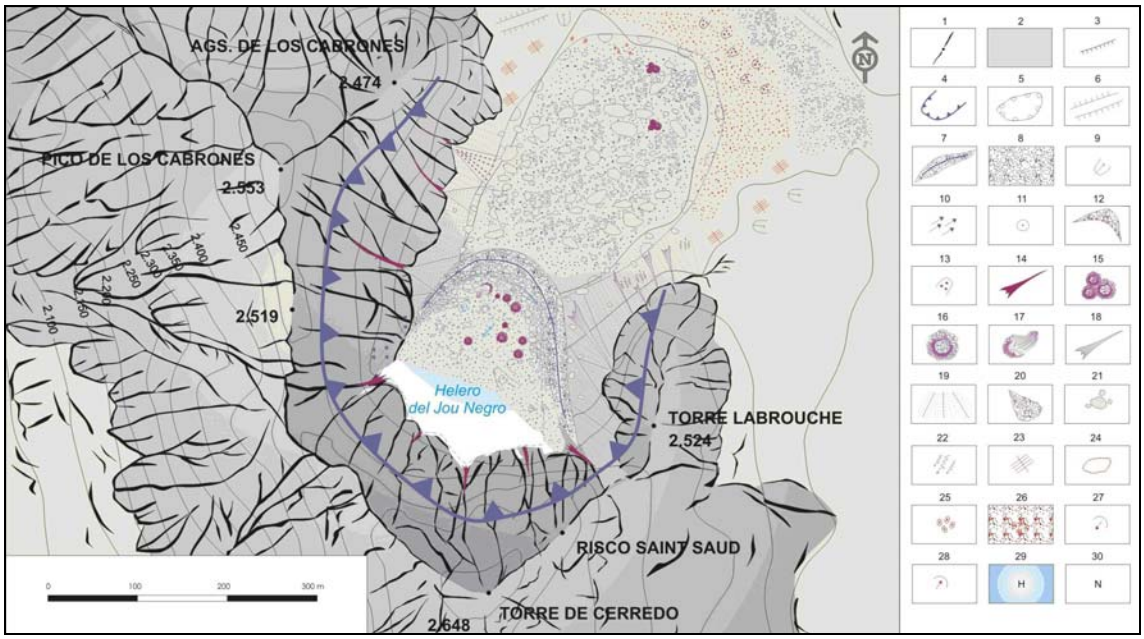

Figure 2: Geomorphological sketch of Jou Negro (Modified from González Trueba, 2007). 1, peaks and ridges. 2, rock wall. 3, scarp. 4, glacial cirque. 5, glaciokarstic bassin. 6, bar. 7, moraine. 8, till. 9, rochés moutoneés. 10, stries and abrasion microforms. 11, Melt hollow. 12, protalus rampart. 13, gelifluction lobe. 14, Snowfall channel. 15, patterned ground. 16, frost mound. 17, mud flow. 18, debris flow. 19, debris slope. 20, rock fall. 21, blocks fall. 22, fluvial incision. 23, lapiaz. 24, doline. 25, karstic hole. 26, recovered doline. 27, Karstic spring. 28, karstic sinkhole. 29, ice-patch. 30, snow-patch.

3.2.- Climatic analysis

Climatic data of Picos de Europa high mountain do not exist until the last year (2008). The nearest meteorological stations of Cantabrian Mountains have fragmentary data and they are also located too far from the ice patch. Out of the mountain exist continuous record of meteorological data (from 1973 until today) in the Leon (95 km southwest), Santander (88 km northeast) and Oviedo (86 km northwest), forming a triangle with the Picos de Europa massif at the centre. On the cirque and glacier soil temperature datalogger have been located. The Leon, Oviedo and Santander climatic record was examined for mean annual and mean summer temperatures to know the deviation between the mean summer temperatures (June/July/August) from the summer annual mean temperatures (1973-2008). The results have used to know the climatic conditions of melting and geomorphological processes during the 2007-2008 period.

3.3.- Geomatic analysis

The use of this technique is used in mountain environments, but not on ice patches in marginal environments where the morphology of the terrain on which the Jou Negro ice patch is situated, i.e. in a narrow and deep glaciokarstic depression, make it impossible to use of GPS. However, it is a potential site to use other geomatic techniques like Photogrammetry and Topographical surveys. Using topographic measuring, the ice patch perimeter has been measured and two transversal cross sections had been taken (NW-SE) during the years 2007 and 2008, and the perimeter of the ice patch as well. The two transversal sections have an average altitude of 2264 and 2243 m. During the year 2008 a longitudinal profile has been mapped which is going to be compared during the next years in order to analyze its dynamics.

4.- Results

Using the topographic technique, we have obtained quantitative data of the ice patch of the Jou Negro, with a length of 173 m and with an orientation of $\theta = 58^g$ (NE). The average width is 51.93m, with a minimum value of 20m and a maximum value of 120m. Comparing the measurements taken during the year 2007 and 2008, the surface of the ice-patch has been reduced by 7.34% (from 9327 m^2 to 6642 m^2). Likewise, during the year 2008 a covering has been produced of 197m2 due to fallen debris flow over the ice patch. In figure 3, can be seen the surface during the years 2007 and 2008, the surface which was hidden by glacial drifts and also the location of the two transversal profiles and the longitudinal profile.

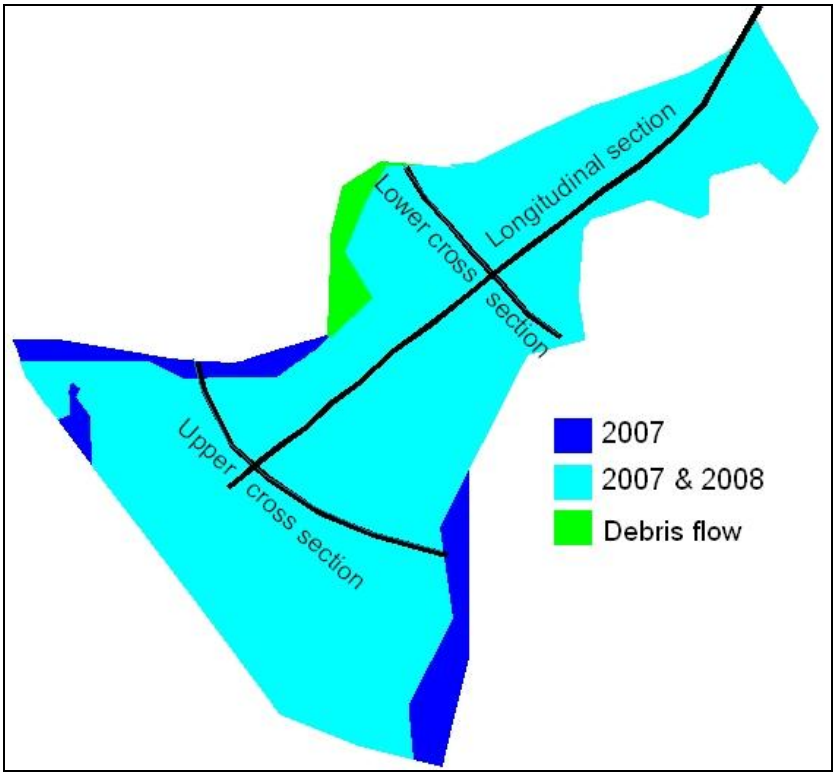

Figure 3: The surface of the ice patch during years 2007 and 2008. The surface hidden by debris flow during 2008. Location of the longitudinal and the transversal profile.

In chart 1 and in figure 4, can be seen the results of the topographic measurements taken during the years 2007 and 2008.. Although nowadays we only have topographic measuring from a very short period of time (2007-2008), the highest cross section/profile shows subsidence of the ice (-0.68m), while in the lowest section it shows a rise (+0.51m). This is due to a movement in the ice patch by melting as a block in the rocky bottom.

Section	*Year*	*#1*	*#2*	*#3*	*#4*	*#5*	*#6*	*#7*	Mean
Upper	2007	2262.74	2263.72	2264.54	2264.41	2264.74	2264.68	2263.65	*2264*
	2008	2262.52	2262.35	2264.24	2263.58	2263.83	2264.06	2263.11	
	Loss	-0.22	-1.37	-0.30	-0.83	-0.91	-0.62	-0.54	**-0.68**
Lower	2007	2245.05	2243.64	2242.24	2241.48	2241.18	2241.66	2242.24	*2243*
	2008	2245.50	2243.89	2242.85	2242.35	2241.92	2242.15	2242.40	
	Gain	0.45	0.25	0.61	0.87	0.74	0.49	0.16	**0.51**

Chart 1: Elevations in meters of the two transversal sections (upper and lower) during the years 2007 and 2008. Loss and gain of each points and medium values.

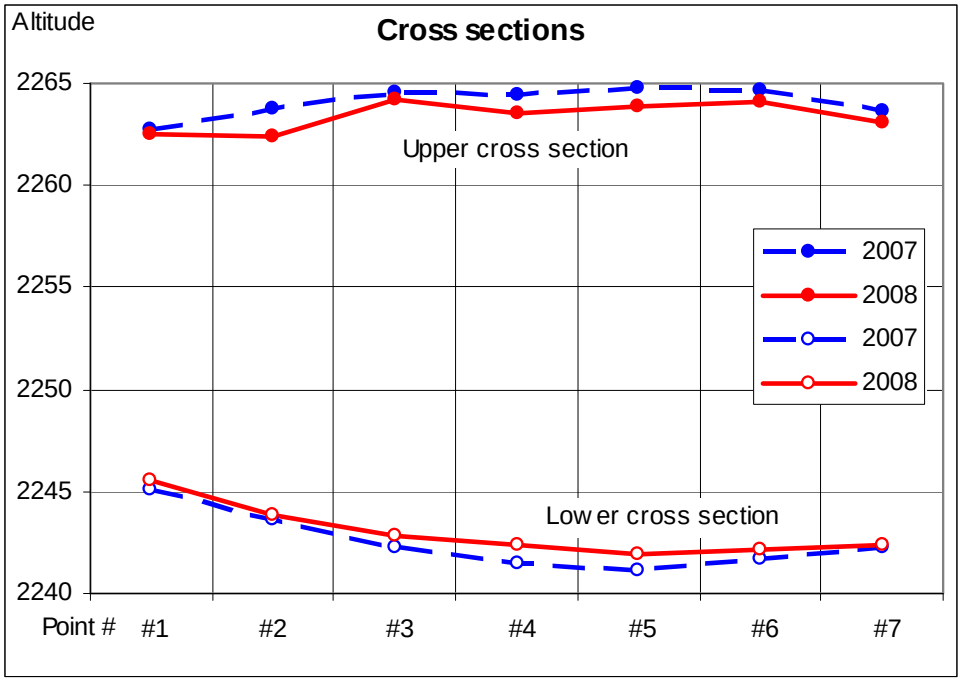

Figure 4: Transversal profiles in the years 2007/2008.

5.- Conclusions

Nowadays, the only thing we can say is that changes are being produced in the ice patch of Jou Negro due to the possible melting and slide of the ice. Although it is too soon to confirm the precise causes, it is true that the use of geomatic techniques such as topographical surveys is efficient in the quantification of the variation of the ice patches.

Acknowledgements

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