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Soil temperatures in an Atlantic high mountain environment: The Forcadona buried ice patch (Picos de Europa, NW Spain)

Jesús Ruiz-Fernández [a,*], Marc Oliva [b], Filip Hrbáček [c], Gonçalo Vieira [b], Cristina García-Hernández [a]

[a] Department of Geography, University of Oviedo, Oviedo, Spain
[b] Centre for Geographical Studies, Institute of Geography and Spatial Planning, Universidade de Lisboa, Lisbon, Portugal
[c] Department of Geography, Masaryk University, Brno, Czech Republic

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ABSTRACT

The present study focuses on the analysis of the ground and near-rock surface air thermal conditions at the Forcadona glacial cirque (2227 m a.s.l.) located in the Western Massif of the Picos de Europa, Spain. Temperatures have been monitored in three distinct geomorphological and topographical sites in the Forcadona area over the period 2006–11. The Forcadona buried ice patch is the remnant of a Little Ice Age glacier located in the bottom of a glacial cirque. Its location in a deep cirque determines abundant snow accumulation, with snow cover between 8 and 12 months. The presence of snow favours stable soil temperatures and geomorphic stability. Similarly to other Cantabrian Mountains, the annual thermal regime of the soil is defined by two seasonal periods (continuous thaw with daily oscillations and isothermal regime), as well as two short transition periods. However, the results showed evidence of a significantly different annual thermal regime at the ground and near-rock surface air. Relatively stable soil thermal regimes were observed at the moraine and talus sites, while a more dynamic pattern was recorded at the rock wall site. Here, a higher interannual variability in the number of freeze–thaw days was also detected, which showed evidence of the important role of the snow cover as a ground surface insulator in the area. Seasonal frost conditions are widespread today in the high lands of the massif. No permafrost regime was detected in the area, though mean temperatures measured at 0.5 m depth at the Forcadona buried ice patch during 2006–07 (0.1 °C) suggest that permanent negative values may be reached at deeper layers.

1. Introduction

Soil temperatures play a key control on geomorphological processes occurring in periglacial environments. In mid-latitude mountain regions such is the case of Iberian mountains, periglacial processes are confined today to the highest elevations and encompass a limited surface above 2000–2500 m (Oliva et al., 2016b). In these areas, snow cover is one of the factors that strongly influence the soil thermal regime and associated periglacial activity (Edwards et al., 2007). The duration and thickness of the snow cover influences both geomorphological and biological processes, but also socio-economic activities in the mountains as well as in neighbouring areas. During the cold season water is stored in the form of snow in the highlands of the mountains and limits geomorphic activity. Moreover, it also insulates the ground from the atmosphere (Ishikawa, 2003; Zhang, 2005; Frauenfeld et al., 2007). When snow melts, geomorphic activity intensifies. Such is the case of the mountains of Iberia, where periglacial dynamics is especially effective during the snow melting period when the ground can still be frozen and high water availability enhances erosion and mass-wasting processes (Oliva et al., 2009, 2014a).

Research on the ground thermal regime in Iberian mountains has been intense during the last years in the highest mountains ranges. Permafrost conditions have been only detected in the highest areas in the Pyrenees (Serrano et al., 2001, 2006; Lugon et al., 2004; González García et al., 2016), as well as in Sierra Nevada where permafrost is spatially limited to the areas which hosted a glacier during the Little Ice Age (Gómez-Ortiz et al., 2014; Oliva et al., 2016a, 2016b). In other mountain environments seasonal frost conditions have been detected, as it is the case of the Galician ranges (Carrera and Valcárcel, 2010), Iberian Central Range (Andrés and Palacios, 2010) or Serra da Estrela (Vieira et al., 2003).

In the case of the Cantabrian Mountains, there has been a substantial advance on the knowledge of present-day periglacial dynamics over the last decades (e.g. Castañón and Frochoso, 1994, 1998; González-Gutiérrez, 2002; Serrano and González-Trueba, 2004; González-Trueba, 2007a; Rodríguez-Pérez, 1995, 2009; Santos-González, 2010; Pellitero, 2012; Ruiz-Fernández, 2013; Ruiz-Fernández et al., 2014). However, only a few studies have examined the relationship between the geomorphological setting and morphoclimatic conditions in the area (Castañón and Frochoso, 1998; Santos-González et al., 2009; González-Trueba and Serrano, 2010;

* Corresponding author at: Department of Geography, University of Oviedo, Teniente Alfonso Martínez s/n, 33011 Oviedo, Spain.
E-mail address: ruizjesus@uniovi.es (J. Ruiz-Fernández).

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Pellitero, 2012; Ruiz-Fernández et al., 2014; Pisabarro et al., 2015). Currently, in the summit areas of the highest massifs periglacial dynamics is active, since the remobilization of particles on the slopes is very intense, through processes such as solifluction, cryoturbation, debris flows and snow avalanches (Brosche, 1978; Castañón and Frochoso, 1994, 1998; Serrano and González-Trueba, 2004; González-Trueba and Serrano, 2010; Ruiz-Fernández et al., 2014).

In this sense, the present study focuses on the analysis of the ground thermal conditions and the near-rock surface air temperatures in the Western Massif of the Picos de Europa, one of the highest massifs of the Cantabrian Mountains. The specific purposes of this research are:

1) Characterize the interannual and intraannual variability of the ground and near-rock surface air temperatures in the last recently deglaciated environment in this massif.
2) Identify the role of snow cover on the ground thermal regime in different topographical settings, as well as its evolution during the study period.

2. Study area

The Picos de Europa (43° 7′ N - 43° 17′ N, 4° 35′ W - 5° 3′ W), protected as National Park and Biosphere Reserve is the highest massif of the Cantabrian Mountains (Torrecerredo, 2648 m a.s.l.). These mountains located in NW Iberia are organized in three single massifs separated by deep gorges: the Western Massif or Cornión, the Central Massif or Urrieles and the Eastern Massif or Ándara. The study area of this research is included in the Western Massif (Fig. 1), the largest and second highest massif with peaks such as Peña Santa de Castilla (2596 m), Torre Santa María (2486 m), Torres del Mediu (2467 m) and Torres del Torco (2452 m).

The Picos de Europa are basically composed of Carboniferous limestones of the Griotte, Montaña and Picos de Europa formations (Marquínez, 1989). Other Palaeozoic rocks (mainly quartzites, sandstones, shales and conglomerates), are also present in the northern and southernmost fringes of the three massifs. Limestone formations are organized in successive layers overthrusting southwards. The bedrock has been deeply shaped by fluvial erosion, intense karstic processes (Miotke, 1968; Smart, 1986; Ballesteros et al., 2015), as well as Quaternary glaciations (Frochoso and Castañón, 1998; Ruiz-Fernández et al., 2009; Moreno et al., 2010; Serrano et al., 2012; Jiménez et al., 2013). Periglacial processes are currently widespread in the highest lands of the Picos de Europa conditioned by the existence of seasonal frost and snowmelt water (Castañón and Frochoso, 1998; Serrano and González-Trueba, 2004; González-Trueba and Serrano, 2010).

Climate conditions in the Picos de Europa are typical of temperate maritime mountain environments, with annual precipitation between 1700 and 1900 mm in northern slopes at 700–900 m and exceeding 2500 mm in the highest elevations. In the later, precipitation mostly fall in the form of snow, and snow cover lasts for ca. 8 months as average per year (Ruiz-Fernández, 2013). In sheltered environments, long-lasting snow fields persist almost throughout the year, such as in the Forcadona area. This research is precisely focused on this area where a buried ice patch is located. This site is placed at 2227 m, between the Peña Santa de Castilla (east) and Torres del Torco (west) peaks (Fig. 1). It is covered by debris which protected it from solar radiation. The Forcadona buried ice patch constitutes the contemporary remnant of a cirque glacier that existed in the area during the Little Ice Age (LIA). During the LIA the Picos de Europa concentrated six glaciers, three of which were distributed in the Western Massif (González-Trueba, 2005, 2006; González-Trueba et al., 2008).

3. Methods

A detailed geomorphological map of the Forcadona area was prepared in September 2011 to identify the main landforms and

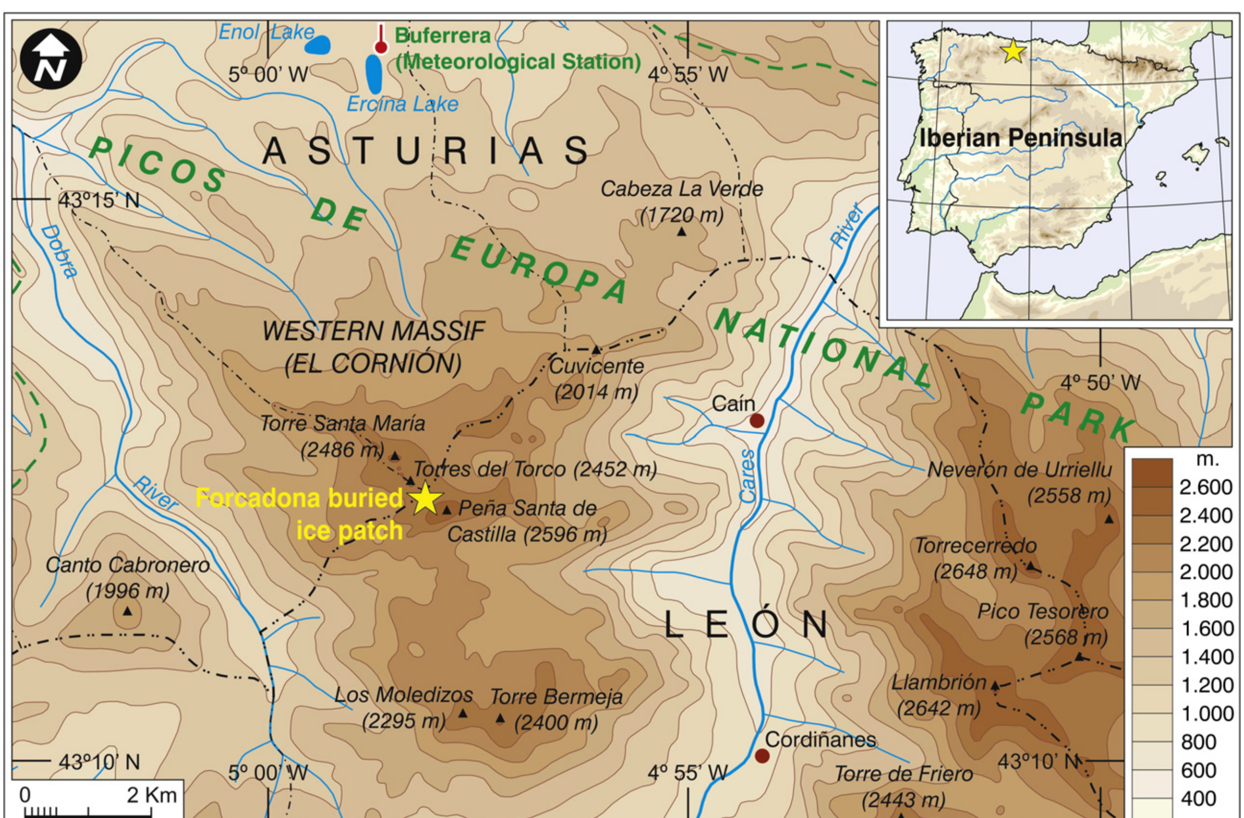

Fig. 1. Location of the Forcadona area within the Picos de Europa.