Quaternary Science Reviews 181 (2018) 1–18

Contents lists available at ScienceDirect

Quaternary Science Reviews

journal homepage: www.elsevier.com/locate/quascirev

Early Holocene humidity patterns in the Iberian Peninsula reconstructed from lake, pollen and speleothem records

Mario Morellón [a, *], Josu Aranbarri [b], Ana Moreno [c], Penélope González-Sampériz [c], Blas L. Valero-Garcés [c]

[a] CITIMAC, Facultad de Ciencias, University of Cantabria, Avenida de los Castros s/n, 39005 Santander, Cantabria, Spain
[b] Department of Geography, Prehistory and Archaeology, University of Basque Country, C/ Tomás y Valiente s/n, 01006 Vitoria-Gasteiz, Basque Country, Spain
[c] Department of Geoenvironmental Processes and Global Change, Pyrenean Institute of Ecology (IPE) – CSIC, Avenida Montañana, 1005 Zaragoza, Spain

ARTICLE INFO

Article history:
Received 25 April 2017
Received in revised form
6 November 2017
Accepted 13 November 2017

Keywords:
Early Holocene
Summer insolation maximum
Aridity
Inner Iberian Peninsula
Palaeohydrology
Vegetation changes
Lake records
Speleothems
Pollen

ABSTRACT

Comparison of selected, well-dated, lacustrine, speleothem and terrestrial pollen records spanning the Holocene onset and the Early Holocene (ca. 11.7–8 cal kyrs BP) in the Iberian Peninsula shows large hydrological fluctuations and landscape changes with a complex regional pattern in timing and intensity. Marine pollen records from Alboran, the Mediterranean and off shore Atlantic sites show a step-wise increase in moisture and forest during this transition. However, available continental records point to two main patterns of spatial and temporal hydrological variability: i) Atlantic-influenced sites located at the northwestern areas (Enol, Sanabria, Lucenza, PRD-4), characterized by a gradual increase in humidity from the end of the Younger Dryas to the Mid Holocene, similarly to most North Atlantic records; and ii) continental and Mediterranean-influenced sites (Laguna Grande, Villarquemado, Fuentillejo, Padul, Estanya, Banyoles, Salines), with prolonged arid conditions of variable temporal extension after the Younger Dryas, followed by an abrupt increase in moisture at 10-9 cal kyrs BP. Different local climate conditions influenced by topography or the variable sensitivity (gradual *versus* threshold values) of the proxies analyzed in each case are evaluated. Vegetation composition (conifers *versus* mesothermophilous taxa) and resilience would explain a subdued response of vegetation in central continental areas while in Mediterranean sites, insufficient summer moisture availability could not maintain high lake levels and promote mesophyte forest, in contrast to Atlantic-influenced areas. Comparison with available climate models, Greenland ice cores, North Atlantic marine sequences and continental records from Central and Northern Europe and the whole Mediterranean region underlines the distinctive character of the hydrological changes occurred in inner Iberia throughout the Early Holocene. The persistent arid conditions might be explained by the intensification of the summer drought due to the high seasonality contrast at these latitudes caused by the orbital-induced summer insolation maximum. New records, particularly from western and southernmost Iberia, and palaeoclimate models with higher spatial resolution would help to constrain these hypotheses.

1. Introduction

Hydrological variability has played a central role in the history of the Mediterranean region, characterized by both, an annual hydrological deficit and an intensive water management during its long history of human occupation. This area is considered as one of the most vulnerable under current Global Warming (Bates et al., 2008; Giorgi and Lionello, 2008) and the scenarios of changing climate and increasing human pressure pose great challenges for societies in the 21st century. The impact of recent climate changes in the hydrological cycle has been analyzed using instrumental data series and models (Vicente-Serrano et al., 2010) and shows increasing variability in flood regimes and drought severity and frequencies. However, longer time-scales are needed to understand the regional variability, the frequency and the internal dynamics of these hydrological fluctuations. Furthermore, due to the high geo- and bio-diversity of the Mediterranean areas, a regional approach

* Corresponding author.
E-mail address: mario.morellon@unican.es (M. Morellón).

https://doi.org/10.1016/j.quascirev.2017.11.016
0277-3791/

based on a network of sites is also crucial to reconstruct spatial patterns of past hydrological fluctuations and their impacts (Fletcher and Zielhofer, 2013; González-Sampériz et al., 2017; Magny et al., 2013a; Moreno et al., 2012a).

The transition from the Younger Dryas (Greenland Stadial 1, GS-1) to the Holocene in the Greenland ice cores occurred within 3 years (Steffensen et al., 2008) and the subsequent first millennia of the Early Holocene (ca. 11.7–8 cal kyrs BP) were generally characterized by a rapid global temperature increase, punctuated by short-lived, abrupt cooling phases. This abrupt warming in the Greenland ice cores following the GS-1 (Taylor et al., 1997) has been associated with a rapid resumption of the Atlantic Meridional Overturning Circulation (AMOC) after centuries of reduced activity (McManus et al., 2004), although the understanding of the parameters driving the change in the intensity and the rate at which these events occurred is still limited (Renssen et al., 2015). Climate models outputs have reconstructed a spatially and temporal heterogeneous increase in temperature across high and mid latitudes (Mauri et al., 2015; Renssen et al., 2009) and have linked it to the progressive deglaciation of the large ice sheets of the Northern Hemisphere (Fennoscandian and Laurentide), still remaining until ca. 8.7 and 7 cal kyrs BP, respectively (Carlson et al., 2008; Lindén et al., 2006; Patton et al., 2017). The presence of these ice sheets likely modulated the effects of the orbitally-induced summer insolation maximum, occurring between ca. 11 to 9 cal kyrs BP (Berger, 1978), and their waning dynamics would have caused abrupt coolings due to variable ice meltwater inputs into the North Atlantic (Alley et al., 2001; Clark et al., 2001; Renssen et al., 2005). As high latitudes were subjected to a delay in the achievement of maximum temperatures, warming in latitudes below 45ºN, like the Mediterranean Basin, was more directly controlled by orbitally driven changes (Renssen et al., 2009). Even within the same broad climate regime, such as the North Atlantic realm, there are increasing evidences on the diachronic character of past climate changes prior to the Holocene onset (Lane et al., 2013) and during the Holocene (Renssen et al., 2012; Wanner et al., 2008).

The hydrological responses during this period of rapid oceanic and atmospheric changes, are even more complex and show a high spatial and temporal variability (Clark et al., 2012). Although there is a general pattern of increase in humidity following arid conditions during the late glacial, differences are evident when comparing records from different latitudes and regions (Garcin et al., 2007; Magny and Bégeot, 2004; Magny et al., 2003). According to terrestrial records, a simultaneous increase in moisture availability occurred in northwestern Europe (Moreno et al., 2014b). In contrast, mid-latitude regions like the Mediterranean Basin, located under the influence of the North Atlantic westerly winds and the Azores High, displayed more variable hydrological changes. Available paleoclimate reconstructions in this region show a progressive increase in humidity during the transition from late glacial to Holocene conditions, but interrupted by arid periods with a variable intensity, timing and temporal duration, in some cases restricted to the Younger Dryas and in other cases, extending longer into the first millennia of the Early Holocene (Magny et al., 2013a; Moreno et al., 2012a; Zielhofer et al., 2017). The Alboran pollen records (Combourieu Nebout et al., 2009; Fletcher et al., 2010) reveal a clear step-wise increase in forest and reconstructed precipitation around 10.5 cal kyrs BP, as well as ~900 year oscillations related to the Early Holocene cooling events. Other western sites, both in marine (Hooghiemstra et al., 1992; Naughton et al., 2007, 2016; Roucoux et al., 2005; Turon et al., 2017) and continental areas (Serra da Estrela, van der Knaap and van Leeuwen (1997); Beliche, Fletcher et al. (2007)) also show a general increase in humidity with centennial-scale changes. Interestingly, in the Mediterranean regions, the occurrence of relatively dry conditions evidenced by lower lake levels and delayed afforestation reached as far south as ca. 40ºN. Contrasting hydrological patterns were reconstructed between northern and southern areas of the Central Mediterranean (Magny et al., 2013a) and western and eastern areas of the Mediterranean Basin (Roberts et al., 2008) and marine records, (Martinez-Ruiz et al., 2015).

The Iberian Peninsula, located at the boundary between Eurosiberian and Mediterranean bioclimatic regions, stands out as an ideally suited region to investigate the timing, amplitude and spatial variability of Early Holocene hydrological fluctuations and their relation to the North Atlantic and subtropical dynamics. Different spatial patterns have been reconstructed for other periods of climate change, such as the late glacial (Carrión et al., 2010; Moreno et al., 2012a), the Mid-to Late Holocene (Fletcher and Zielhofer, 2013), the last 2000 years (Sánchez-López et al., 2016) and the Medieval Climate Anomaly (Moreno et al., 2012b) and for specific regions, such as the Southern Pyrenees (González-Sampériz et al., 2017; Morellón et al., 2012). The increasing number and better spatial distribution of new and well-dated records in the Iberian Peninsula, as lake sequences (Moreno et al., 2012a; Valero-Garcés and Moreno, 2011) and references therein and speleothems (Moreno et al., 2010a, 2017; Stoll et al., 2013) allows a critical review and synthesis of the main hydrological changes occurred during the late glacial - Holocene in the Iberian Peninsula.

In this paper, we evaluate the timing and spatial variability of hydrological changes occurred in the Iberian Peninsula during the transition between the Greenland Stadial 1 (GS-1) and the Mid Holocene (between ca. 13 and 8 cal kyrs BP) based on the comparison of available records located in different bioclimatic regions and geographical contexts, from the Atlantic façade to the northeastern Mediterranean coast and from high altitude sites to the lowlands. Records from critical areas of the Iberian Peninsula as the western, central and southern regions are still scarce. The combination of proxies, including pollen, sedimentology and geochemistry in lake records and stable isotopes in speleothems has enabled a more detailed reconstruction of the main environmental changes occurred during this key period in climate history. Detected synchronies and asynchronies in reconstructed hydrological phases evidence the complexity of this period and allows discussion on the different sensitivities of reviewed proxy data series, identification of the main potential climate forcing mechanisms and teleconnections affecting this region during the transition from late glacial conditions to the Holocene.

2. Regional setting

The Iberian Peninsula (IP) (36º00′-43º27′N, 9°50′W-3°20′E) is located in the southwestern corner of Europe (Fig. 1A) and with a total surface of 582,000 km^2 is one of the largest landmasses in the Mediterranean. Geology and orography are quite varied (Vera et al., 2004). In northern Iberia, the Galaico-Leones, Cantabrian and Pyrenean ranges comprise the most prominent orographic features while the central IP is defined by the high elevation plateaux (Northern and Southern *Mesetas*), divided by the Central Ranges. The NW-SE trending Iberian Range constitutes the hydrological divide between Atlantic and Mediterranean watersheds (Fig. 1B).

Average annual temperatures range from 0 °C in the northern mountains (Pyrenees, Cantabrian) to 18 °C in the southern and eastern areas; highest precipitations are recorded on the northern mountains (>1500 mm/yr), while the inland and southern regions are drier (<500 mm/yr) (Capel Molina, 1981). Climate conditions are mostly controlled by the position and intensity of the Azores High Pressure, particularly in western and northern areas of the IP. Dry and hot conditions occur in summer because of the stronger influence of this subtropical high pressure belt (Sumner et al.,