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Solar and proxy-sensitivity imprints on paleohydrological records for the last millennium in west-central Europe

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ABSTRACT

This paper presents a lake-level record established for the last millennium at Lake Saint-Point in the French Jura Mountains. A comparison of this lake-level record with a solar irradiance record supports the hypothesis of a solar forcing of variations in the hydrological cycle linked to climatic oscillations over the last millennium in west-central Europe, with higher lake levels during the solar minimums of Oort (around AD 1060), Wolf (around AD 1320), Spörer (around AD 1450), Maunder (around AD 1690), and Dalton (around AD 1820). Further comparisons of the Saint-Point record with the fluctuations of the Great Aletsch Glacier (Swiss Alps) and a record of Rhône River floods from Lake Bourget (French Alps) give evidence of possible imprints of proxy sensitivity on reconstructed paleohydrological records. In particular, the Great Aletsch record shows an increasing glacier mass from AD 1350 to 1850, suggesting a cumulative effect of the Little Ice Age cooling and/or a possible reflection of a millennial-scale general cooling until the mid-19th century in the Northern Hemisphere. In contrast, the Saint-Point and Bourget records show a general trend toward a decrease in lake levels and in flood magnitude anti-correlated with generally increasing solar irradiance.

Introduction

The perspective of a global warming scenario has provoked an increasing interest in studies of climate variability over the last millennium. They preferentially document past changes in temperature (Mann et al., 1999, 2008; Crowley, 2000; Jones et al., 2001; Guiot et al., 2005; Moberg et al., 2005). However, the reconstruction of changes in the hydrological cycle associated with climatic oscillations and with relationships concerning availability of water resources is a scientific key question for the paleoclimatologist community (Vörösmarty et al., 2000).

As a contribution to such studies, this paper presents a new paleohydrological record for the last millennium based on the reconstruction of changes in lake level at Lake Saint-Point in the French Jura Mountains. This record offers the opportunity to test hypotheses about the possible driving factors behind regional paleohydrological variability during this period (Magny et al., 2008), while inter-regional comparisons with other paleohydrological records point to other possible imprints on records such as proxy sensitivity and/or complex interactions between precipitation and temperature.

Site and methods

Lake Saint-Point (46°48′N, 6°12′E) is a 7.6-km-long narrow and overdeepened basin of glacial origin. The present water depth reaches 41 m and the lake area is 7 km^2. It is located at an altitude of 850 m a.s.l. in the highest part of the French Jura Mountains (Fig. 1). The surrounding mountains attain ca. 1450 m a.s.l. The catchment area of the lake covers ca. 247 km^2. The substratum mainly comprises Upper Jurassic and Tertiary limestones (Leroux et al., 2008).

The main inlet (as well as the outlet) of the lake is the Doubs River. The seasonal fluctuations of the water table are characterized by maximal levels most often due to autumn rains and spring snowmelt, while minimal levels result from summer droughts (Magnin, 1904; Barbe et al., 1979). The Lake Saint-Point region is marked by relatively

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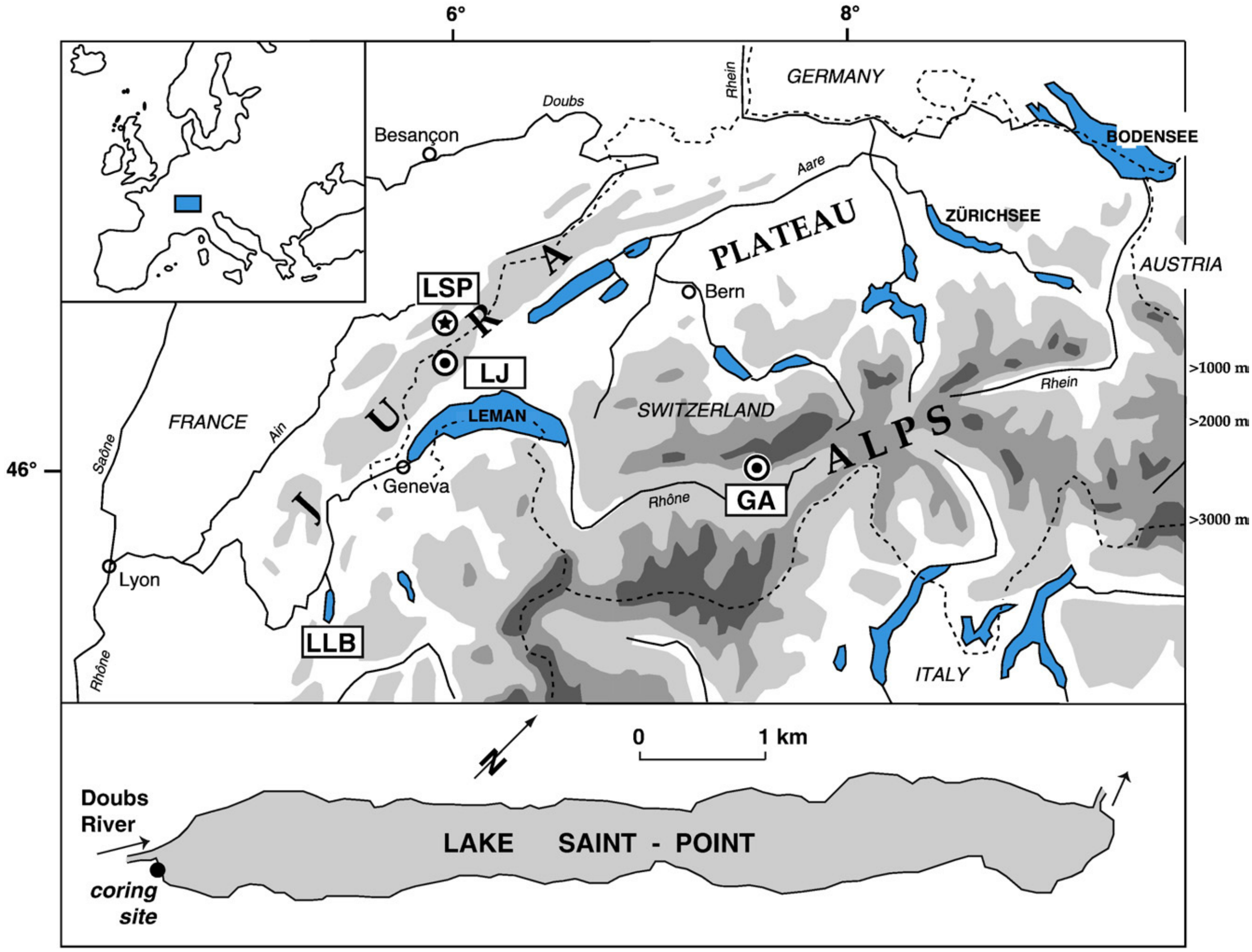

Figure 1. Geographical location of the study site and reference sites. LSP: Lake Saint-Point; LJ: Lake Joux; LLB: Lake Le Bourget; GA: Great Aletsch Glacier.

severe semi-continental climatic conditions. At lake altitude, mean annual precipitation attains ca. 1500 to 1900 mm, mean annual temperature ca. 10.2°C (2.7°C in the coldest month, and 21.3°C in the warmest month). During severe winters, the lake surface may remain frozen for several successive weeks.

The coring site is located in a littoral mire, close to the southwestern lake shore (Fig. 1). After establishing a core transect perpendicular to the shore by means of a Russian peat corer, a core (labeled core 7) was taken for lake-level studies on a site where the sediment sequence shows an alternation of peat and carbonate layers characteristic of past changes in lake level. While previous studies of Lake Saint-Point sediment sequences focused on the early and mid-Holocene (Magny and Ruffaldi, 1995), the present paper deals with the late Holocene as documented by the upper part of the core 7 sedimentary sequence.

The lake-level fluctuations were reconstructed using a specific sedimentological method (Magny, 1998, 2006), based on multiple lines of evidence, including changes in the lithology (organic versus carbonate deposits) and the relative frequency of various carbonate concretion morphotypes of biochemical origin. Modern analogue studies have given evidence that each morphotype shows a specific spatial distribution from the shore to the extremity of the littoral platform, with the successive domination of oncolites (nearshore areas with shallow water and high energy environment), cauliflower-like forms (littoral platform), plate-like concretions (encrustations of leaves from the Potamogetonion and Nymphaeion belts), and finally tube-like concretions (stem encrustations from the Characeae belt on the platform slope; Magny, 1998, 2006). In addition to variations in the assemblages of carbonate concretions, the relative frequency of plant macro-remains provides further information about the deposition environment. Thus, abundance of vegetal remains partly inherited from littoral vegetation (particularly ligneous vegetal remains) increases toward the shore.

The chronology is based on five radiocarbon dates (Table 1). Ages have been calibrated using Calib 5.1 (Stuiver et al., 1998; Reimer et al., 2004). Probably due to reworked material, level 47 cm provided an

Table 1
Radiocarbon dates obtained from the upper part of Saint-Point core 7.

Depth (cm)	Radiocarbon date	Calibrated age at 2 sigma range (maximum probability intervals)	Laboratory reference	Material
9.5–10.5	117.27 ± 0.38 pMC	>AD 1955	Poz-18513	Peat
31–32	245 ± 30 ^{14}C yr BP	AD 1523–1951 (AD 1630–1681 and AD 1763–1802)	Poz-18514	Charcoal + carex seeds + wood
71.5–72.5	350 ± 30 ^{14}C yr BP	AD 1458–1635 (AD 1458–1531 and AD 1537–1635)	Poz-18517	Charcoal
97–98	840 ± 30 ^{14}C yr BP	AD 1058–1265 (AD 1155–1265)	Poz-18519	Charcoal + wood
111–112	3315 ± 30 ^{14}C yr BP	3631–3471 cal yr BP	Poz-20683	Wood

pMC: percent modern carbon (Goslar et al., 2005).