



Solar forcing, climate dynamics and human activities in Mediterranean Mountains during the last millennium: the Lake Estanya record (Southern Pyrenees, NE Spain)

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The multi-proxy study of short sediment cores recovered in small, karstic Lake Estanya ($42^{\circ}02' N$, $0^{\circ}32' E$, 670 m.a.s.l.) in the Southern Pre-Pyrenean Ranges (NE Spain) provides a detailed record of the complex climatic and anthropogenic interactions occurring in Mediterranean areas since medieval times. The integration of sedimentary facies, elemental and isotopic geochemistry (^{18}O calcite, ^{13}C calcite and ^{13}C org) and biological proxies (diatoms, chironomids and pollen), together with a robust chronological control, provided by AMS radiocarbon dating and ^{210}Pb and ^{137}Cs radiometric techniques, enabled precise reconstruction of the main phases of environmental change during the last millennium, associated with the Medieval Climate Anomaly (MCA), the Little Ice Age (LIA) and the Industrial Era.

Shallow lake levels and saline conditions with poor development of littoral environments prevailed during medieval times (1150–1300 AD). Generally higher water levels and more dilute waters occurred during the LIA (1300–1850 AD), although this period shows a complex internal palaeohydrological structure and is contemporaneous with a gradual increase of farming activity. Maximum lake levels and flooding of the littoral shelf occurred during the nineteenth century, coinciding with the maximum expansion of agriculture in the area and prior to the last cold phase of the LIA. Finally, declining lake levels during the twentieth century, coinciding with a decrease in human pressure, are associated with warmer climate conditions reconstructed by instrumental records. A strong link with solar irradiance is suggested by the chronology of the main hydrological phases reconstructed in Estanya. Lower lake levels dominated during periods of enhanced solar activity (MCA and post—ca. 1850 AD) and higher lake levels during periods of diminished solar activity (LIA). Changes in winter precipitation, dominance of NAO negative phases and a strengthening of the westerlies would be responsible for wet LIA conditions in western Mediterranean regions. In Lake Estanya, periods of rapidly decreasing water level or generally lower water table lie within phases of maximum solar activity: (1) the MCA, (2) 1340–1380 AD; (3) the 1470–1490 AD, (4) ca. 1770 AD, (5) post ca. 1850 AD. Periods of higher lake levels or evidence of increased water balance in the basin occurred during the solar minima of Wolf (1282–1342 AD), (onset of the LIA), Spörer (1460–1550 AD), Maunder (1645–1715 AD) and Dalton (1790–1830 AD).

The main environmental stages recorded in Lake Estanya are consistent with results obtained in the nearby Lake

Montcortès, the main phases of advance and retreat of Pyrenean mountain glaciers and with dendroclimatic reconstructions carried out in the area. These results are also in phase with most Western Mediterranean continental records, and show similarities with both Central and NE Iberian reconstructions, reflecting a strong common climatic control of both the hydrological and anthropogenic changes (i.e., farming activities) during the last 800 years.