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The transmission of the NAO signal to alpine lakes in the Iberian Peninsula

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The North Atlantic Oscillation (NAO) is one of the main climate circulation patterns ruling winter rainfall and temperature in western Europe. In particular, the NAO pattern controls to a large extent the seasonal and inter-annual precipitation variability in the Iberian Peninsula (IP).

Alpine lake ecosystems can be excellent records of NAO influence. They have been shown to respond significantly to local and regional climate variability dominated by large-scale climatic fluctuations, including the NAO. Physical lake parameters seem to reflect these meteorological forcing more immediately and sensitively than other lacustrine ones (i.e biological parameters). Specifically, ice phenology has become one of the most valuable indicators of NAO winter influence. Many studies carried out in lakes located in Northern Hemisphere have in common to find this transmission through air temperature. In addition, only few works have found a significant relationship between NAO signal and other climate variables, such as precipitation or snow. Conversely, to the best of our knowledge this kind of assessments have not been performed yet in Southern Europe.

Two alpine lakes, with a glacial origin and located in the Spanish Central Range (IP) have been selected to perform a conceptual model of the transmission of NAO signal to lakes: Cimera (dimictic at 2140 m a.s.l., 384 m long, 177 m wide and 9.4 m deep) and Peñalara (monomictic at 2017 m a.s.l., 115 m long, 71.5 m wide and 4.8 m deep). This conceptual model has been built using Pearson's r correlation coefficients between winter season (December-March) data sets of NAO index, local meteorology (precipitation, temperature and snow days) and limnology (ice phenology records and lake water surface temperatures) available for the period 1993-2011 in Lake Peñalara and for the period 2007-2013 in Lake Cimera.

The conceptual model results suggest that NAO winter signal is mainly reflected in ice phenology by air temperature but also by snow days. During negative (positive) winter phase of NAO, when precipitation increases (decreases) and temperature decreases (increases) in southern Europe, a major (minor) amount of snow is accumulated in these high mountain lakes and their ice cover period is longer (shorter). Moreover, lake water surface temperature is stronger correlated with snow days than with air temperature but it seems to reflect weaker NAO signal than ice phenology. Hence, at meridional latitudes of Europe snow plays a key role in the limnological evolution of high mountain lakes owing to its isolated thermal effect.