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A quantitative ∼1ky lake level record of Lake Prespa (SW Balkans) derived from beach ridge sediments: implications for hydro-climatic changes from the Medieval Climate Anomaly to the present

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We present the first quantitative lake stage record of Prespa that covers the past millennium, based on the singular isthmus beach ridge complex, allowing numerical reconstruction of precipitation-driven inflow changes during the Medieval Climate Anomaly (MCA) and the Little Ice Age (LIA). Mediterranean precipitation change, based on lake-proxy reconstructions, shows a distinct W-E pattern over the past millennium. Generally, the West experienced drier conditions during the MCA and wetter conditions during the LIA; the East experienced opposite conditions. This pattern is linked to the multi-decadal North Atlantic Oscillation (NAO) Winter Index: positive phases are associated with drier (wetter) and negative phases with wetter (drier) conditions in the W (E) Mediterranean. The SW Balkans is located at the juncture of proposed boundary between these contrasting climate and hydrological domains. It is not clear which, if any, of these patterns reflects past precipitation changes in the region, given the lack of detailed palaeo-hydrological data.

The beach ridge complex that underlies the entire isthmus separating Lakes Mikri- and Megali Prespa offers a unique opportunity to address this question. High, oblique, sediment-supply allows the formation and preservation of beach ridges that register the annual water level fluctuations of Lake Megali Prespa which are driven by wet season precipitation and contain a strong NAO-signal. Modern beach-ridge sediment facies were calibrated against observed lake levels, thus allowing the reliable determination of past lake levels from the geological record. Lake surface area variation was found to be a more reliable indicator of hydro-climate change than water level fluctuations as the latter are strongly influenced by lake bathymetry. Accordingly, surface areas were calculated for different water levels to enable the conversion of lake level stage-indicators to quantitative inflow estimates. The isthmus profile reveals a “high” surface between 849-852m separated by a knickpoint from a “low” surface between 843-847m that slopes towards Lake Megali Prespa. This 847m level constitutes an important threshold, as lake surface area significantly decreases below it. Therefore, stable lake levels above/below this threshold reflect significant long-term (i.e. multi-decadal) inflow changes.

Continuous sediment exposure along channel banks (844-848m) allowed identification of all major low lake level phases for the past ∼1000 years. The “high” isthmus surface consists of four composite beach-ridge complexes; its sediments were accessed in quarries and trenches. Sediment facies were dated by 14-C and OSL age-estimation methods. Low lake levels (842-847m) during the MCA (∼900-1400AD) suggest 10-15% less inflow per year, related to drier winter-springs and less runoff. Lake levels were generally high (>847m) from ∼1450 to 1988AD, except for a multi-decadal fall to ∼845m around 1640AD. There were more frequent very high lake levels (>850m) between ∼1450-1600AD, ∼1660-1750AD and ∼1800-1987AD, suggesting repeated very wet winter-springs with much snowmelt-derived runoff. The 1987-2000AD lake level fall to 842-845m (∼5% less inflow per year) is mainly caused by water abstraction. These results indicate that the SW Balkans experienced similar hydro-climatic changes as the W Mediterranean over the past millennium; particularly strong similarities are apparent with lacustrine proxy-records in the S Alps.