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Influence of the Solar Activity on the Variability of Water Isotopes over Europe during the Late Holocene

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Numerous European proxy archives demonstrate strong decadal to millennial scale variability in the δ^{18}O signal during the Mid- to Late Holocene. The origin of this variability and its climatic forcing is however not well defined. Many of these records provide consistent evidence that solar grand minima/maxima affect climate. Reconstructions of the total solar irradiance during the Holocene imply a grand solar maximum (minimum) approximately 5,000 (6,000) years ago.

Here, we apply an atmosphere general circulation model (ECHAM5-wiso) that allows the explicit simulation of the water isotopes to investigate the influence of solar activity on the stable water isotope distribution signal for these Mid-Holocene periods. The simulations are driven by changes in orbital configuration, greenhouse gases, and changes in total solar irradiance due to solar activity. Dynamical downscaling is obtained by the high horizontal resolution of T106 (approx. 1x1°) to provide suitable results for model-data comparison. Following this approach, present-day simulations of the distribution of stable water isotopes are in very good agreement with meteorological observations.

In this study the effect of solar activity is marked out from climatic changes driven by the variability of orbital parameters during the Mid-Holocene. For the evaluation of the influence forced by orbital parameter changes a first set of simulations is performed. Here, prescribed fields of sea surface temperatures (SST) and sea ice concentrations (SIC) are derived from a transient run using an earth system model with coupled atmosphere and ocean circulation. To account for solar induced effects originating in the stratosphere a second set of simulations is performed using anomalies in the prescribed SST and SIC. For each time slice externally derived SST/SIC anomalies for the two different modes of solar activity (high/low solar activity in comparison to a mean solar activity) are added to the boundary fields of the first set of simulations.

Changes in solar activity during the Mid-Holocene have been shown to result in major effects on the sea ice distribution and sea level pressure fields that strongly affects climate in Europe. During winter North Atlantic westerlies are shifted northward during the solar minimum leading to higher precipitation and depleted δ^{18}O values in northwestern Europe and Scandinavia. The Mediterranean is thus affected by drier conditions. During a phase of increased solar activity westerlies are shifted to the South transporting more moisture to the Mediterranean. At the same time Central Europe is affected by a blocking atmospheric high during winter, which transports cold air from the Barents Sea to the European continent.

The heterogeneity observed in the high-resolution model simulations is helpful for the interpretation of the regional isotopic signal in speleothem records. The values of stable water isotopes are in generally not only influenced by temperature but also by precipitation and atmospheric circulation patterns. However, both the model and the data suggest strong influence of solar activity on climate conditions during the Holocene.