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Non-linear Ice Sheet influence during deglaciation and its impact on the evolution of atmospheric teleconnection patterns

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During present conditions atmospheric teleconnections such as the Arctic Oscillation/North Atlantic Oscillation (AO/NAO) have a major impact on Northern Hemispheric climate. However, the Early Holocene is characterized by the presence and melting of the Laurentide Ice Sheet (LIS) leading to a different background climate in comparison to today. Here we investigate the climate evolution during the early (9 ka BP, including LIS and melt water), mid (6 ka BP) and late Holocene (pre-industrial conditions) focussing on the mechanisms and feedbacks during deglaciation by applying the state-of-the-art earth system model COSMOS. A special interest is set on the evolution of atmospheric teleconnection patterns such as the AO/NAO and the Atlantic Multidecadal Oscillation (AMO) that have a major influence on North Atlantic/European climate. The evolution and relative importance of these oscillations throughout the Holocene, however, is still largely unknown.

We demonstrate that North Atlantic/European climate is affected by a shift from a more ocean-ice-dominated climate during approx. 9 ka towards a more atmosphere-dominated one during the mid to late Holocene. To isolate the contributions of the presence of the LIS and the melt water we run four different model simulations for the early Holocene sensitivity study (a standard configuration only forced with green house gases and orbital parameters, one with the additional LIS topography, one with a melt water flux of 0.09 Sv, and a fourth that combines all the external forcings).

The model results show that the influence of the LIS and its melt water contribution lead to a strong non-linear cooling of surface air temperatures during deglaciation. This synergetic influence of the Laurentide Ice Sheet strengthens the effect of melting on ocean circulation during the early Holocene. The severe colder background climate during deglaciation leads to a more vulnerable ocean circulation in terms of the Atlantic Meridional Overturning Circulation. Changes of this circulation are known to affect the atmosphere as well via mechanisms like the AMO. The corresponding sea level pressure pattern is an atmospheric response to oceanic thermal forcing, which results from variations of the thermohaline circulation. The AMO has a potential to influence the shape of the subtropical high and to shift AO/NAO pressure centres towards easterly and north-easterly directions during the early Holocene.

This non-stationary behaviour of the AO/NAO due to deglaciation processes is also demonstrated by a novel set of North Atlantic/European speleothem records that show an active AO/NAO all over the Holocene.