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Atmospheric circulation in the early Holocene: Sensitivity of the North Atlantic winter climate to moderate changes in the ice-sheet configuration

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A prominent feature of interglacials, such as the Holocene, is the reduced size of the continental ice sheets. At present-day, only two ice-sheets (namely Greenland and Antarctica) exist which themselves are likely to retreat in the future due to global warming. Changes in the global ice-sheet distribution have distinct consequences for the surface climate and the atmospheric circulation since ice-masses shape the topography and define the local surface characteristics.

Past interglacial periods offer the potential to study the climate dynamics and stability of warm periods, also concerning the impact of changes in the ice-sheet distribution. For this purpose, we use a comprehensive climate model to perform a set of time-slice simulations for the present, the early-Holocene and the Eemian warm period. In particular, we perform sensitivity experiments to assess the atmosphere's reaction to modest changes in the global ice-sheet distribution.

In a first attempt, we focus on a set of four early-Holocene simulations which include the paleo-topographies from 9000BP, 8000BP, 7000BP and the present orography as lower boundary conditions, respectively. The early Holocene orography differs from the present-day state by the presence of remnants of the Laurentide ice-sheet and newly ice-free regions in Scandinavia and North America with a higher altitude due to the post-glacial rebound effect. For all simulations, the orbital forcing is set to the state of 8000BP, whereas the solar constant and greenhouse gas concentrations are fixed on pre-industrial levels.

The Northern Hemisphere (NH) winter surface climate shows moderate and mostly non-significant changes due to the different lower boundaries. Significant differences in surface temperature are limited to areas which experience a local change in orography. However, there is a clear impact on the mid-level troposphere downstream of the Laurentide ice sheet remnants leading to a cooling over the North Atlantic and a warming over Southern Europe. These changes are likely associated with a change in the North Atlantic winter jet. The analysis shows that the subtropical branch of the jet is intensified whereas the eddy-driven jet is slightly weakened. Nevertheless, the induced changes in the jet do not lead to a change in the main NH modes of atmospheric variability (e.g., the North Atlantic Oscillation or the East Atlantic Pattern). This analysis illustrates that although the impact of the lower boundaries is significant, the magnitude is too small to lead to a significant reorganization of the mean atmospheric flow in the NH.