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The North Atlantic atmospheric circulation and its variability at the Last Glacial Maximum: role of the ice sheets and the ocean circulation state

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The North Atlantic jet-stream plays an important role in the European climate. Its fluctuations at the synoptic scale are one way to define the North Atlantic storm-track, which bears a strong relationship with winter precipitation. Its fluctuations at the interannual time scale relates to major modes of atmospheric circulation variability such as the North Atlantic oscillation. Here, we examine the North Atlantic jet stream and its fluctuations at synoptic and inter-annual time scales for a period with a climate very different from present: the Last Glacial Maximum (LGM), 21,000 years ago. This period was characterized by extensive ice sheets over northern North America and northern Europe, as well as low concentrations of atmospheric greenhouse gases, which both act to modify the large-scale temperature gradients in the atmosphere. In this work, we will present an analysis of the LGM jet stream as simulated by the PMIP3-CMIP5 models (Palaeoclimate Modelling Intercomparison Project, phase 3, part of the Coupled Model Intercomparison Project – phase 5 simulations). These simulations show a range of results for the position of the winter jet stream, which are related to temperature differences over the northwestern North Atlantic. The latter could relate to inter-model differences in ice sheet altitude and extension (Beghin et al., 2016). We have further tested the impact of the height of the North Atlantic ice sheet on the North Atlantic jet stream with the LMDZ atmospheric general circulation model. Our results confirm the important role of topography in setting up the southward shift of the winter jet stream (Beghin et al., 2015).

In a second part of this work, we show how the North American ice sheet impacts the synoptic variability. Indeed, despite a favourable baroclinicity, the North Atlantic storm track is weaker in our LGM simulations. Additional experiments with an idealized model show that the North American ice sheet prevents the eddies from stretching in the meridional direction and efficiently extract the available potential energy (Rivière et al., submitted). Further downstream, the characteristics of the Rossby wave breaking also change from pre-industrial to LGM conditions and are related to changes in the characteristics of the North Atlantic Oscillation-type variability (Rivière et al., 2010). Finally, we will present sensitivity experiments in which the Atlantic Meridional Overturning Circulation is forced to vary under glacial conditions. These show significant differences in the position of the North Atlantic jet stream and patterns of interannual variability.

All in all, this work shows that the Last Glacial Maximum conditions give the opportunity to test our knowledge on the interplay between the mean North Atlantic jet stream, storm-track and inter-annual variability in a context very different from the present one. This also helps better understanding the available reconstructions.

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