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Simulated cold events in the northern North Atlantic during the last millennium

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Paleoceanographic data show large inter-decadal cold excursions in sea-surface temperatures (SSTs) in the western subpolar gyre region and north of Iceland throughout the last millennium. A series of such events could have contributed to demise the Norse settlements over Greenland during the 13th to the 15th century due to associated deteriorating environmental conditions in the region. However, spatial extent, attribution and mechanism(s) of these cold events are not known. In this contribution, we use climate model simulations to clarify the role of the ocean and of coupled ocean-atmosphere dynamics in triggering these cold events, and to assess whether they can be explained by internal climate variability alone. Specifically, we investigate the North Atlantic-Arctic climate variability in a 1000-year control run describing an unperturbed pre-industrial climate, and in a 3-member ensemble of full-forcing transient simulations of the last millennium. Simulations are performed with the Max Planck Institute-Earth System Model for paleo-applications.

In the control and transient simulations, we identified cold events of similar amplitude and duration to the reconstructed data. Spatial patterns and temporal evolutions of simulated cold events are similar in both simulation types. In the transient runs, furthermore, they do not robustly coincide with periods of strong external forcing (e.g. of major volcanic eruptions). We therefore conclude that such events can emerge because of internally-generated regional climate variability alone.

Local ocean-atmosphere coupled processes in the North Atlantic subpolar gyre region appear as key part of the mechanism of simulated cold events. In particular, they are typically associated with the onset of prolonged positive sea-level pressure anomalies over the North Atlantic and associated weaker and south-eastward displaced subpolar gyre. The salt transport reduction by the Irminger Current together with an intensification of the southward fresh water transport through the Denmark Strait reduce the sea-surface salinity and trigger reduced deep ocean mixing in the Labrador Sea. The consequent weakening of the Atlantic Meridional Overturning Circulation peaks well after the minimum of SST anomalies, allowing us to exclude, in contrast to former suggestions, the overturning circulation as a major triggering factor of such cold events. Cold SSTs and the weakened atmospheric circulation over the Labrador Sea force reduced ocean heat losses in the ocean basin, being the main cause of the cold anomalies over Greenland. The simulated climatic anomaly further entails sea-ice expansion along the eastern coast of Greenland. This would have reduced the trade and fishery in the region, thus increasing the stress on the Norse society during the time of its settlement demise over Greenland.