Geophysical Research Abstracts
Vol. 15, EGU2013-6980-1, 2013
EGU General Assembly 2013

Was the Little Ice Age the result of a volcanically-triggered regime shift in the North Atlantic ocean circulation?

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One of the most important events in the climate history of the North Atlantic region during the last millennium is the transition from the Medieval Climate Anomaly (MCA) to the Little Ice Age (LIA), a transition that had substantial impact on societies in medieval Europe. The origin of this shift in regional climate, however, is not fully understood. Volcanic eruptions and changes in the total solar irradiance (TSI) as well as internal climate variability on multi-centennial time-scales might have contributed, and it is likely that an interplay of a variety of forcings in combination with regional climate feedbacks is needed to understand the MCA-LIA transition.

Here, we present transient last millennium simulations of the fully-coupled model Climber 3α. Based on reconstructions for the North Atlantic Oscillation (NAO), the dominant mode of North Atlantic atmospheric climate variability, as well as on observational data, we stochastically generated wind field ensembles over the last millennium. We performed ensemble simulations prescribing atmospheric and natural forcings and also separated the individual forcings. We find good agreement with paleo reconstructions of Nordic Sea sea-ice cover and AMOC strength over the last millennium. The ensemble spread for different stochastic wind fields reconstructions is substantial, thus highlighting the importance of atmospheric dynamics for North-Atlantic oceanic climate variability. However, when separating individual forcings, pure atmospheric forcing alone as well as in combination with TSI forcing are found to be insufficient to reproduce key features of the MCA-LIA transition as apparent in paleo reconstructions, whereas volcanic forcing can generate a transition in agreement with the reconstructions.

Our results indicate a coupled sea-ice ocean feedback mechanism behind the MCA-LIA transition and decadally-paced volcanic eruptions as a potential trigger. The latter will lead to a substantial sea-ice increase in the Nordic Seas, hindering convection and subsequently weakening the overflows over the Greenland-Scotland Ridge. This in turn leads to a strengthening of the subpolar gyre circulation and eventually a weakening of the Atlantic Meridional Overturning Circulation (AMOC). The subsequent basin-wide cooling helps to maintain a greater sea-ice cover in absence of external forcing and thereby stabilises the new circulation regime. Our results demonstrate the possibility of a persistent regime shift in the North Atlantic oceanic circulation regime in response to a short-lived external forcing in a fully coupled climate model and highlight the importance of regional climate feedbacks in order to advance the understanding of past and future climate.

References:
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