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The Atlantic Multidecadal Oscillation in comprehensive Earth System Model Simulations in the 1st millennium AD

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Recent studies investigating the Atlantic Multidecadal Oscillation (AMO) primarily focus on the 2nd millennium AD and the most recent period. An important and yet still not fully resolved issue relates to the main drivers of this mode of North Atlantic variability in the context of external versus internal forcings.

Here we investigate changes of AMO in three ensemble simulations with the fully coupled Earth System Model MPI-ESM-P in the 1st millennium AD including changes in orbital, solar and greenhouse gas forcing and a newly developed volcanic data set. Changes in land use are set to constant 800 AD values and are prescribed afterwards based on empirical reconstructions.

From the methodological point of view we set out to disentangle the externally versus the internally forced part by cross-correlating the individual AMO time series of the different ensemble simulations. The rationale is that the squared correlation provides a measure of the shared variance and thus represents exactly the part of the AMO variability that is driven by changes in external forcings, because all three simulations are driven with the same set of external forcings. Practically we use simulated sea surface temperatures averaged over the North Atlantic Ocean filtered by a 10 year running mean representing the AMO in the model.

Results indicate that the different simulations share a common variance of around 25%. This is the amount that is caused by the influence of changes in external forcings, i.e. mainly the impact of volcanic eruptions. To estimate the effect of the serial correlation within the filtered AMO time series, similar analysis was carried out for an unforced pre-industrial control simulation indicating that this potential spurious effect within the shared variance can be neglected. Thus the common variance of the forced simulations indicates that during the 1st millennium AD a quarter of the total AMO variance is triggered by changes in external forcings.

Besides changes in external forcing factors, additional driving mechanisms of AMO variability are investigated using correlation and composite analysis of according decadal and annual averaged sea level pressure (SLP) fields over the North Atlantic. The patterns indicate that a small, albeit physically relevant part of AMO variability is linked to an intensification of the westerly circulation. This leads to an increased subtropical and subpolar gyre circulation in conjunction with an increased northward heat transport.

In the context of the historical perspective the AMO might thus also be a driver of climatic anomalous periods, e.g. related to the Late Antique Little Ice Age during the 6th century AD and considered as an additional term influencing specific climatic periods on the adjacent European continent.