Atlantic meridional overturning circulation during the Holocene

Implications for understanding modern climate

Over the past 25 years scientists have drawn on a variety of sources to identify periods and forcers of change in global climate. In the 2013 study 'Long-term variations in Iceland–Scotland overflow strength during the Holocene', David Thornalley and his team added another significant piece to the puzzle of deep water formation, a system that is crucial to the transport of heat around the globe.

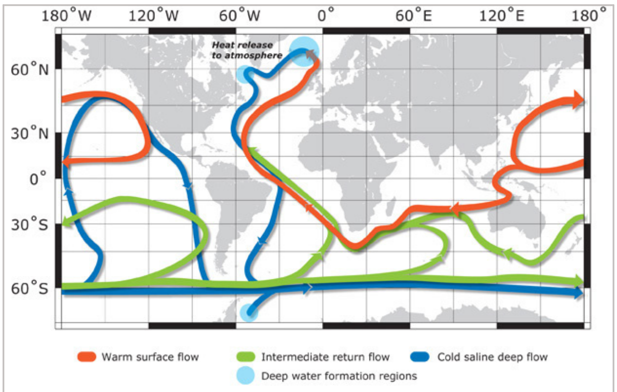
By assessing the grain size of 13 sediment cores, Thornalley and collaborators were able to reconstruct the overflow of dense bottom waters from Nordic seas across the Iceland–Scotland undersea slope to the North Atlantic during the Holocene. Overflow strength is determined by ocean bathymetry (the topography of the ocean floor) and the difference in density between the Nordic and North Atlantic waters. Factors influencing seawater density include temperature and salinity, and as high winds blow across Nordic waters, more water is evaporated, leaving denser, more saline water behind. Winds also contribute to the effects of ocean bathymetry, forcing waters across undersea barriers.

Thornalley's team was able to obtain a measure of the strength and depth of the Atlantic meridional overturning circulation (AMOC) – an essential component of the Earth's climate system that allows the formation of the North Atlantic Deep Water. Their results showed that overflow strength was weaker in the early and latter part of the Holocene and strongest due to a deepening of the overflow path around 7,000 years ago – coinciding with a period of regional high temperatures.

Deepening overflow of the Nordic waters contributes to a complementary strengthening in the inflow of North Atlantic waters northwards. This results in regional warming that helps to control the balance of ice sheets and overall climate of northwestern Europe. Large freshwater influxes from melting of ice sheets due to global warming are suspected to weaken the AMOC by raising the depth of overflow in the North Atlantic and decreasing both the regional warming and balancing effect of the North Atlantic waters on northwestern Europe.

Although current forcing factors of climate change are primarily anthropogenic rather than natural, and expected to remain so in the future (the projections by the International Panel on Climate Change look to the end of the current century), research on the past can help us understand the future.

In his paper, Thornalley also ran model simulations that showed a predicted reduction of around 40% in the maximum winter overflow depth by the end of the 21st century, broadly in line with the results from other studies reviewed in the IPCC Working Group I report. Previous palaeoclimate reconstructions have shown that reduction or cessation of Nordic overflow would have resulted in extreme widespread climate impacts, including increased instability of climate and ice sheets in the North Atlantic.



Warm water produces warmer air and increases atmospheric moisture. Therefore, regions affected by warm currents such as the Gulf Stream are characterised by milder, moister climates. (Credit: Thornalley et al., 2013)

Although past events aren't directly analogous to present changes, Thornalley identifies in an interview two key benefits from a deeper understanding of pre-anthropogenic change. First, he says, it allows us to identify the range of climate impacts and build up our understanding of the past: "It's not until relatively recently that we knew that climate could change so abruptly", a statement mirrored in the IPCC's recent Working Group I report where they referred to 'unprecedented changes' in climate. And second, Thornalley believes that if we can use models to replicate past variation, we can gain confidence in the predictions made by the same models for future climate change.

Given the multiple feedbacks associated with the climate system, both positive and negative, the regional climate implications of a reduction in overflow depth in the North Atlantic are not obvious. What is clear is that current levels of anthropogenic CO_2 emissions are likely to have far-reaching changes that we don't yet fully understand. As Thornalley puts it: "There's a lot we still need to learn about the Atlantic meridional overturning circulation and the complexities of climate."

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