

Perspectives

Has a warm North Atlantic contributed to recent European cold winters?

Noel Keenlyside¹ and
Nour-Eddine Omrani²

¹Geophysical Institute,
University of Bergen and
Bjerknes Centre, Postboks 7803,
5020 Bergen, Norway

²GEOMAR Helmholtz-Zentrum
für Ozeanforschung Kiel,
Düsternbrooker Weg 20, 24105
Kiel, Germany

E-mail: noel.keenlyside@gfz.uni-bremen.de
no and nomrani@geomar.de

Abstract

The rise of global surface temperature waned during the last decade, despite increasing greenhouse gas concentrations. The temperature changes were most pronounced over northern hemisphere land masses during winter (Cohen *et al* 2012). They were largely associated with weakening of the mid-latitude westerly flow. To some, these temperature changes may seem paradoxical in the light of anthropogenic global warming, and thus there is much interest in explaining them. Peings and Magnúsdóttir (2014 *Environ. Res. Lett.* 9 034018) provide evidence that recent warming of the North Atlantic sea surface temperature (SST) may be part of the explanation.

Keywords: AMV, climate change, winter climate

Explanations for the recent cold winters have included the strong reduction in arctic sea ice (Francis and Vavrus 2012) and increases in Eurasian snow cover (Cohen *et al* 2012). Global warming likely contributed to both and as it is expected to accelerate, we may see more harsh winters. However, cold winters are not uncommon in the historic record (Jones *et al* 2012), and unforced internal climate variability could also play a major role (Wallace *et al* 2012).

In particular, North Atlantic SST shows pronounced variability with a time scale of 70–80 years—a phenomenon commonly referred to as Atlantic multi-decadal variability (AMV) or the Atlantic Multi-decadal Oscillation. Peings and Magnúsdóttir (2014 *Environ. Res. Lett.* 9 034018) suggest that the current warm phase of AMV could also have contributed to recent cold winters. Through analysis of historic observations and atmospheric model experiments they show that the warm phase of AMV increases the occurrence of the negative phase of the North Atlantic Oscillation (NAO), and vice versa for cold phases. Independently, Omrani *et al* (2014) came to similar conclusions using differently defined indices and a different atmospheric model.

These two studies are exciting because they provide modeling evidence for an extra-tropical atmospheric response to North Atlantic SST in winter. Importantly, the response compares well to observations, not only in terms of its pattern but also its strength. This is in contrast to previous studies that found only a weak atmospheric response (Rodwell *et al* 1999, Bretherton and Battisti 2000).

Why do these two studies reach new conclusions? One reason might be that previous studies have mostly considered the SST tripole pattern, which is primarily a thermodynamic response to the NAO, while the new studies consider SST patterns associated with AMV. The AMV's basin-wide warming (cooling) is not a direct thermodynamic response to the associated negative (positive) NAO like patterns, and models suggest ocean dynamics are important (Eden and Jung 2001). This point, which Bjerknes (1964) noted, has recently been confirmed



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

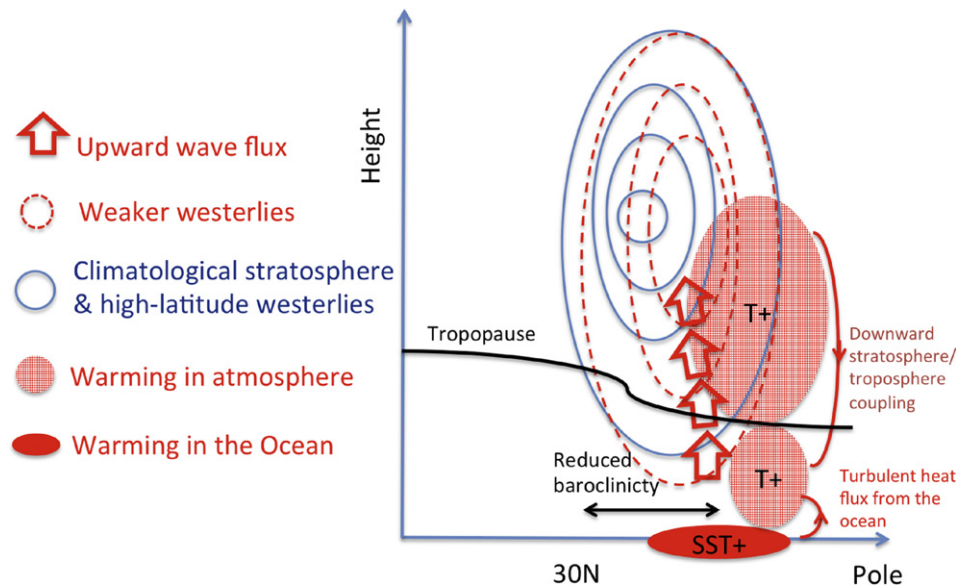


Figure 1. Schematic of atmospheric response to extra-tropical ocean heating. Red colours indicate the perturbations to the oceanic and atmospheric states.

through analysis of reconstructed turbulent heat flux data (Gulev *et al* 2013). Thus, multi-decadal SST variations in the Gulf Stream and its extension may act to drive atmospheric circulation changes on decadal timescales.

However, there have been other studies that investigated the atmospheric response to AMV and these have not found a consistent response in winter (Hodson *et al* 2010). In both new studies, the extra-tropical heating weakens the meridional temperature gradient and thus reduces baroclinicity (Czaja *et al* 2003). This leads to less synoptic scale eddy activity and a weakening of the westerly flow. Omrani *et al* (2014) further show that this leads to an increase in upward propagation of quasi-stationary planetary waves and thus to weakening of stratospheric polar vortex and warming in high-latitude stratosphere. The stratospheric warming propagates in turn down into the troposphere, further reducing the baroclinicity, and thus enhancing the negative NAO-like changes in late winter. This wave driven feedback involving the stratosphere (figure 1) adds to our classical understanding of the NAO-response to extratropical SST (Czaja *et al* 2003).

Omrani *et al* (2014) stress that poorly representing stratosphere and its variability (e.g., major stratospheric warming) can lead to deficiencies in simulating the wintertime response to the AMV, and this could be a key difference to most previous studies. Peings and Magnusdottir’s [Pers. Comm.] model results partly agree with this concept, but the stratospheric response is weaker and less significant, consistent with the model’s poorer representation of the stratosphere. Other reasons for differences could be the implementation of *sponge-layers* at the model top, or the background atmospheric state. For example, the strength and structure of the westerly flow controls the upward propagation of quasi-stationary waves. Thus, further work is required to understand the robustness of these modeling results.

The existence of an extra-tropical response to North Atlantic SST could have far reaching implications. Firstly, it implies the northern hemisphere winter climate may be partly predictable on decadal timescales, as SSTs in this region are predictable (Keenlyside *et al* 2008). Secondly, it opens the possibility for a coupled ocean-atmosphere mode of variability on multi-decadal timescales, possibly extending predictability further. Lastly, it has implications for interpreting global climate variability (Li *et al* 2013).

The cause of the recent northern hemisphere winter cooling remains an open question. While these two new studies suggest the AMV could have contributed, other recent studies have suggested arctic sea ice reduction, increased Eurasian snow cover, and internal climate variability could all have played a role. Understanding the relative importance of these different factors is a high priority. Coordinated model experiments provide one approach to address this issue. This is a theme of a workshop to be held in Bergen in early June, and to which we hope to interest the international modeling community.

Acknowledgments

NK is supported by the GREENICE project, funded by the NordForsk Top-level Research Initiative (Project n. 61841).

References

- Bjerknes J 1964 Atlantic air-sea interaction *Adv. Geophys.* **10** 1–82
- Bretherton C S and Battisti D S 2000 An interpretation of the results from atmospheric general circulation models forced by the time history of the observed sea surface temperature distribution *Geophys. Res. Lett.* **27** 767–70
- Cohen J L, Furtado J C, Barlow M A, Alexeev V A and Cherry J E 2012 Arctic warming, increasing snow cover and widespread boreal winter cooling *Environ. Res. Lett.* **7** 014007
- Czaja A, Robertson A W and Huck T 2003 The role of atlantic ocean-atmosphere coupling in affecting North Atlantic oscillation variability *The North Atlantic Oscillation: Climate Significance and Environmental Impact* ed J W Hurrell, Y Kushnir, G Ottersen and M Visbeck (Washington, DC: American Geophysical Union)
- Eden C and Jung T 2001 North Atlantic interdecadal variability: oceanic response to the North Atlantic oscillation (1865–1997) *J. Climate* **14** 676–91
- Francis J A and Vavrus S J 2012 Evidence linking Arctic amplification to extreme weather in mid-latitudes *Geophys. Res. Lett.* **39** L06801
- Gulev S K, Latif M, Keenlyside N, Park W and Koltermann K P 2013 North Atlantic ocean control on surface heat flux on multidecadal timescales *Nature* **499** 464–7
- Hodson D L R, Sutton R T, Cassou C, Keenlyside N, Okumura Y and Zhou T J 2010 Climate impacts of recent multidecadal changes in atlantic ocean sea surface temperature: a multimodel comparison *Climate Dynamics* **34** 1041–58
- Jones P D, Lister D H, Osborn T J, Harpham C, Salmon M and Morice C P 2012 Hemispheric and large-scale land-surface air temperature variations: an extensive revision and an update to 2010 *J. Geophys. Res.* **117** D05127
- Keenlyside N S, Latif M, Jungclaus J, Kornblueh L and Roeckner E 2008 Advancing decadal-scale climate prediction in the North Atlantic sector *Nature* **453** 84–8
- Li J, Sun C and Jin F-F 2013 NAO implicated as a predictor of northern hemisphere mean temperature multidecadal variability *Geophys. Res. Lett.* **40** 2013GL057877
- Omrani N E, Keenlyside N S, Bader J R and Manzini E 2014 Stratosphere key for wintertime atmospheric response to warm atlantic decadal conditions *Climate Dynamics* **42** 649–63
- Peings Y and Magnusdottir G 2014 Forcing of the wintertime atmospheric circulation by the multidecadal fluctuations of the North Atlantic ocean *Environ. Res. Lett.* **9** 034018
- Rodwell M J, Rowell D P and Folland C K 1999 Oceanic forcing of the wintertime North Atlantic oscillation and European climate *Nature* **398** 320–3
- Wallace J M, Fu Q, Smoliak B V, Lin P and Johanson C M 2012 Simulated versus observed patterns of warming over the extratropical northern hemisphere continents during the cold season *Proc. Natl. Acad. Sci.* **109** 14337–42