Relationship between changes in the AMOC, North Atlantic heat content and SST

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1. Introduction

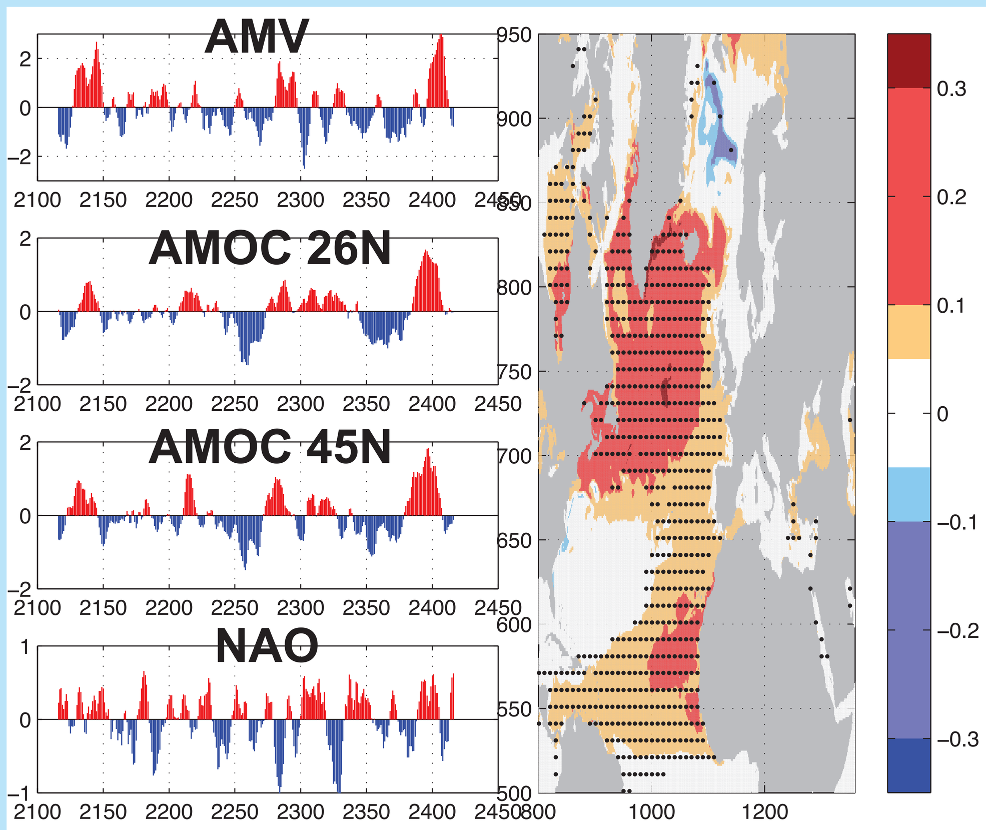
The North Atlantic undergoes swings in sea-surface temperature (SST) on multidecadal timescales, with consequent impacts on the climate of adjacent land areas. Proposed mechanisms behind this Atlantic Multidecadal Variability (AMV) fall into two main categories: external forcing e.g. due to anthropogenic aerosols; or internal modes of variability e.g. involving the Atlantic Meridional Overturning Circulation (AMOC) and the North Atlantic Oscillation (NAO). The relationship between the changes in oceanic heat transport and the SST is not well understood. Here we develop a framework to investigate which physical processes determine SST variability on decadal to multidecadal timescales by evaluating contributions from the net ocean-atmosphere heat flux, the divergence of the temperature transport, and entrainment between the mixed layer and the layer beneath. We analyse the 300-year present-day control simulation of the HADGEM3-GC2 coupled climate model, which shows a 20-30 year AMV variability similar to that observed.

2. The AMV, NAO and AMOC in HADGEM3-GC2

The AMV is thought to be influenced by the atmospheric and oceanic circulations.

The leading mode of atmospheric circulation is the NAO and ocean variability is strongly associated with the AMOC on decadal time scales.

We look for relationships between the AMOC, NAO and AMV indices and investigate the mechanisms behind these by evaluating the ocean heat budget.



The model variability in these indices is comparable with observations.

3. Ocean Heat Budget

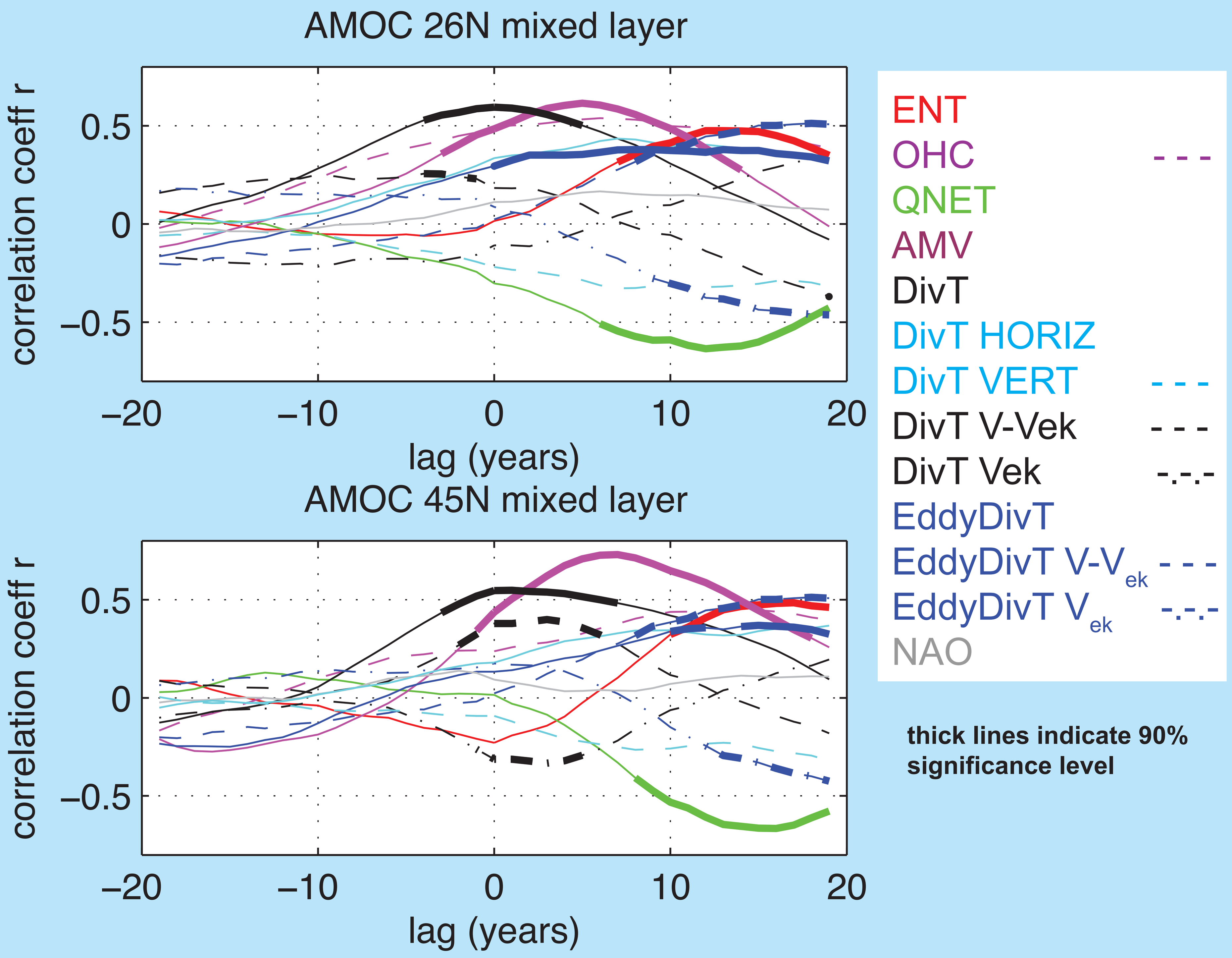
$$\frac{dOHC}{dt} = DivT + EddyDivT + Entrainment + Qnet$$

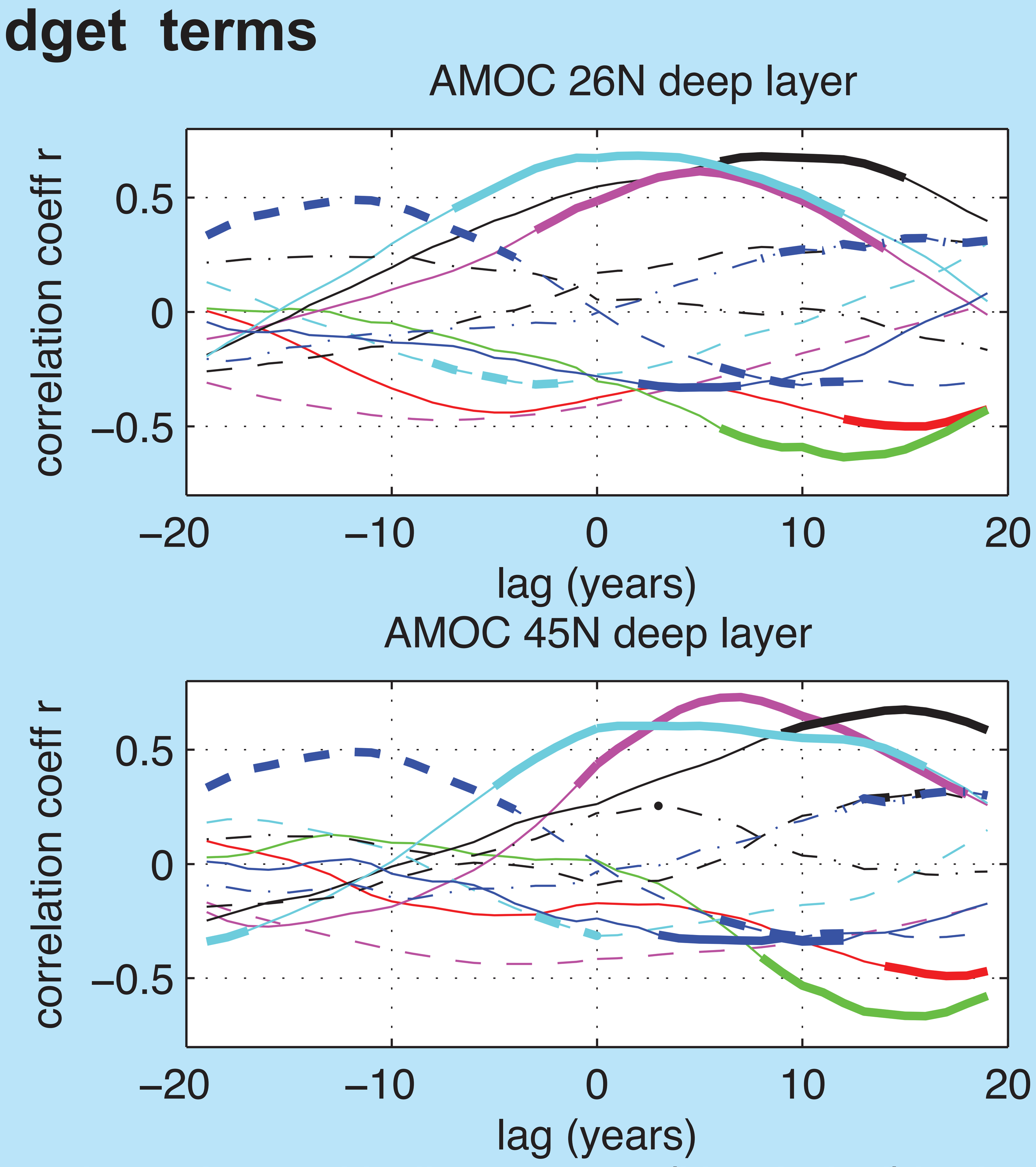
(1) (2) (3) (4) (5)

1) Change in Ocean heat content
2) Heat transport divergence (3 terms: velocity (V) , Ekman Velocity (Vek), V-Vek)
3) Eddy heat transport divergence (3 terms: velocity (V) , Ekman Velocity (Vek), V-Vek)
4) Entrainment in/out of the mixed layer
5) Net surface heat flux

Each term is calculated using the HADGEM3-GC2 model data: a) within the mixed layer and b) in the deep ocean beneath the mixed layer. The divergence term (2) is further split into horizontal and vertical components.

4. Correlations between AMOC, AMV, NAO and heat budget terms





- Changes in the AMOC lead to changes in AMV (PINK) about 5 years later.
- The main physical process causes this is the heat transport divergence (BLACK)
- The AMV leads to changes in surface heat flux (Qnet) and entrainment into the mixed layer.
- The instantaneous NAO shows weak correlations with the AMOC.

- The total non-ekman eddy divergent term (blue dashed) leads to changes in the AMOC 12 years later.
- The vertical divergence (cyan dashed) leads to changes in the AMOC 5 years later.
- The changes in the AMOC lead to further changes in the heat transport divergence (black solid) which potentially initiate further changes in the mixed layer.

6. Summary

- In the GC2 climate model the AMV is strongly determined by the AMOC with a lag of about 5 years.
- Variations in the AMOC are initiated below the mixed layer by changes in the non-ekman related eddy divergence 12 years earlier. This is potentially related to westward propagating signals such as Rossby waves.
- There is a lag between the peak of the AMV and subsequent heat flux to the atmosphere of 10 years possibly related to near simultaneous changes in the entrainment between the deep ocean and the mixed layer.

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