**ENSO and NAO response to a weakening Atlantic meridional overturning circulation**

Tarjei Breiteig, Nils Gunnar Kramstø and Jürgen Bader
Bjerknes Centre for Climate Research and Geophysical Institute, University of Bergen
tarjei.breiteig@bjerknes.uib.no

**Background**

Otterå et al. (2004) performed a sensitivity experiment with the Bergen Climate Model (BCM). The freshwater flux into the high latitude seas was threefold increased compared to the BCM control run (CTRL hereafter). The experiment was integrated over 150 years, with the added freshwater flux kept constant. The Atlantic Meridional Overturning Circulation (AMOC) weakened during the first 50 years, followed by a gradual recovery (Fig. 1).

During the weakening phase of the AMOC (defined in Fig. 1), the persistence of SSTs in the North Atlantic is reduced. This might influence the temporal characteristics of the atmosphere as well. Here, we seek to investigate possible responses in atmospheric temporal variability to a weakening AMOC, in terms of NAO and ENSO variability.

**ENSO response**

![Figure 2](image)

**NAO response**

![Figure 3](image)

**Figure 2** Regression of monthly Niño3.4-index on monthly mean SST (left, contour interval 0.25 K) and power spectrum of the Niño3.4 index (right) for the AMOC weakening phase (above) and CTRL (below). Grey lines in the power spectra show the 95% confidence levels.

The ENSO develops a significant biennial mode, as can be seen by the peak at 24 months periodicity. The ENSO tends to oscillate between La Niña and El Niño states every year in the AMOC weakening phase. The annual cycle is less pronounced in the weakening phase, as can be seen by the magnitude of the peaks at 12 months periodicity.

**Figure 3** The first EOF of Atlantic wintertime SLP variability (left, C.I. 0.5 hPa) and power spectra of time series generated by regressing the EOF pattern on monthly mean SLP (right), for the weakening phase (above) and CTRL (below).

The first EOF reveals the NAO pattern. In the weakening phase of the AMOC, the NAO develops pronounced year-to-year variability, as seen by the peak at 24 months in the frequency plot. As a result, the NAO oscillates between positive and negative values almost every year in the AMOC weakening phase.

**Figure 4** Power spectrum of the equatorward ocean transport. It exhibits pronounced biennial variability in the AMOC weakening phase, as seen by the peak at 24 months. Figure 5 shows that the transport, accumulated over the 12 preceding months, is associated with the equatorial thermocline depth and hence the ENSO phase.

**Figure 5** Lag-correlation between the instantaneous thermocline depth and the equatorward ocean transport accumulated over the instantaneous and the 11 preceding months during the AMOC weakening phase.

**Figure 6** SST (shaded, 0.2 K) and SLP (contours, 0.25 hPa) anomalies as composites of positive NAO winters during the weakening phase (left), and the following fall (right).

During winter, the NAO produces a tripolar SST pattern (Fig. 6, left). Fig. 6 (right) shows that the sub-tropical part of the cold anomaly west of North Africa, re-appears the following fall (called re-emergence). This effect is strengthened in the AMOC weakening phase due to enhanced trade winds. Associated with this is a Rossby wave extending northwards in the upper troposphere, which include a pressure anomaly east of Britain. This pattern favours a southward shift of the jet path and a negative NAO, favouring a NAO sign opposite to the prior winter. This allows for a two-year NAO cycle, since a corresponding process takes place following negative NAO winters.

The ENSO also seem to affect the NAO through zonal wind anomalies extending from the Pacific. It is unclear why this teleconnection is stronger in the AMOC weakening phase, but may be due to less persistence internal to the Atlantic climate due to the cooling trend in the ocean there. Such a situation could make the climate more susceptible to remote forcings, such as the ENSO.

**Figure 7** R3 for Niño3.4 index vs. 300 hPa zonal wind for the AMOC weakening phase. Timeseries are averages over Dec-Feb. Contours are drawn every 0.2, with the zero contour omitted.

**Conclusions**

In this study, the ENSO and NAO variability response to a weakening Atlantic meridional overturning circulation (AMOC) in a coupled model is investigated.

The main findings are:

- When the AMOC weakens, a pronounced two-year cycle appear in both ENSO and NAO.
- The ENSO response is mediated through a more effective recharge-mechanism. It is unclear why this process is altered in the AMOC weakening phase.
- The NAO response is influenced by enhanced re-emergence in the sub-tropical North Atlantic, which is followed by pressure anomalies in the North Atlantic.
- The NAO also seems to be affected by ENSO through zonal wind anomalies extending over the North American continent.