Separating ENSO and NAO signatures in the North Atlantic

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Introduction

ENSO is known to affect climate in remote areas of the world, including the mid- and high-latitudes, but its influence on the **North Atlantic-European (NAE) sector** is still under debate.

The difficulties in detecting the ENSO-related signal in the North Atlantic are mainly due to the large **internal variability** of the region, and to the tendency of the ENSO signature to project on a **"NAO-like" pattern**, particularly at surface.

It is important to **distinguish ENSO from the internally-generated variability associated with the NAO**, which is linked to different dynamical processes. Separating the two contributions would represent a first step towards better understanding the ENSO-NAE teleconnection and potentially improving the **seasonal prediction** capabilities for this region.

‣ The target season of this study is **late winter (JFM)**, when the ENSO signal in this region appears to be strongest and fully-established. Observational and model data are used to investigate the ENSO-related component and its dynamics versus internal variability.

1. ENSO and NAO signals in reanalysis

Linear regression on two indices is used to detect the ENSO- and NAO-related signals in reanalysis (NOAA-20CR).

- **Niño3.4-index** = area-averaged SST anomalies (HadISST) over Niño3.4 region (5°N-5°S; 170°W-120°W)
- **NAO-index** = leading principal component (EOF) of mslp over NAE domain (20°N-90°N; 90°W-40°E)

‣ Over the North Atlantic, the surface (mslp) wintertime signature of ENSO (Fig.1a) consists of a dipolar structure that resembles the NAO (Fig.1b).

‣ The regression of z200 on the NAO-index projects on the circumglobal waveguide pattern (Fig.1d; *Branstator, 2002*), while the regression on the Niño3.4-index shows the well-known troposhperic wavetrain associated with ENSO (Fig.1c; *DeWeaver and Nigam, 2002; Bladé et al., 2008*).

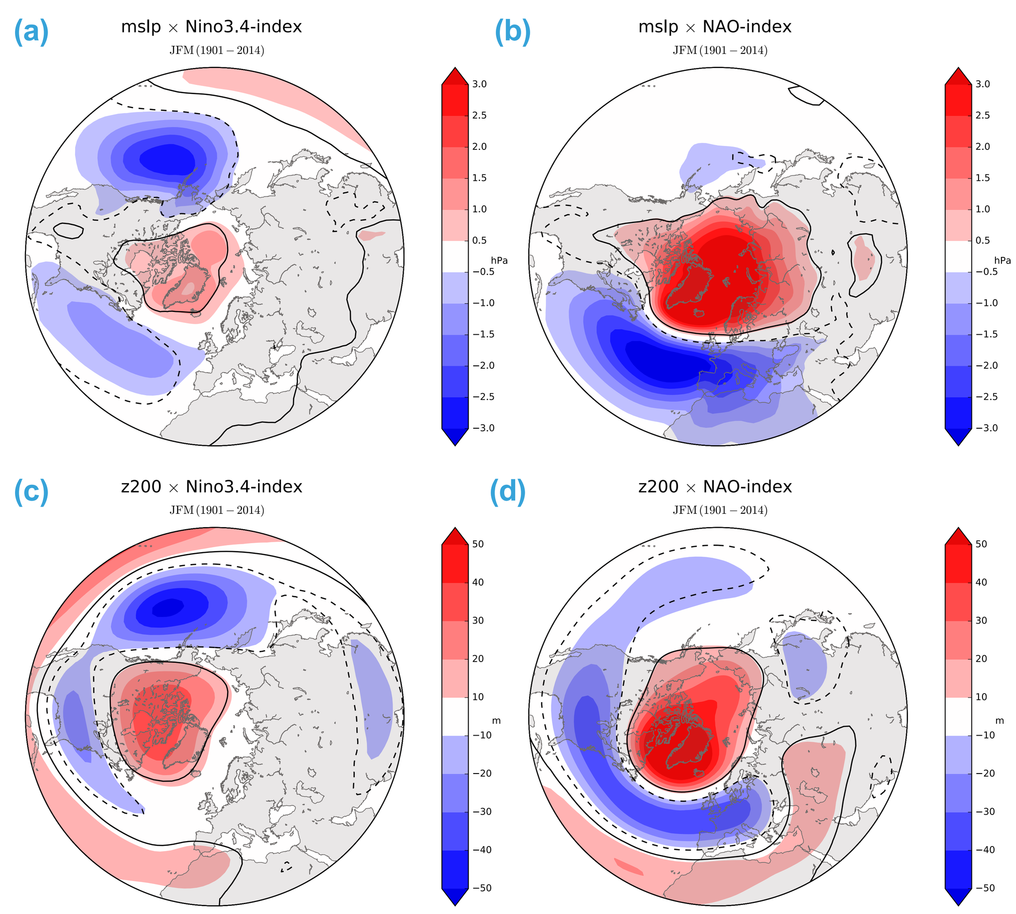


Figure 1. *Top:* linear regression of mslp anomalies on the (a) Niño3.4-index and (b) NAO-index. *Bottom:* linear regression of z200 anomalies on (a) Niño3.4-index and (b) NAO-index. NOAA-20CR, JFM, 1901-2014. Contours indicate 95% significance.

2. Disentangling ENSO and NAO dynamics

Transient-eddy diagnostics are used to separate the dynamics linked to ENSO and the NAO.

The **eddy momentum flux** at 200hPa is computed from daily data using the 24-h filter (*Wallace et al., 1988*) and regressed on the two indices.

‣ ENSO mainly affects the storm-tracks in the **North Pacific** (Fig.2a), and consequently precipitation over North America (Fig.2c).

‣ In the **North Atlantic**, ENSO weakens the eddy-driven jet (Fig.2a) and has little impact on European precipitation (Fig.2c), while the NAO shifts the jet in latitude (Fig.2b), leading to the characteristic wet-dry dipole over Europe (Fig.2d) associated with the displacement of the storm-tracks.

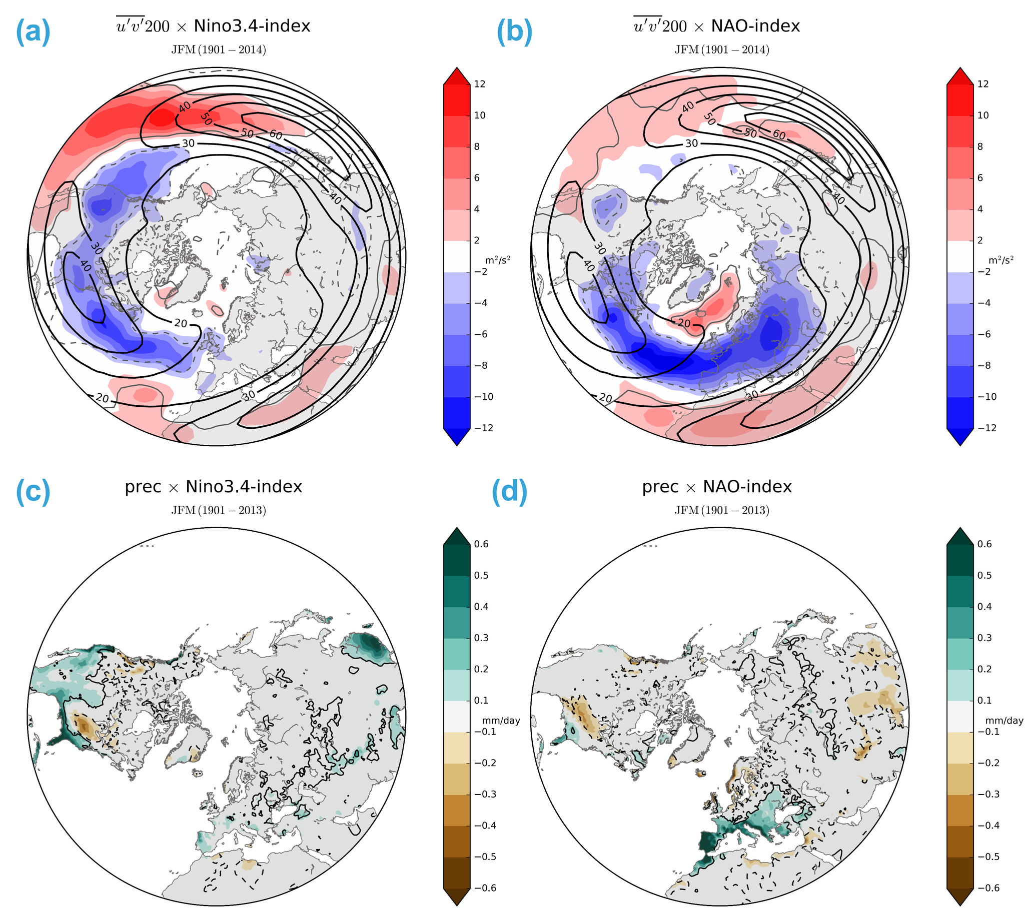
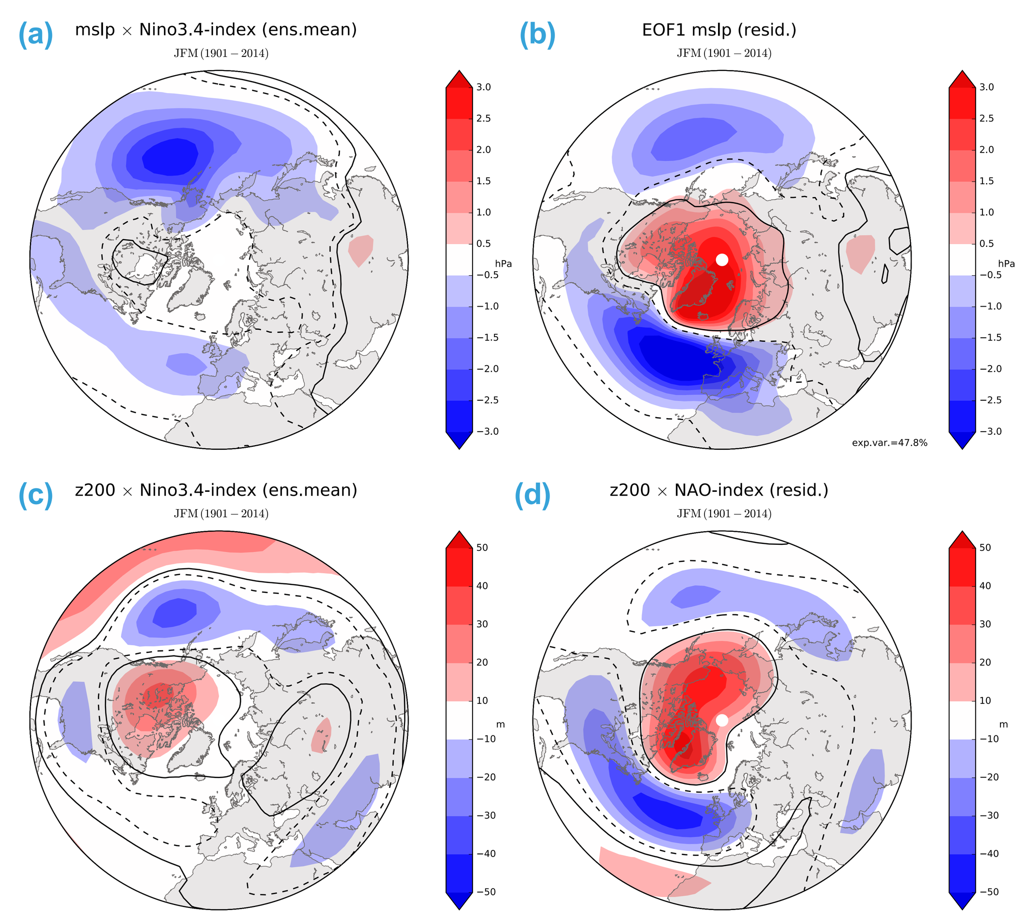


Figure 2. *Top:* linear regression of eddy momentum flux at 200 hPa on the (a) Niño3.4-index and (b) NAO-index, with climatological u (thick contours). NOAA-20CR, JFM, 1901-2014. *Bottom:* linear regression of precipitation anomalies on (a) Niño3.4-index and (b) NAO-index. GPCC, JFM, 1901-2013.Contours indicate 95% significance.

3. ENSO-forced and internal-NAO signals in two models



The **SPEEDY model** (ICTP AGCM) is run with prescribed SST anomalies from HadISST to produce a 10-member ensemble (1901 to 2014).

- The Niño3.4-index is used to linearly regress **ensemble-mean** mslp and z200 anomalies, to isolate the SST-forced signal (Figs.3a,c).
- The internal variability of the model is studied by considering the **residuals** of each member around the ensemble mean. The leading "residual" EOF mode (Fig.3b) represents the internally generated NAO.

‣ The ensemble mean captures the extra-tropical wavetrain response to ENSO (*c.f.* Figs.1c,3c) and part of the surface signature over the NAE region (*c.f.* Figs.1a,3a).

‣ SPEEDY properly captures the hemispheric signature of the NAO at upper levels (*c.f.* Figs.3d,1d).

Similar results are found for the **ECMWF ERA-20CM model integrations** (AGCM-IFS). Again, the ENSO-forced upper-level response is properly captured (Fig.4b) but the surface signature is not fully represented (Fig.4a).

Figure 3. *Left:* linear regression of ensemble-mean (a) mslp and (c) z200 anomalies on the Niño3.4-index. *Right:* (b) leading "residual" EOF mode of mslp over the NAE domain, after removing the ensemble mean and concatenating the members; (d) linear regression of z200 residual anomalies on the "residual" NAO-index. SPEEDY, JFM, 1901-2014. Contours indicate 95% significance.

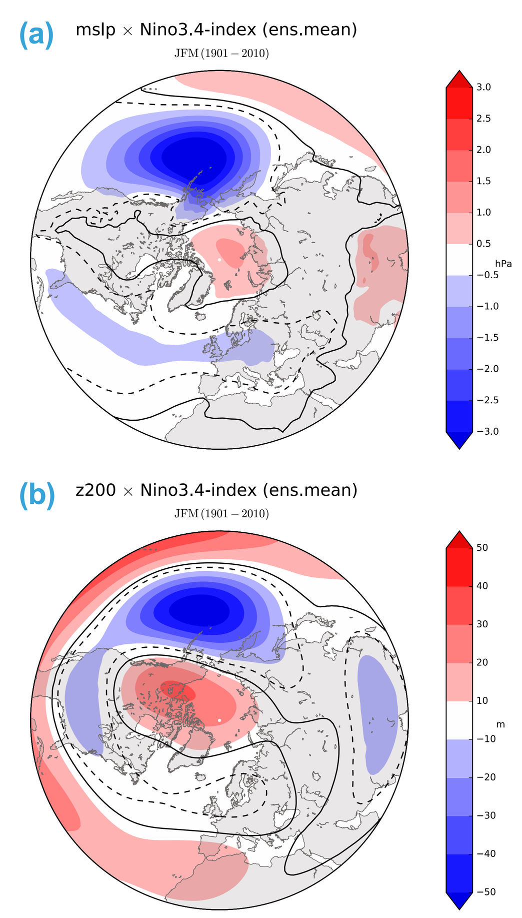


Figure 4. Same as Fig.3a,c but for ERA-20CM (1901-2010).

4. Skill and variability in models

The **skill** in capturing the observed **variability** of z200 and mslp is evaluated with both ensemble-means, using NOAA-20CR as reference.

‣ The ENSO-forced extra-tropical wavetrain is visible in both models as regions of higher correlation (*c.f.* Fig.5a,3c; Fig.5b,4b).

‣ The excessive variability in ERA-20CM over the Arctic in the Eastern Hemisphere (Fig.5d) suggests that the positive signal in Fig.4a is unrealistic.

‣ The missing part of the surface ENSO signature at high latitudes in SPEEDY (Fig.3a) may be due to a **lack of variability** (Fig.5c), related to related to a model bias (*e.g.* no proper stratosphere) or to the experimental protocol not allowing for atmosphere-ocean coupling, as some reduced variability is also present in ERA-20CM (Fig.5d).

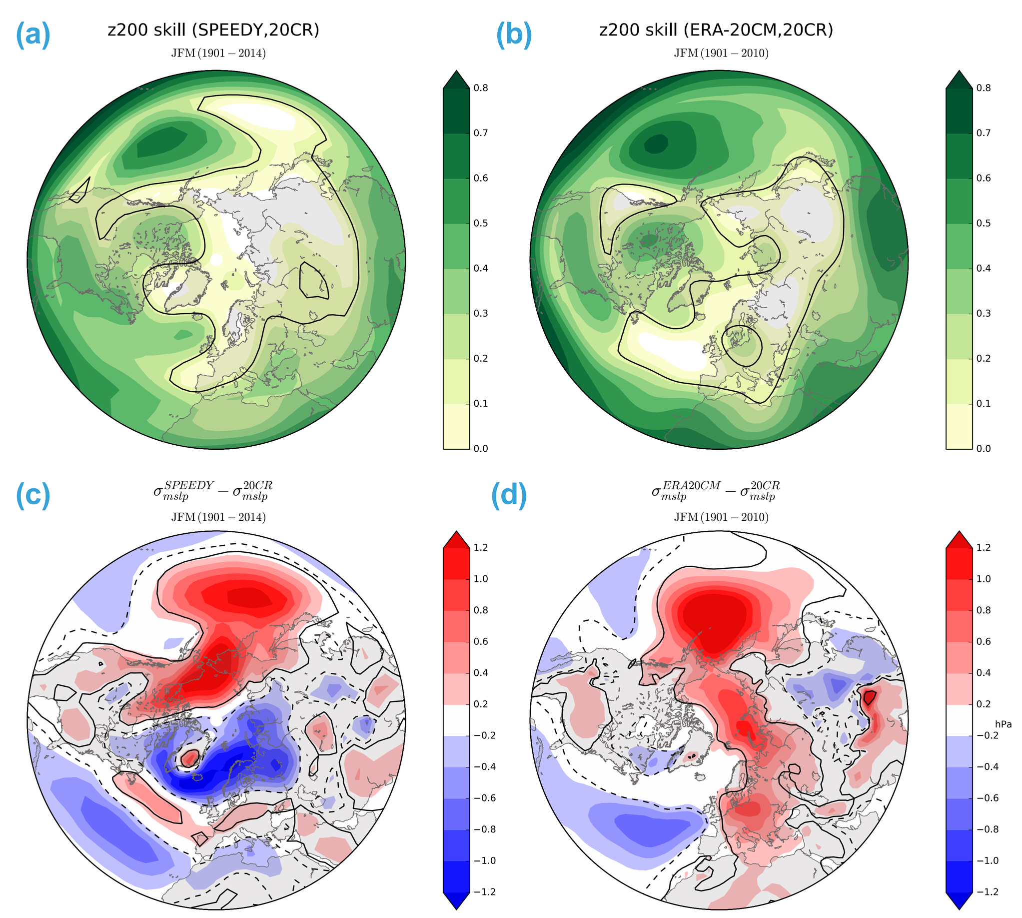


Figure 5. *Top:* z200 skill of (a) SPEEDY (b) ERA-20CM with respect to NOAA-20CR. *Bottom:* difference in standard deviation of mslp for (a) SPEEDY and NOAA-20CR and (b) ERA-20CM and NOAA-20CR; for the models, the standard deviation is computed across all members. Contours indicate 95% significance.

Summary and conclusions

Despite some similarities in their surface signatures over the NAE region, **ENSO and the NAO represent independent manifestations of climate variability**.

‣ The **observed** upper-tropospheric patterns show marked differences. The use of transient-eddy diagnostics highlights separate dynamical imprints, that lead to **different impacts** in other fields such as precipitation, stressing the importance of separating the two contributions.

‣ A **model approach** allows to further isolate the SST(ENSO)-forced component from the internal variability corresponding to the NAO. In two models of different complexity and resolution, a similar experimental set-up leads to comparable results that confirm the differences observed in reanalysis.

‣ In both simulations, the **upper-level wavetrain associated with ENSO is well captured**, but the models **fail in representing the canonical ENSO signature at surface**, particularly at high latitudes, probably because of model biases and the difficulty of modelling surface variability with atmosphere-only experiments.

The role of the stratosphere on surface variability/predictability and in the ENSO-NAE teleconnection remains to be further analysed, as the two models treat it differently.

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