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. Its impacts are evident and well-understood for some extratropical regions, such as the North Pacific, while the ENSO influence on the North Atlantic-European (NAE) sector is still under debate, concerning both the amplitude of the impacts and the underlying dynamics driving the teleconnection. 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 the 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. Linear regression and EOF analysis are applied to observational and model data to investigate the ENSO-related component and its dynamics versus internal variability.

1. ENSO and NAO signals in reanalysis

Linear regression analysis is used as a first step to detect the ENSO-related signal in reanalysis. The Niño3.4 index, based on area-averaged SST anomalies from the HadISST dataset, is used to regress mslp and z200 anomalies from the NOAA 20CR dataset (Figs.1a,c).
Over the North Atlantic, the surface wintertime signature of ENSO consists of a dipolar structure that resembles the NAO (Fig.1a), which corresponds to the leading EOF pattern of mslp over the NAE sector (20N-90N,90W-40E; Fig.1b). The associated principal component time series (NAO index), however, is poorly correlated with the Niño3.4 index (r=0.24; <5%).
The regression of z200 with 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 wave-train associated with ENSO (Fig.1c; *DeWeaver and Nigam 2002, Bladé et al. 2008*).

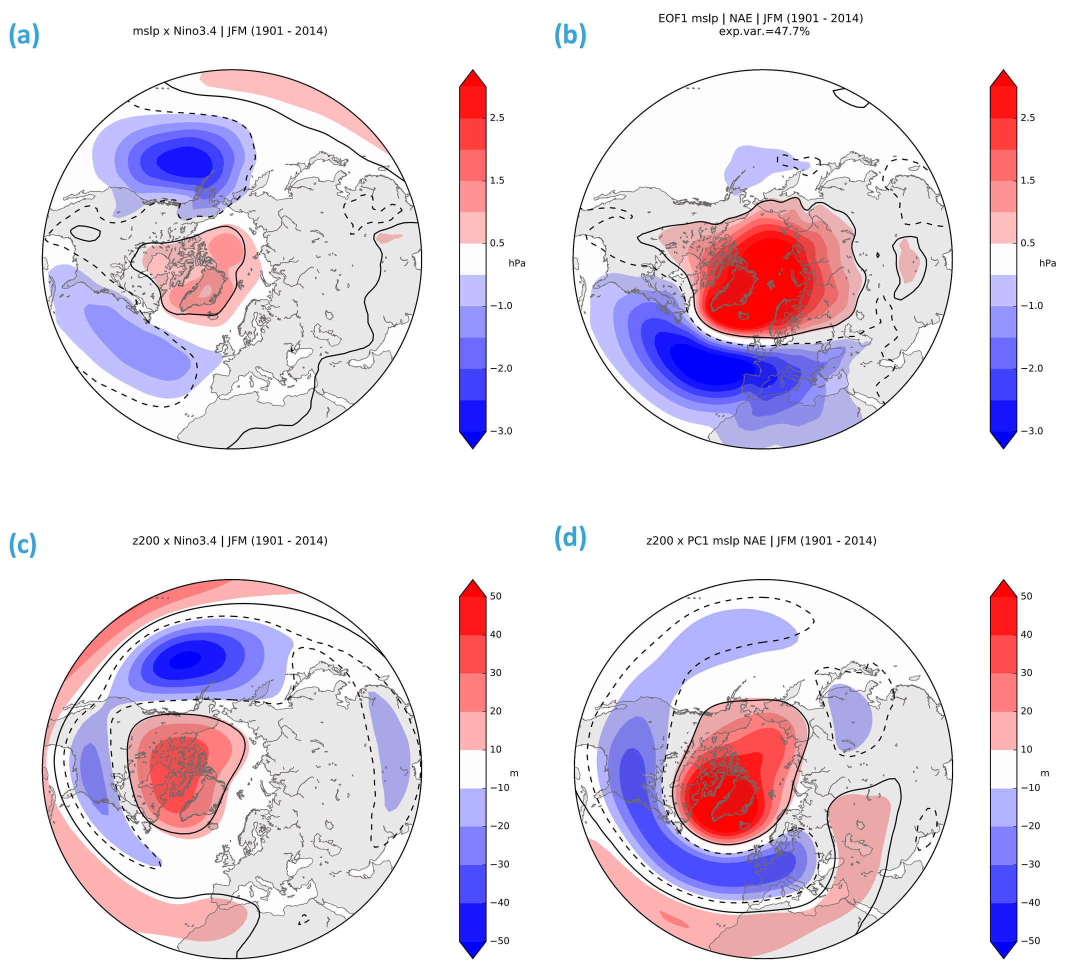

Figure 1. *Left:* linear regressions of (a) mslp and (c) z200 anomalies on the Niño3.4 index. *Right:* (b) leading EOF pattern of mslp over the NAE domain; (d) linear regression of z200 anomalies on the NAO index. For all the figures, JFM is considered and the analysed the period is 1901-2014.Reanalysis.

2. ENSO-forced and internal-NAO in SPEEDY

An intermediate complexity model (ICTP AGCM/SPEEDY) is run with globally prescribed SST anomalies from reanalysis (HadISST dataset) and slightly different initial conditions to produce a 10-member ensemble (1901 to 2014).
The observed Niño3.4 index is then used to linearly regress ensemble-mean mslp and z200 anomalies, to isolate the SST-forced signal (Figs.2a,c). The ensemble-mean captures the extratropical wavetrain response to ENSO (*c.f.* Figs.1c,2c) and part of the surface signature over the NAE region.
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.2b) represents the internally generated NAO.
SPEEDY properly captures the hemispheric signature of the NAO at upper levels (Fig.2d).

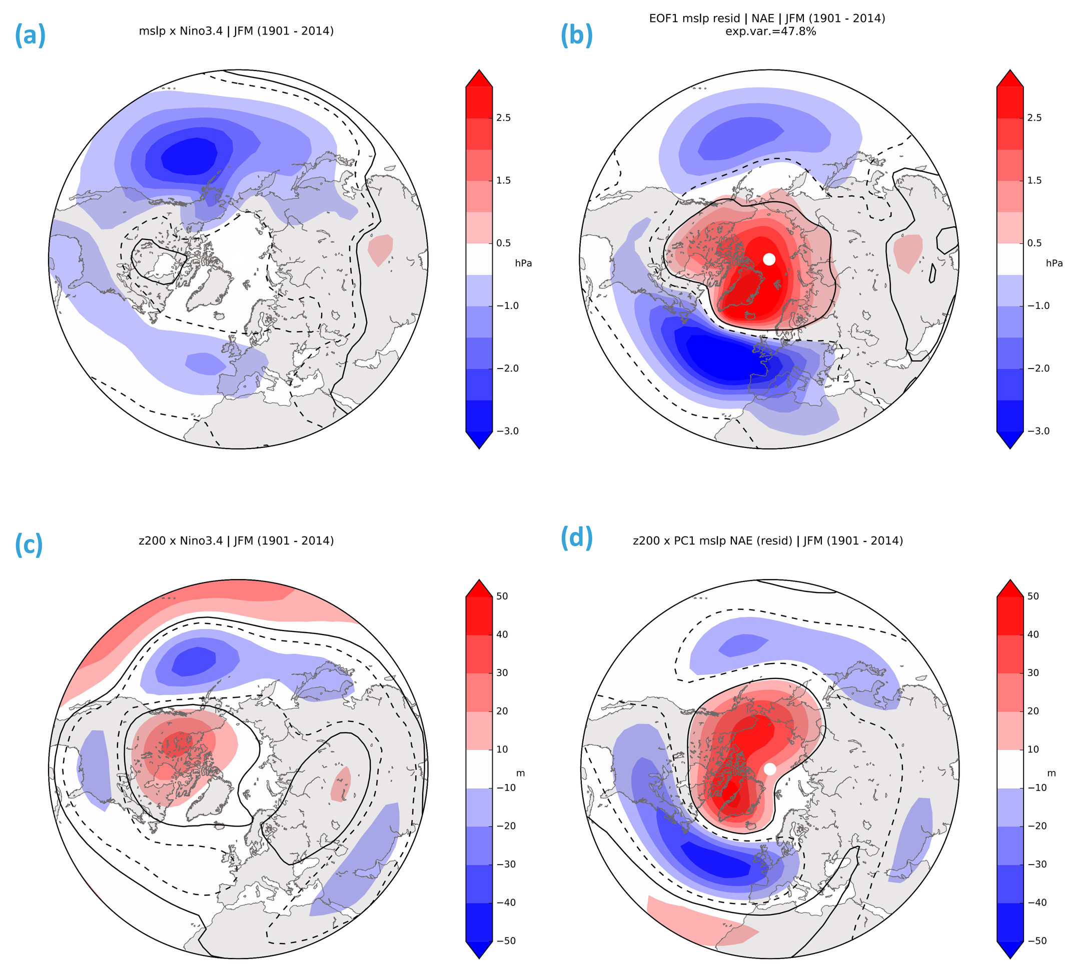

Figure 2. *Left:* linear regressions of ensemble-mean (a) mslp and (c) z200 anomalies on the observed Niño3.4 index. *Right:* (a) leading "residual" EOF mode of mslp over the NAE domain, after removing the ensemble mean from each member and concatenating them; (d) linear regression of z200 anomalies on the "residual" first principal component of mslp. For all the figures, JFM is considered and the analysed the period is 1901-2014.Model.

3. SST-forced signal in SPEEDY

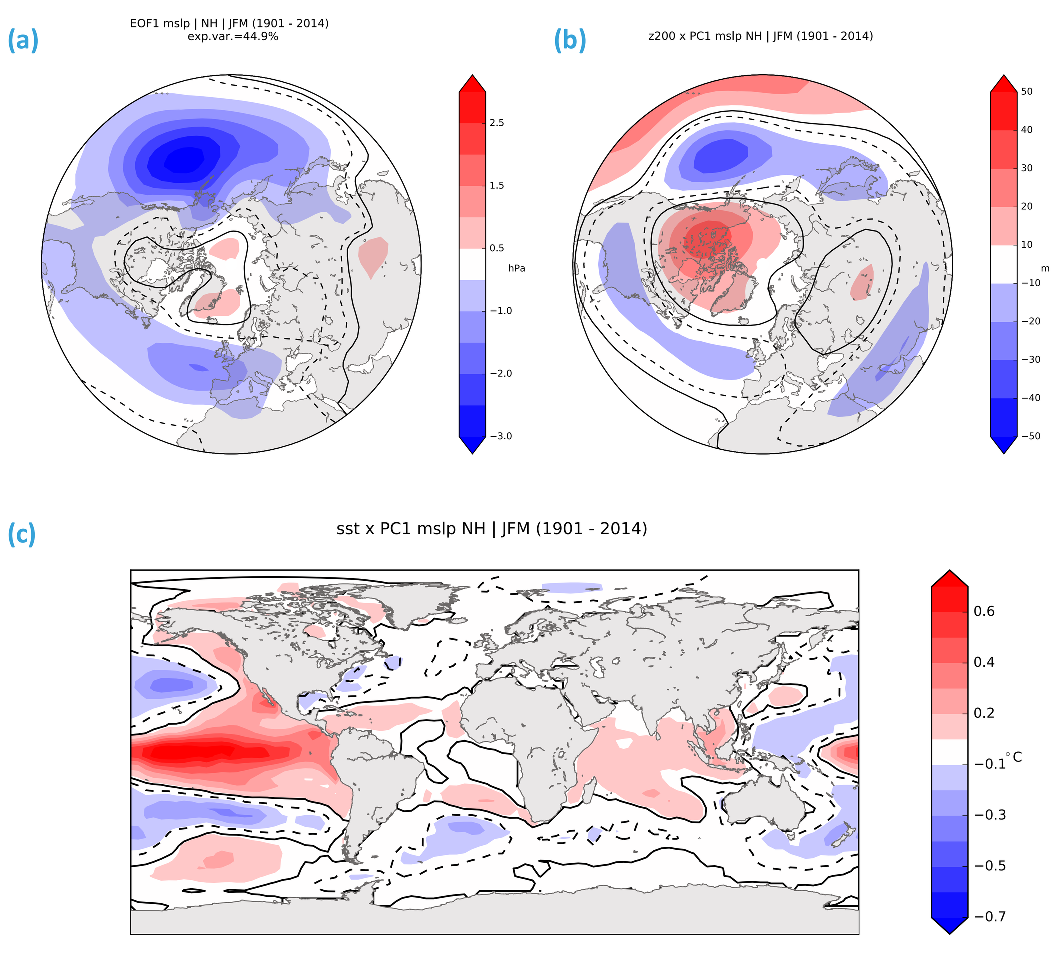

Figure 3. (a) Leading EOF pattern of ensemble-meab mslp over the hemispheric domain; (b) linear regression of ensemble-mean z200 with the first principal component time series of mslp over the hemispheric domain; (c) same as (b) but for SST. For all the figures, JFM is considered and the analysed the period is 1901-2014.Model.

The SST-forced component in the model is studied without any assumption about the source region of the forcing. EOF analysis is applied to the ensemble-mean mslp, on a hemispheric domain (20N-90N; 0-360E) to maximize the forced component. Regression analysis is performed on this "forced" principal component using ensemble-mean z200 and SST anomalies.
The resulting patterns are very similar to the regression maps obtained for ENSO, both at surface (Figs.3a,2a) and upper levels (Figs.3b,2c), projecting on the observed dipolar structure (Fig.1a) and wavetrain (Fig.1c) respectively.
The SST pattern (Fig.3c) confirms the dominant role of ENSO in the globally forced signal; the correlation between the "forced" principal component and the observed Niño3.4 index is r=0.87.

4. Disentangling ENSO and NAO dynamics

Transient-eddy diagnostics are used to try to separate the dynamics linked to ENSO and the NAO in reanalysis. The eddy momentum flux at 200hPa is computed from daily data using the 24-h filter (*Wallace et al, 1988*). Regressions are performed onto the observed Niño3.4 (Fig.4a) and NAO (Fig.4b) indices.
The ENSO wavetrain mainly affects the storm-tracks in the North Pacific.
In the North Atlantic, ENSO weakens the eddy-driven jet, while the NAO shifts it in latitude.

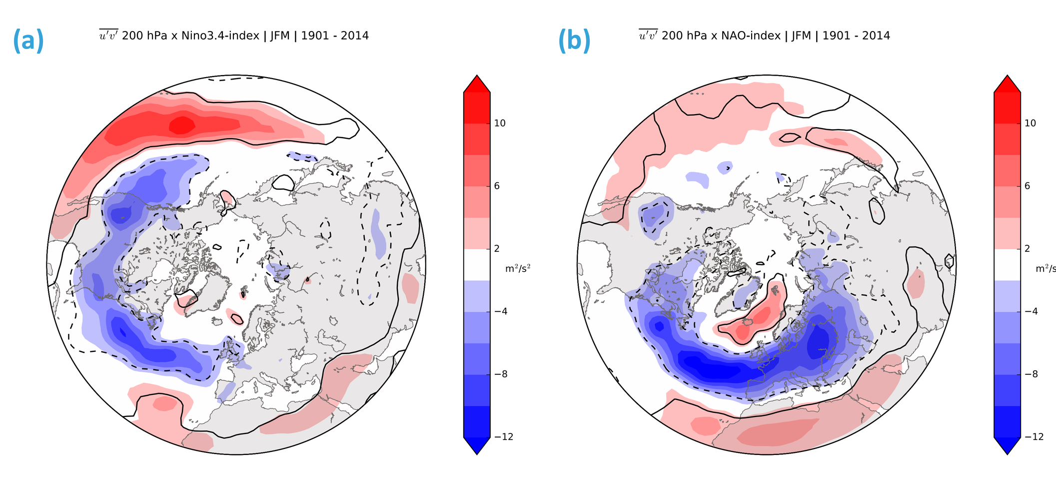

Figure 4. Linear regressions of eddy momentum flux at 200 hPa on (a) Niño3.4 index and (b) NAO index. For all the figures, JFM is considered and the analysed the period is 1901-2014. Reanalysis.

5. Future Work

Further analysis using the 20CR and other observational datasets will be carried on. AMIP runs from state-of-the-art climate models will be employed to complement the analysis performed with SPEEDY, including both low-top and high-top models. Subsequently, long control runs performed with fully coupled models (EC-EARTH3, CAM5.3, …), with and without resolved stratosphere, will be used to investigate the relationship between the ENSO teleconnection in the North Atlantic and stratospheric variability. At a later stage, the contribution of the ENSO-NAE teleconnection to the regional prediction skill will be assessed, by analysing operational seasonal forecast systems (EUROSIP, NMME).

References

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