Decadal NAO-Gulf Stream SST front interaction

Luca Famooss Paolini[a,b] (luca.famooss@cmcc.it), Noureddine Omrani[c,d], Panos Athanasiadis[a], Alessio Bellucci[e], Paolo Ruggieri[a,f]

[a] Euro-Mediterranean Centre on Climate Change, Bologna, Italy; [b] Ca' Foscari University, Department of Environmental Science, Informatics and Statistics, Venice, Italy; [c] Geophysical Institute, University of Bergen , Bergen, Norway; [d] Bjerknes centre for climate research, Bergen, Norway; [e] Institute of Atmospheric Sciences and Climate - National Research Council, Bologna, Italy; [f] University of Bologna, Department of Physics and Astronomy, Bologna, Italy

Introduction

The extratropical atmospheric circulation is affected by the Gulf Stream sea surface temperature front (GSF) variability. Therefore, studying the drivers of the GSF variability is important for understanding the associated coupled variability and predictability. The variability of the GSF position has been mainly linked to the North Atlantic oscillation (NAO) variability. The NAO can affect the GSF position by influencing the wind-driven oceanic circulation, exciting oceanic Rossby waves and changing the transport of the deep western boundary current (DWBC). This work investigates the spectral characteristics of the GSF–NAO system and assesses the mechanisms through which the NAO can force the variability of the GSF position on interannual to decadal timescales. ERA5 and ORAS5 data are used.

Methodology

- **Position of the GSF**: zonally averaged latitude of the maximum SST gradient in the 50°—68°W longitudinal range in DJF season.
- **NAO**: the projection of mean sea level pressure (MSLP) anomalies on the leading eof over the North Atlantic sector during DJF season.
- **Cross-wavelet analysis**: analysis performed to analyze the time-dependent GSF-NAO covariability in spectral domain

Results 1

The GSF and NAO covary at (6—12)-years timescale between 1970—2015, with the NAO leading the GSF by about 1.5—3.5 years (phase relationship 100° on average). A peak at (6—12)-years timescale is also present in GSF and NAO power spectra, providing further evidence of the GSF-NAO covariability. In order to deepen the understanding of the ocean-atmosphere interaction at these timescales, the data have been band-pass filtered at frequency band corresponding to periods of (6—12)-years.

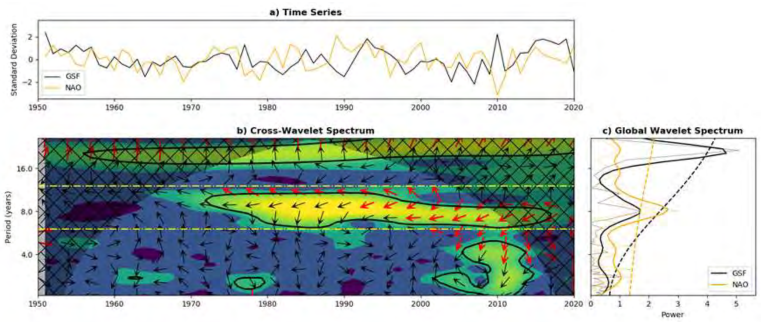

Figure 1 – Cross-wavelet analysis between the NAO and the GSF. a) GSF and NAO time series. b) GSF-NAO wavelet spectrum (shading) and phase relationship (vectors). The black lines (red vectors) highlight regions where the cross-wavelet spectrum (coherence) is significant. c) Global wavelet spectrum for the GSF and the NAO.

Results 2

Strong positive NAO-like anomalies lead the northward shifts of the GSF by about 3 years. These anomalies are associated with a tripolar SST pattern 1 year after the strongest NAO changes and 2 years before the GSF shifts. These changes are consistent with the NAO forcing both SST tripole and GSF shifts.

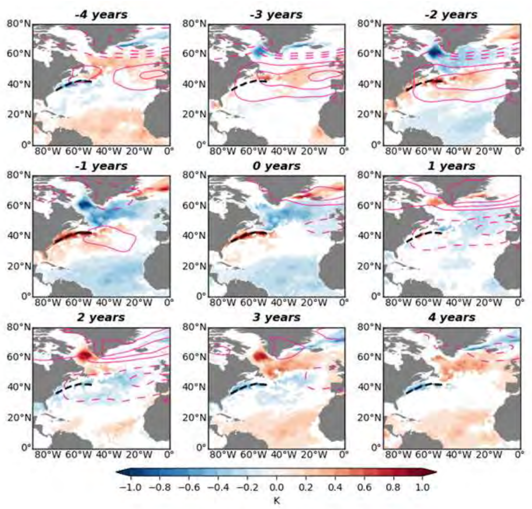

Figure 2 – Lead-lag linear regression of SST (shades) and MSLP (contours) anomalies on the GSF.

Results 3

- **NAO-GSF**: In the decadal timescale, the NAO leads the GSF shifts by about 3 years, consistently with results shown before.
- **Wind-driven oceanic circulation adjustment**: the meridional Ekman velocity over the GSF area adjusts instantaneously to the NAO, explaining the onset of the GSF shifts in response to the NAO.

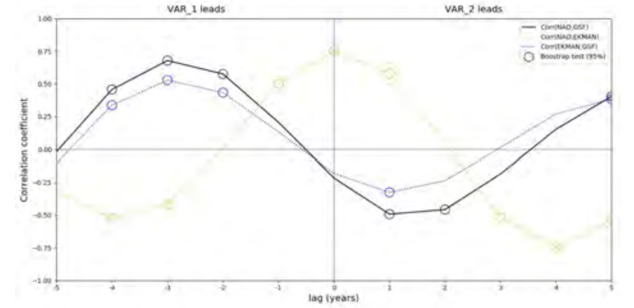

Figure 3 – Lead-lag cross-correlation between band-pass filtered NAO, GSF and Ekman index: NAO-GSF (black), NAO-Ekman (yellow), Ekman-GSF (blue). Ekman index: meridional Ekman velocity averaged over the GSF area.

Results 4

- **Rossby waves mechanism**: Evidence of Rossby waves travelling westward between 1975—1990. Positive (negative) SST anomalies in the eastern North Atlantic are forced by positive (negative) NAO phase. A positive (negative) NAO phase is associated with northward (southward) GSF shifts after about 3 years, i.e. the time for the SST anomalies to reach the western North Atlantic in the maturation phase of the GSF shifts.

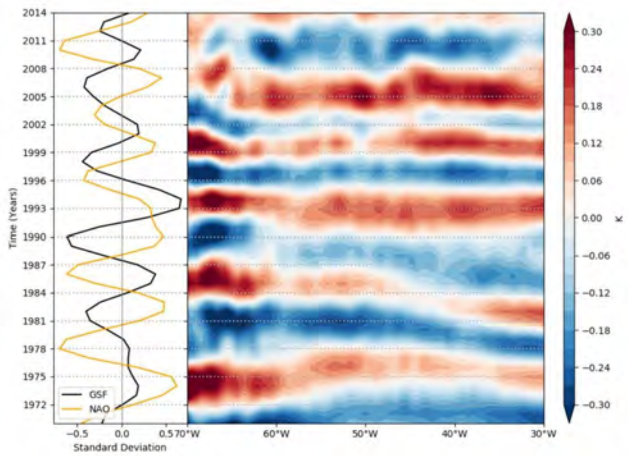

Figure 4 – Left: band-pass filtered NAO (orange) and GSF (black). Right: SST anomalies averaged in the 35°N—38°N latitudinal band

Outcomes

- The GSF and NAO covary at decadal timescale in the period 1970—2015, with the NAO leading the GSF variability by about 1.5—3.5 years.
- The wind-driven oceanic circulation adjustment to the NAO forcing is important in the onset of the GSF shifts.
- The Rossby waves induced by the NAO forcing are important during the maturation phase of the GSF shifts. However, this mechanism is not stationary (1975—1990).
- There are indication of involvement of the DWBC during the growing phase of the GSF shifts (not shown). These results are still under investigation.