Modes of Climate Variability and Atmospheric Circulation Systems in the Euro-Atlantic Sector

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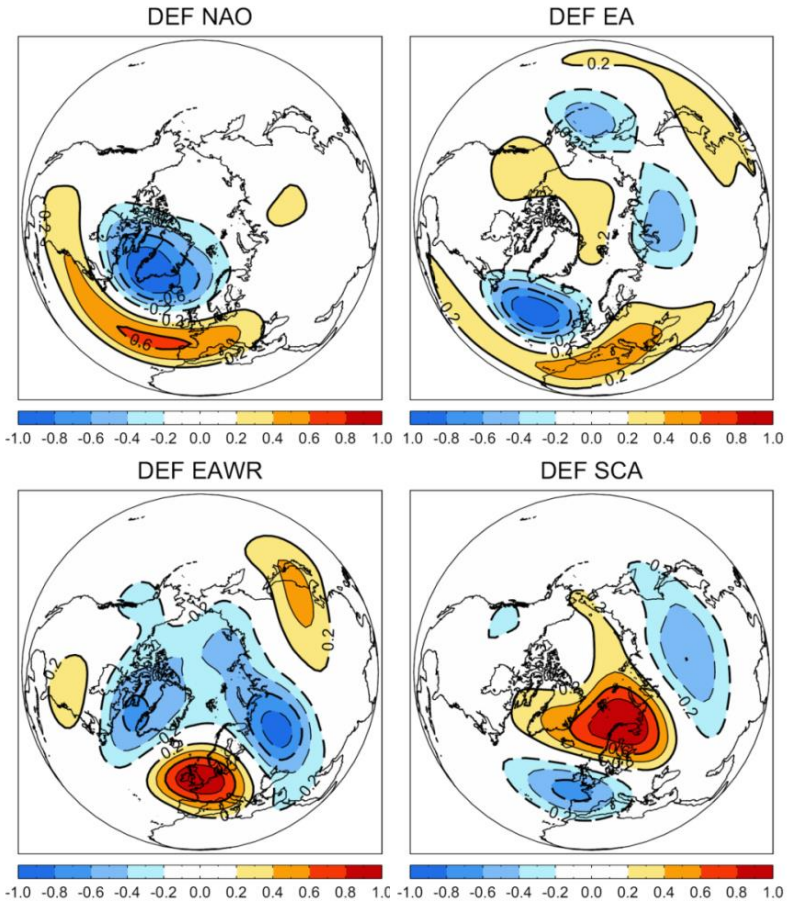
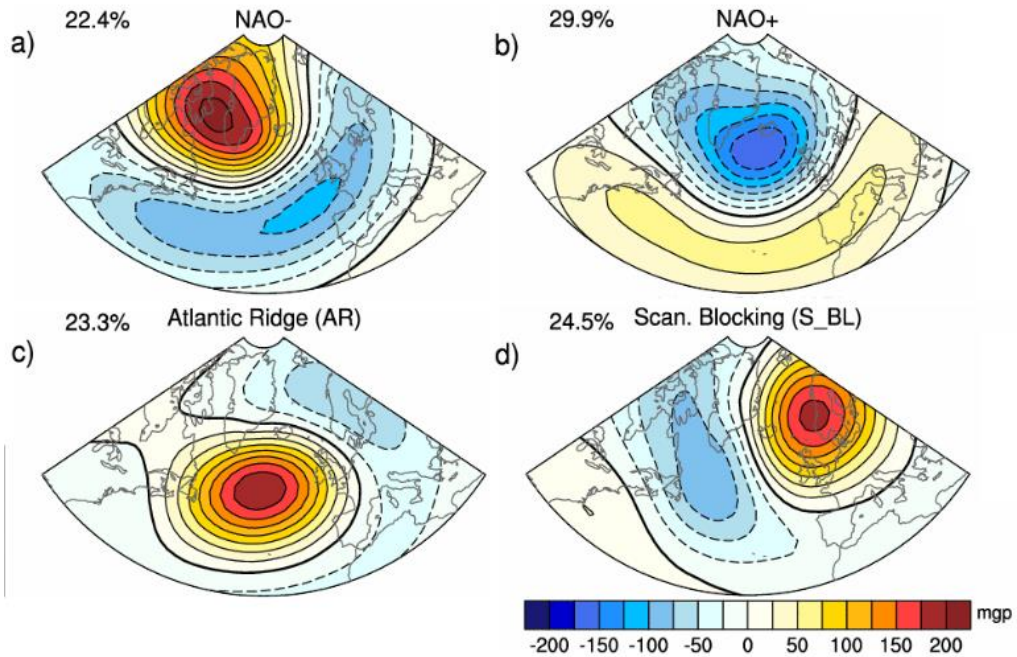
Introduction

- A large fraction of the climate variability in the Euro-Atlantic sector can be explained by a few modes of atmospheric circulation
- They mostly reflect internal variability, but may also respond to external forcings ⇨ predictability



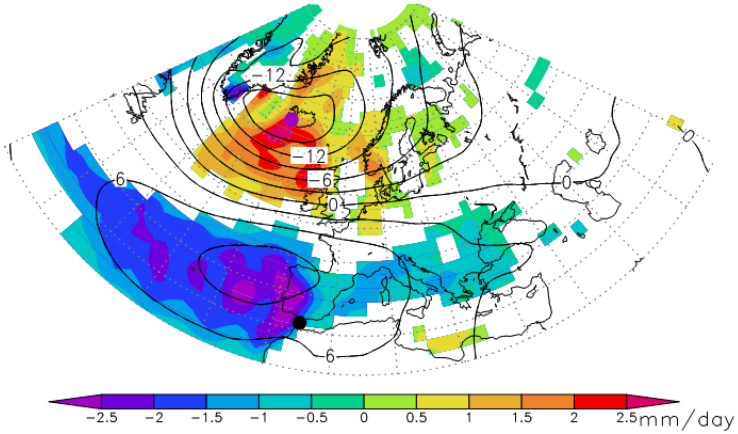


Cassou et al. 2010. Clim. Dyn.

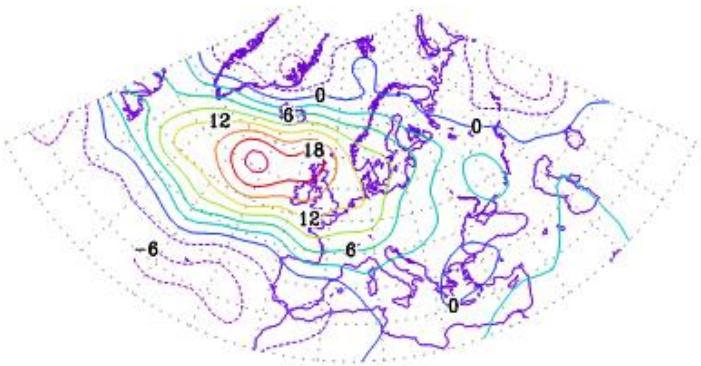
The North Atlantic Oscillation

- Significant NAO **effects in precipitation** with large socio-economic impacts: water resources, energy (solar, wind & hydroelectric production), etc.
- **Asymmetries** between the NAO signals in maximum and minimum **temperatures**

SLP & prec.

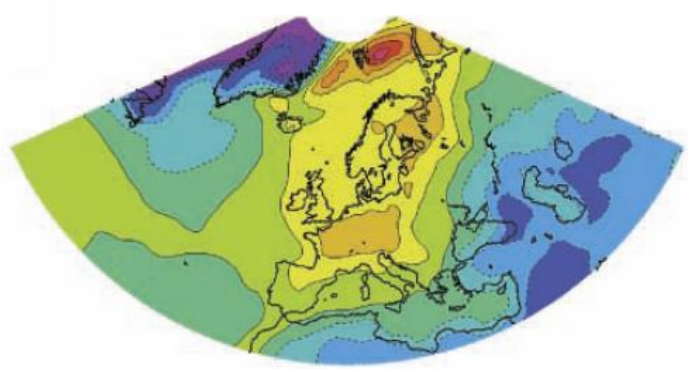


Storm-tracks



Trigo et al. 2002. Clim. Res.

Tmax



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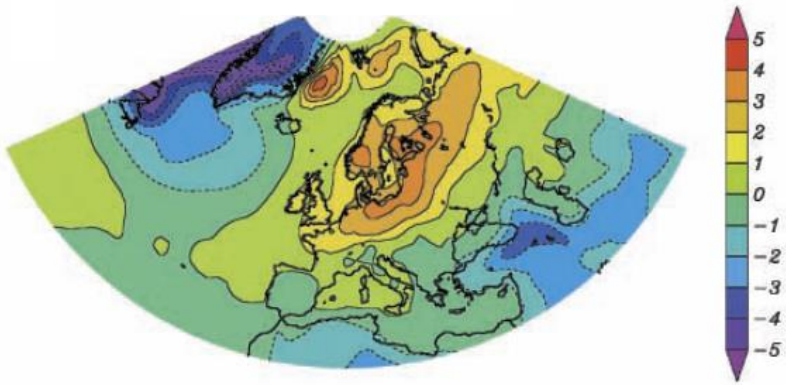
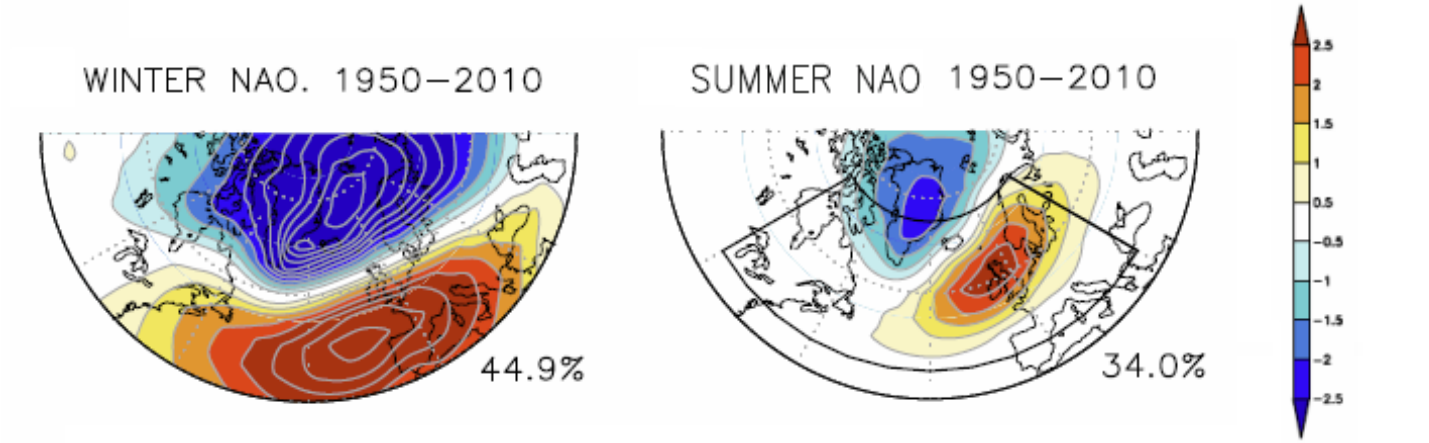
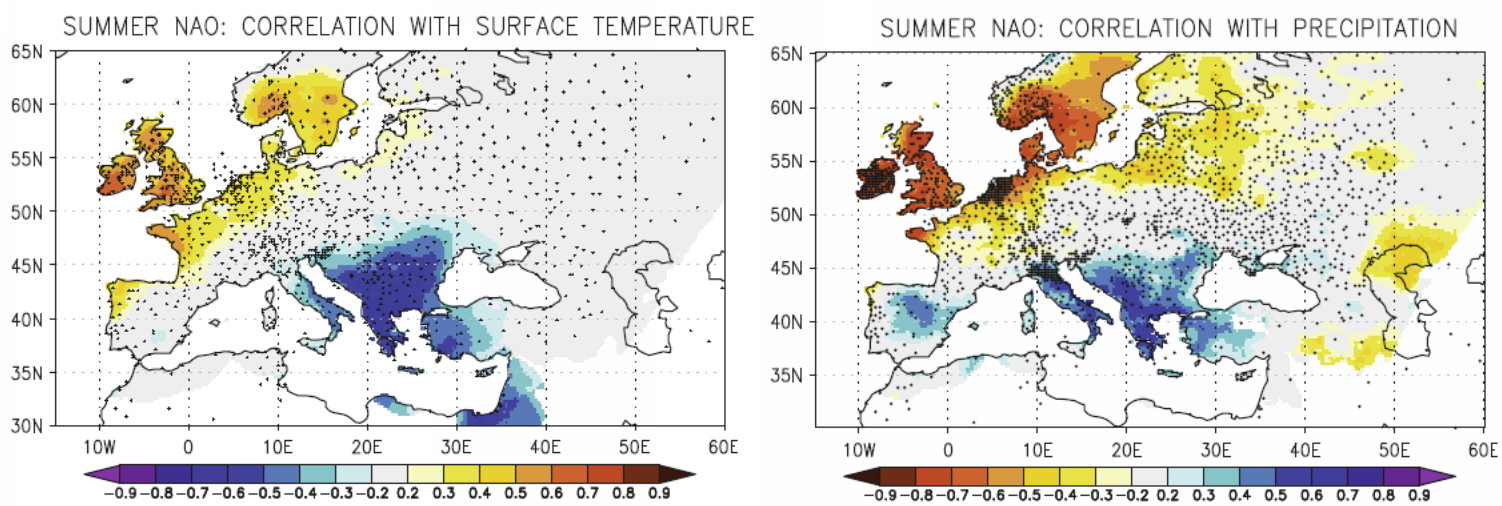


High (>1) minus Low (<-1) winter (DJFM) NAO composite differences

The North Atlantic Oscillation

- The **summer NAO** is the main mode of atmospheric variability in Europe during the high-summer season
- Large signals in precipitation, but nearly opposite to those of its winter counterpart

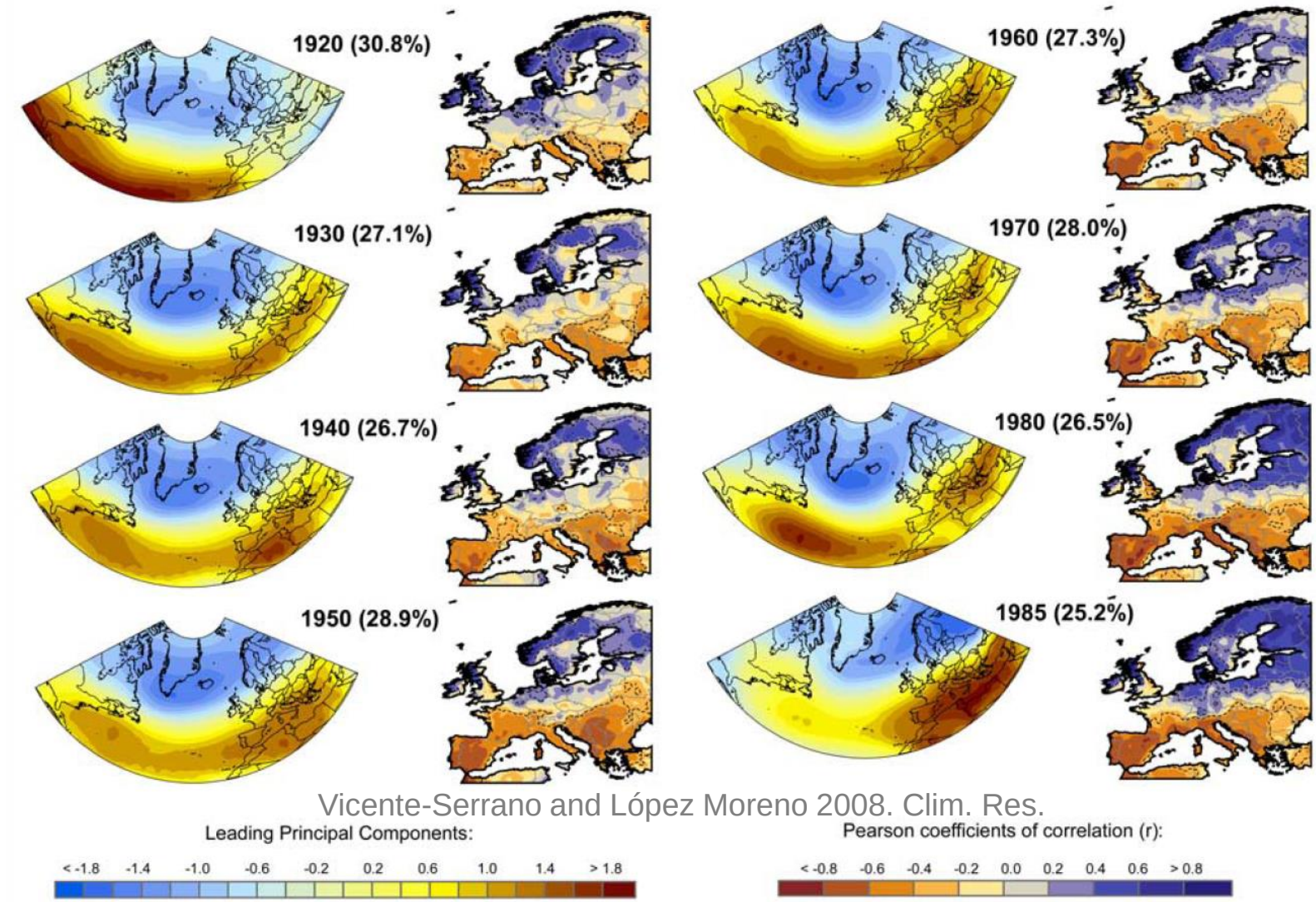




Bladé et al. 2011. Clim. Dyn.

The North Atlantic Oscillation

- **Non-stationary NAO impacts** through the 20th century with a strengthened signal since the 1960s, mainly related to an eastward shift of its action centers.

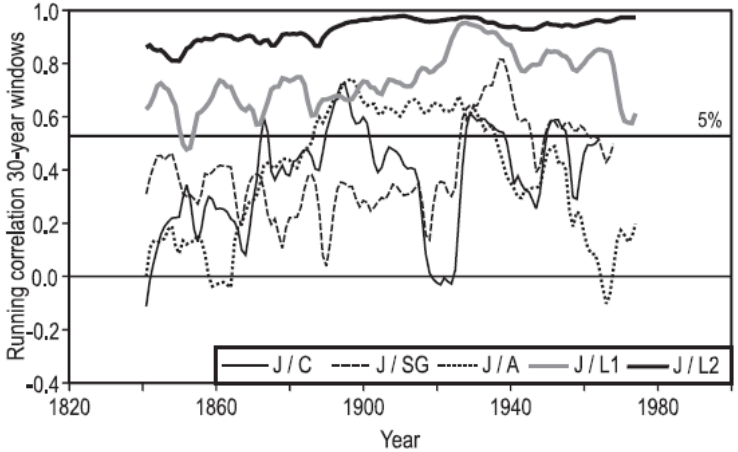


Vicente-Serrano and López Moreno 2008. Clim. Res.

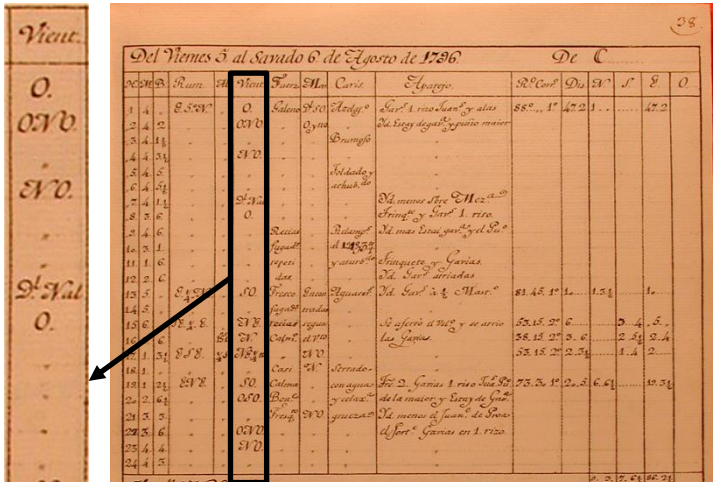
SLP EOF1 (left) and correlation between PC1 and precipitation (right) for selected time periods of the 20th Century

The Westerly Index

- **Wind direction**, an instrumental observation: 1) measured with a 32-point compass; 2) no need of subjective judgments or re-scaling.
- Royal Navy ships' logbooks (1685-1850) + CLIWOC v1.5 + ICOADS v2.1 (1851-2008) ⇨ **Westerly Index (WI)**: persistence (% of days per month) of westerly wind (225º-315º) direction in the English Channel [Wheeler et al. 2009]



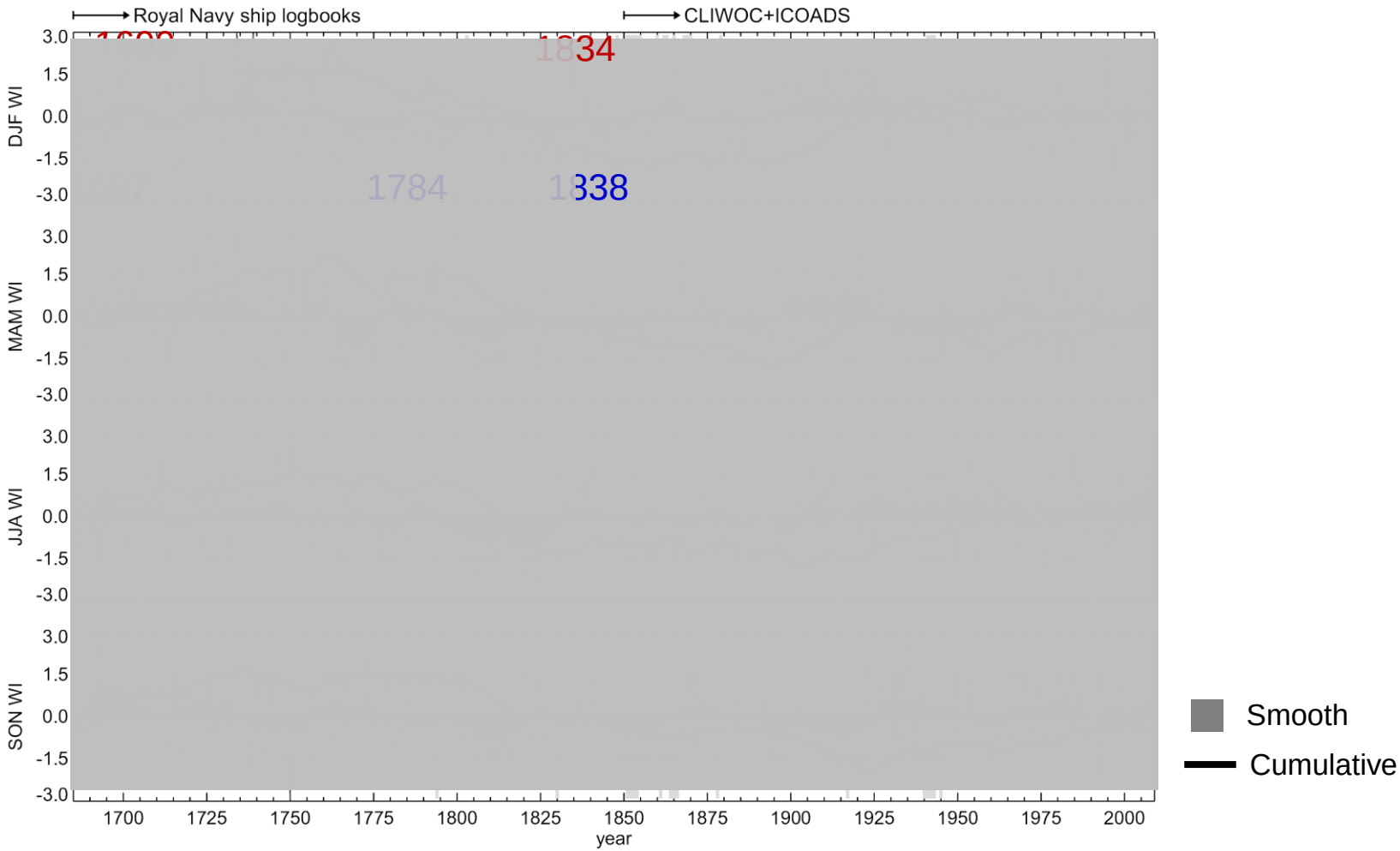
30-yr running correlations between the instrumental NAO (J) and proxy-based NAO reconstructions [Schmutz et al. 2000]



Barriopedro et al. 2014. J. Clim.

WI time series

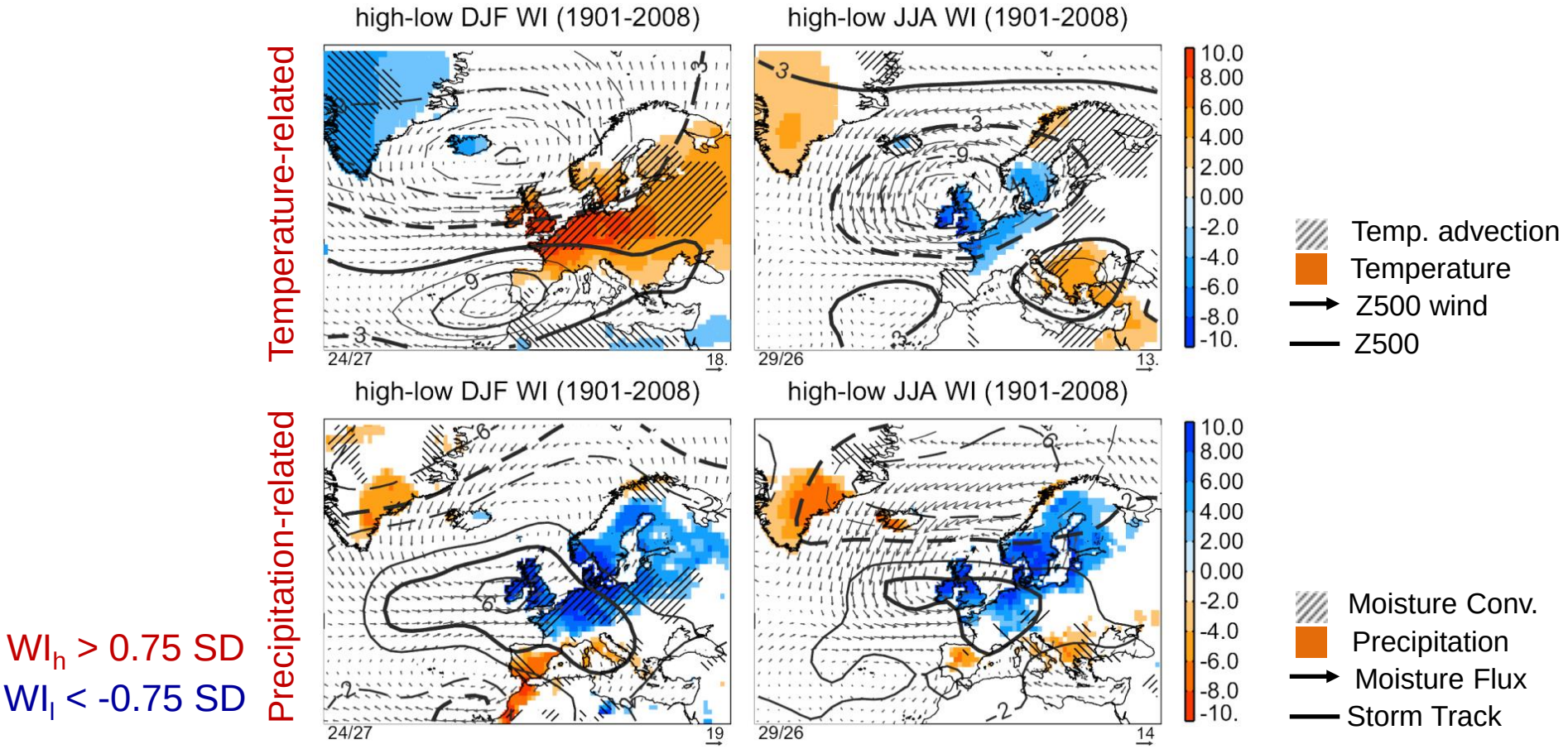
- [illegible] (e.g., Cornes et al. 2012) [illegible] text of the last centuries.



Standardized seasonal series of WI (1685-2008), 11-year running average (shading) and cumulative normalized anomalies (thick). Vertical gray bars indicate periods of missing data

WI and the European climate

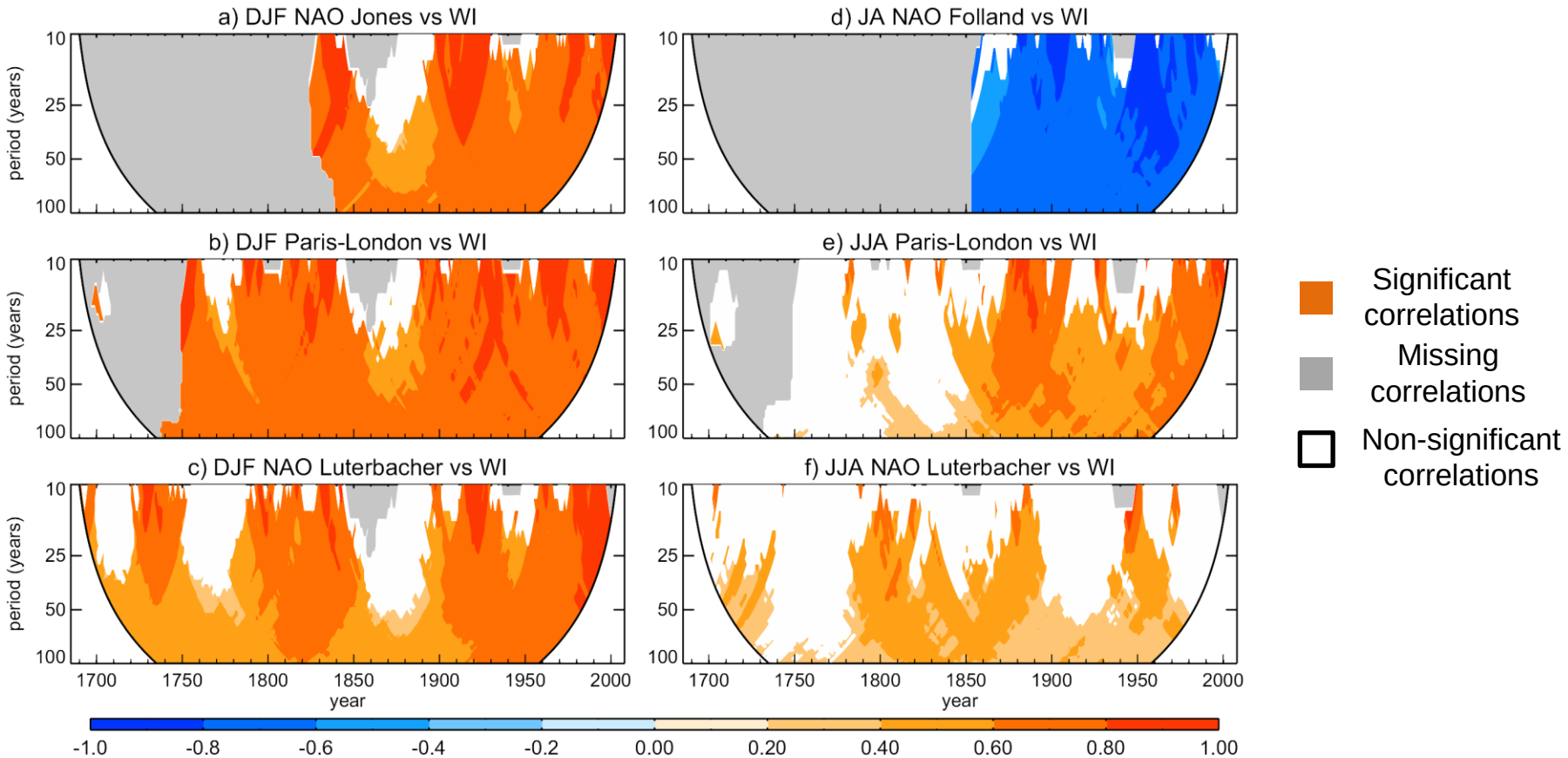
- WI signatures: 1) warm N Europe & cold Greenland, with opposite patterns in summer; 2) wet N Europe & dry Mediterranean & Greenland.
- WI shares some features with the winter NAO and the high-summer NAO (sNAO)



Scaled seasonal composites (dimensionless) for high-low WI (data source: 20CR)

WI and other circulation indices

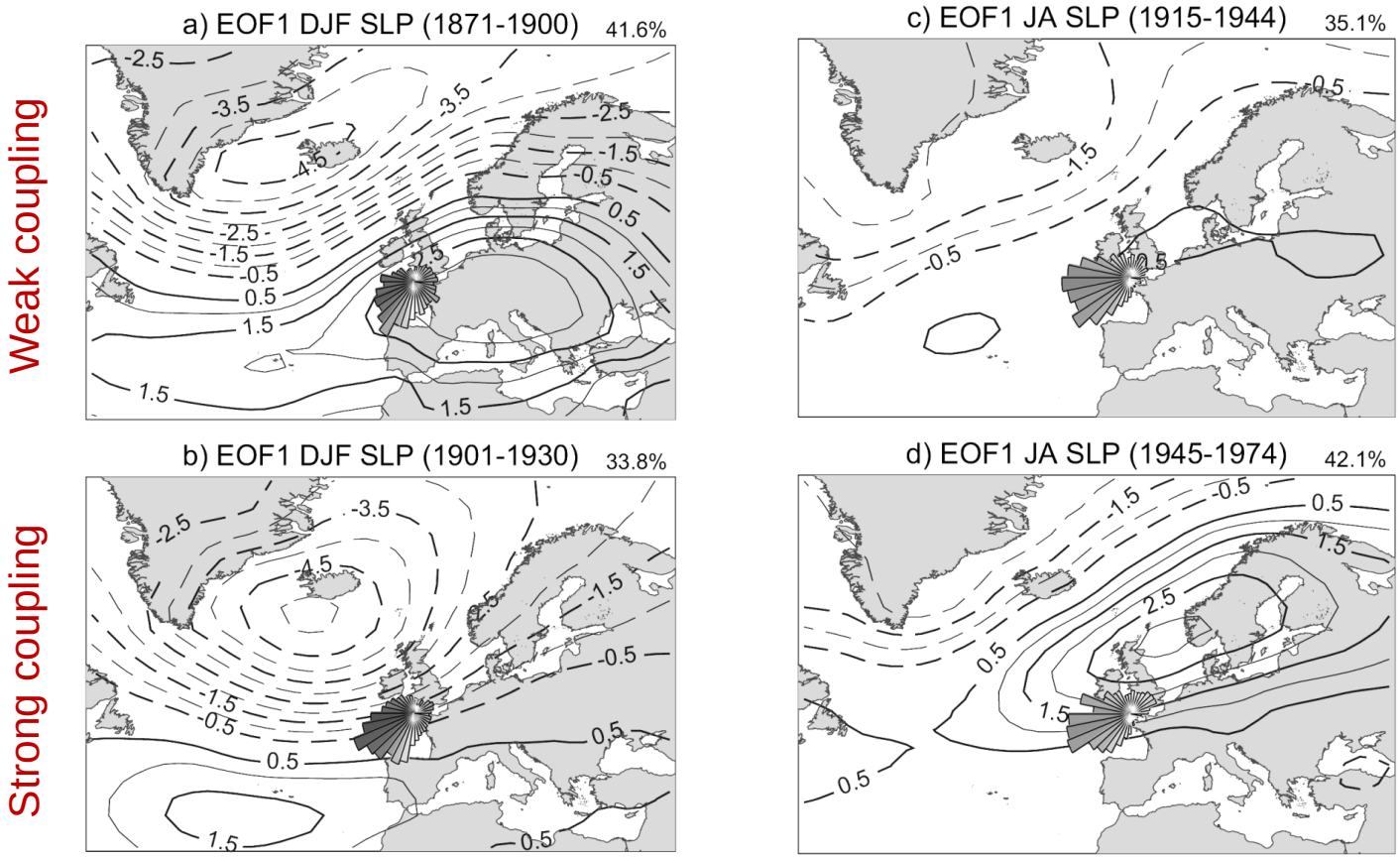
- There are common **decoupled periods** between WI and NAO-like indices (e.g., 1855-1895 in winter, 1830-1860 in summer).
- Purely **proxy-based NAO** reconstructions **correlate poorly** with the WI.



Running correlations for windows of different length between the WI and different zonal indices. White areas show non-significant correlations at $p<0.05$. Grey shading indicates missing correlations .

Decoupling periods of WI and NAO

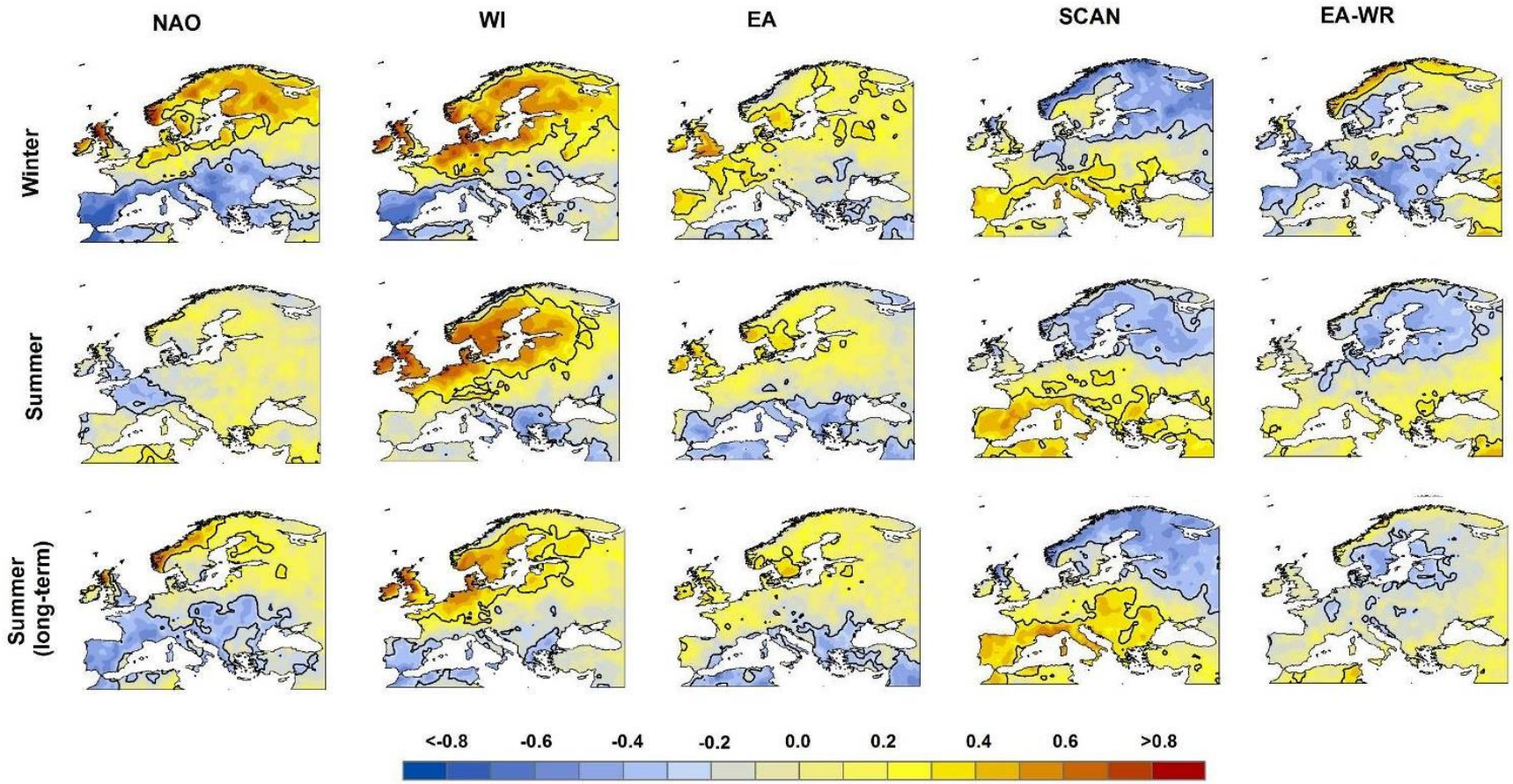
- Winter decoupling → departures from zonality (i.e. migration of centres of action).
- Summer decoupling → low teleconnectivity between Greenland and UK centres (weak activity of the UK lobe).
- The **WI reflects potential non-stationarities of the NAO** dipole.



Seasonal mean SLP (hPa) regressed onto the first EOF for the 30-year periods of maximum and minimum correlation between WI and the winter and high-summer NAO within the 1871-2008 period

WI and droughts

- European drought variability is relatively well explained by the station-based NAO index and the WI
- WI & NAO arise as **complementary circulation indices**: WI (NAO) is a better indicator of water-balance anomalies in Northern Europe (Southern Europe).



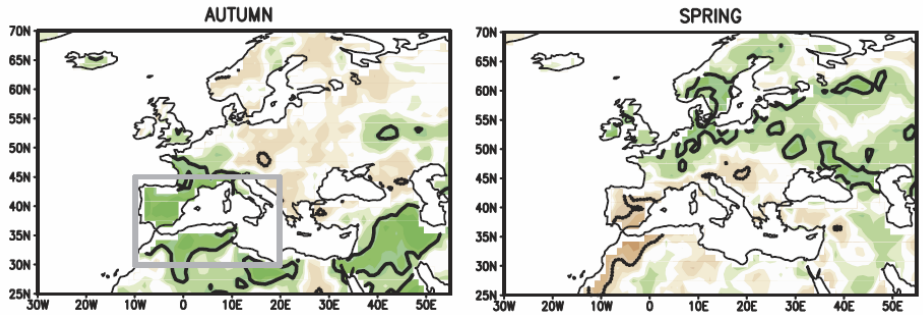
Correlation coefficients (1951-2008) between SPEI and circulation indices at seasonal and long-term (9-month) scales. Black line denotes significance ($p < 0.05$).

Vicente-Serrano et al. (2015) (under review)

ENSO teleconnections in Europe

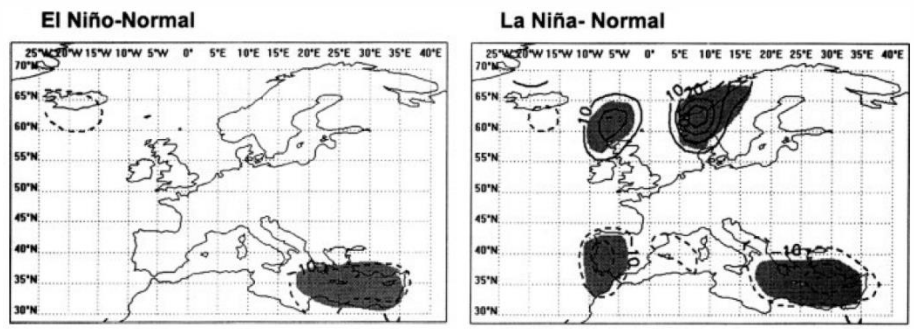
- ENSO signals in Europe are: 1) **seasonally varying** (stronger in autumn and spring); 2) **asymmetric** (stronger during LN); 3) **non-linear** (opposite responses to moderate and strong events); 4) **non-stationary** (multidecadal modulation by the AMO and PDO)

r (N3.4-prec.) (1948-96)



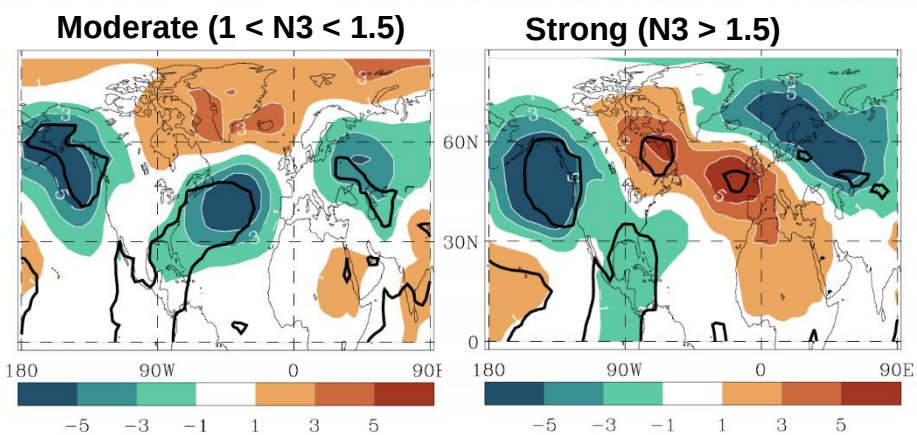
Mariotti et al. 2002. GRL

DJF prec. anom. (1900-98)

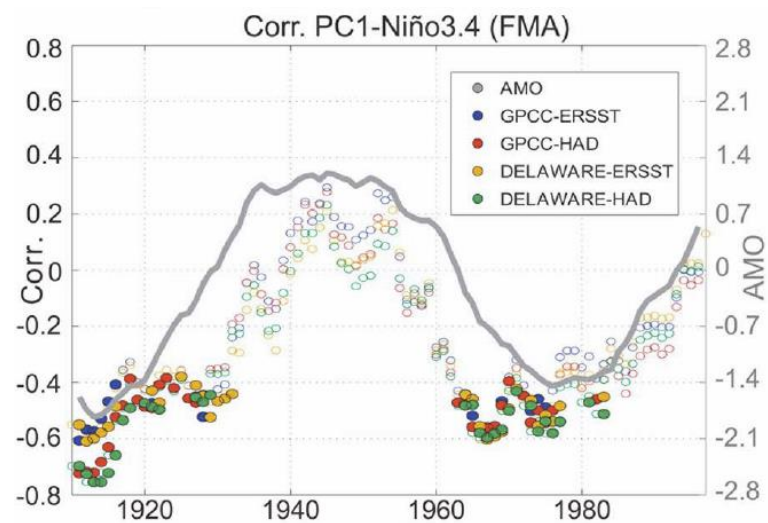


Pozo-Vázquez et al. 2005. IJC

JF SLP anom. (1950-2000)



Toniazzo & Scaife 2006. GRL

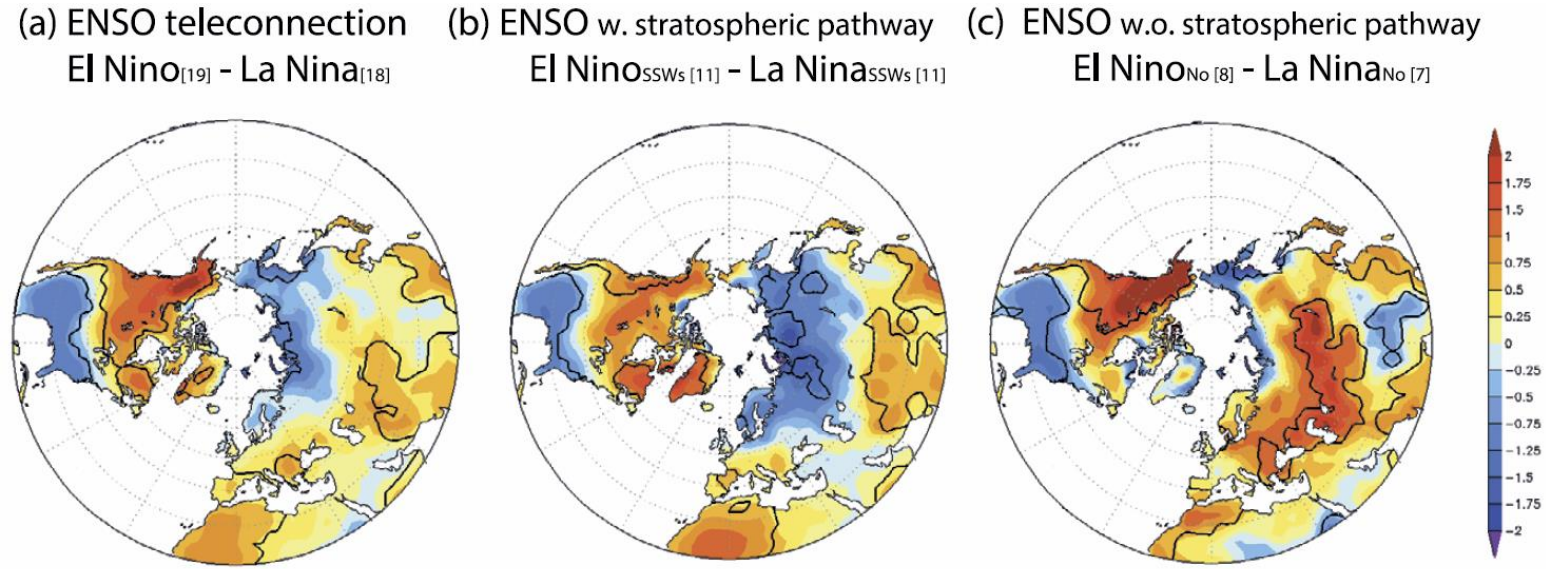


AMO (grey) & running correlations (reversed sign) between N3.4 and PC1 (black)

López-Parages et al. 2012. GRL

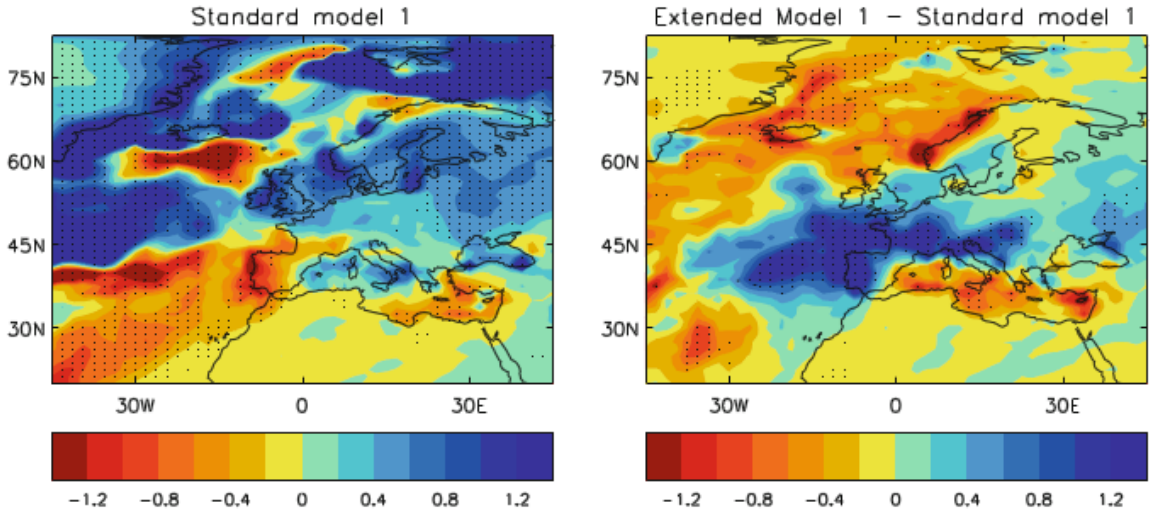
ENSO signals in Europe

- 5) the full response may be a mixture of tropospheric and **stratospheric influences**



Composite differences of NDJFM surface temperature (K) anomalies for EN-LN (N3.4 0.5 sd)

Butler et al. 2014. ERL

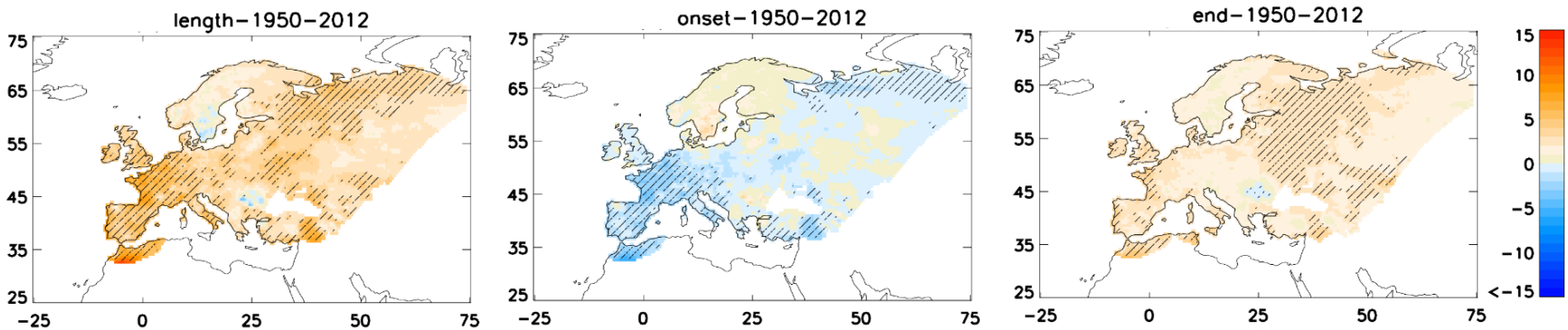


Climate change signal in winter precipitation response (mm day^{-1})

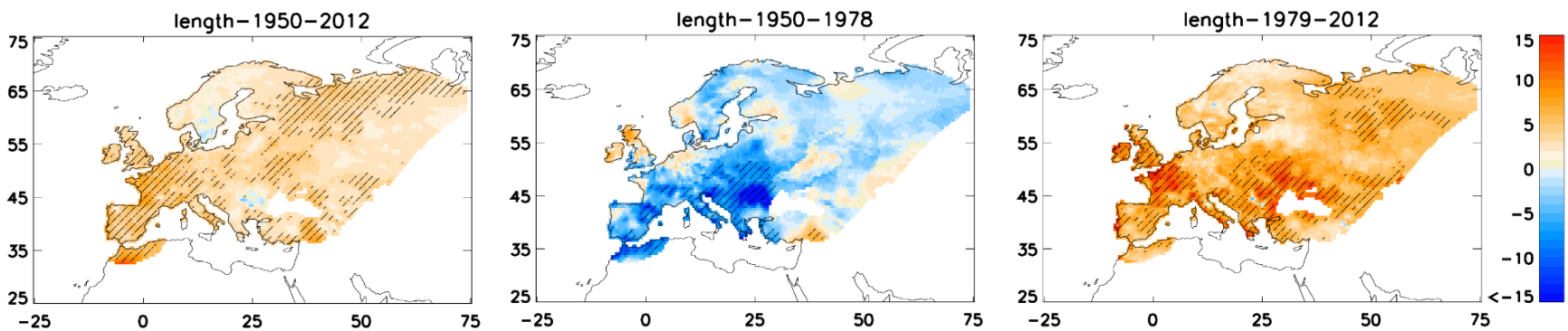
Scaife et al. 2011. JGR

Summer length in Europe

- European mean **summer lengthening** of **2.4 days decade^{-1}** for 1950-2012, but with substantial **multidecadal variability**
- Trends are mainly related to an advance of the summer onset and, to a lesser extent, to the delay of the summer end.



Trends of summer length, onset and end (days decade^{-1}) for 1950-2012

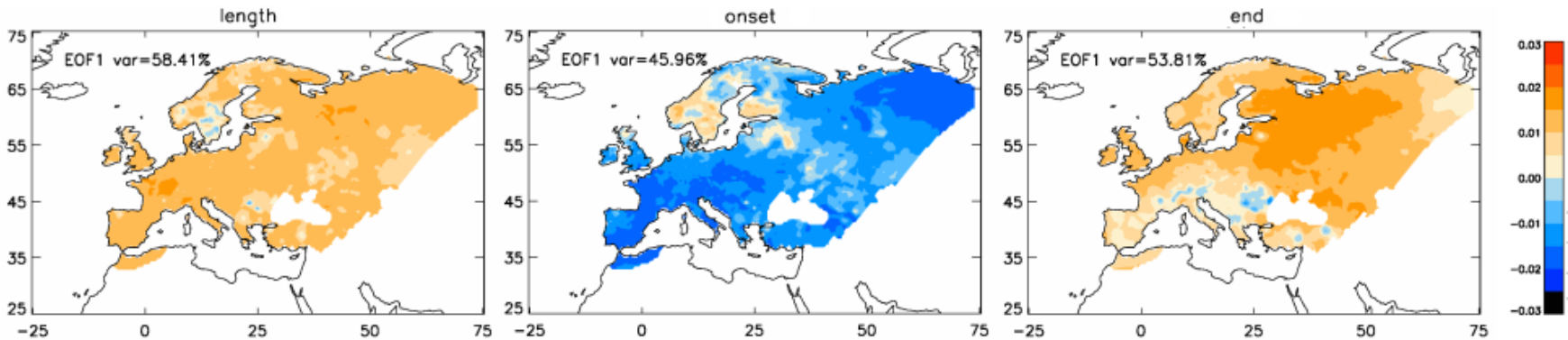


Trends of summer length (days decade^{-1}) for 1950-2012, pre-1979 and post-1979

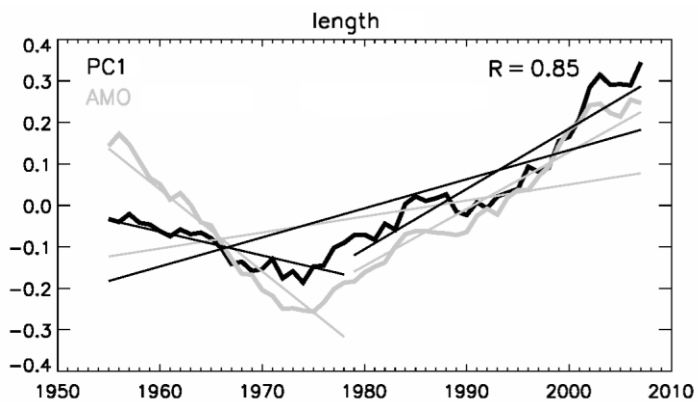
Peña-Ortiz et al. 2015 (under review)

Summer length in Europe

- The shortening and lengthening of the summer length is a leading mode of multidecadal variability.
- Changes in the summer length can be explained by the **superposition** of an **AMO** signal, **and** a **long-term trend** towards more persistent summers in Europe.



EOF1 of 10-yr low-pass filtered summer length, onset and end



Time series of PC1 (black) and AMO (grey)

1950-2012			1950-1978			1979-2012		
Actual	AMO	Global	Actual	AMO	Global	Actual	AMO	Global
2.4	**0.9**	**2.7**	**-4.5**	**-5.2**	0.4	**6.3**	**3.7**	**3.8**

Actual, AMO- and CC-related linear trends (days decade^{-1}) of the European-mean summer length for 1950-2012, 1950-1978 and 1979-2012