CHANGES IN EL NIÑO SIGNAL AND ITS INFLUENCE ON THE NW IBERIAN PENINSULA RAINFALL

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INTRODUCTION

Climate variability in the Euro-Atlantic sector is difficult to forecast. The area is located in the mid-latitude belt, which is dominated by internal variability. This makes the identification of a clear connection between atmosphere and ocean a complex task

The Atlantic part of the Iberian Peninsula is located in middle latitudes of the Northern Hemisphere with great oceanic influence on its climate. This region presents a significant amount of rainfall all over the year, particularly important in its northwestern corner: Galicia (42ºN - 44ºN) the region under study

INTRODUCTION

The North Atlantic atmospheric variability exerts an influence over European climate via the North Atlantic Oscillation (NAO). Tropical oceans also show some influence as well as the El Niño–Southern Oscillation (ENSO)

The ENSO has a determinant impact on the tropical regions, it also influences on the extratropical latitudes. The strength of these relations or connections can change with changes in the atmospheric circulation. Between 1976 and 1977, a change in the atmosphere-ocean system (change on the PDO) was observed in the North Hemisphere. This phenomenon is called *Climate Shift*.

The present work explores the relationship found in a previous work of Lorenzo et al. (2010)* focusing in the linearity and stationarity of the signal and the changes in the dynamics and impacts before and after the *Climate Shift*, hypothesizing possible dynamical mechanisms to explain this change.

** Lorenzo M.N., J.J. Taboada, I. Iglesias and M. Gómez-Gesteira (2011):* ***Predictability of the spring rainfall in North-west of Iberian from sea surfaces temperatures of ENSO areas****. (Climatic Change 107: 329-341) DOI: 10.1007/s10584-010-9991-6.*

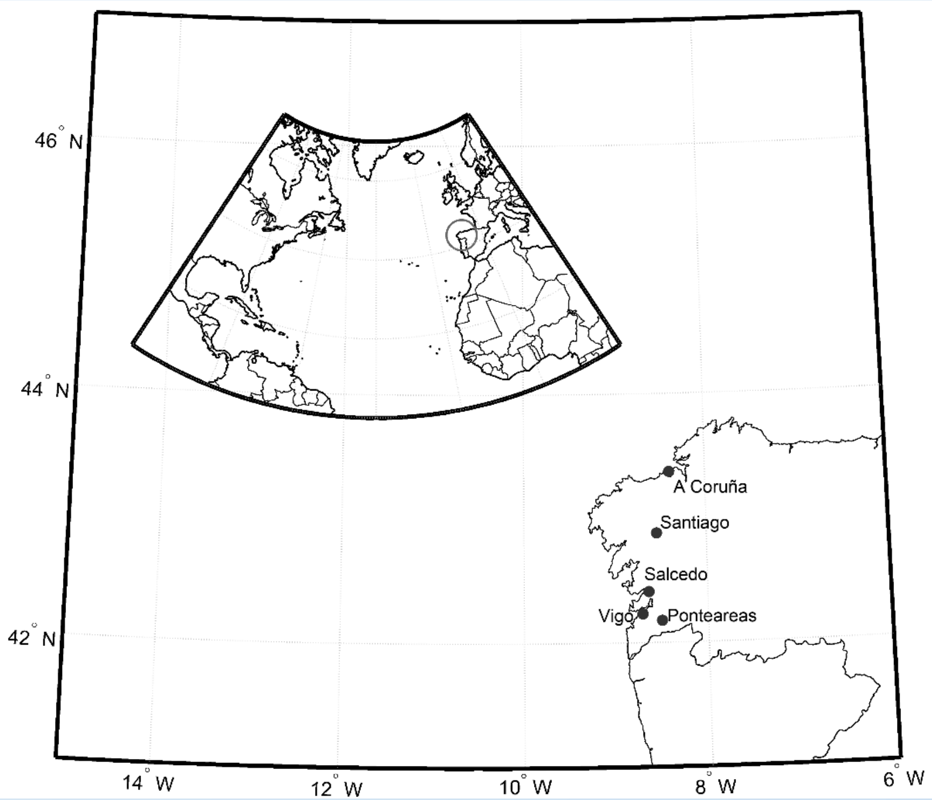
DATA

- Precipitation data:
  - *Agencia Estatal de Meteorología* (AEMET)
  - Period: from 1951 to 2006.
  - Five meteorological stations with high correlation

- SST data:
  - Earth System Research Laboratory (ESRL) of NOAA
  - Monthly averaged on a 2º × 2º lat-lon grids
  - Period: from 1951 to 2006.

- Streamfunction at 200 hPa:
  - Reanalysis data of the NCEP/NCAR
  - Resolution of 2.5º × 2.5º.

- Niño indices (Niño 1+2, Niño 3, and Niño 3.4):
  - Climate Prediction Center of the NOAA



METHODS

The monthly rainfall totals are expressed with a rainfall anomaly index*:

$$NWIPR = 100\sum_{1}^{N}\left(X / \overline{X}\right)$$

X is the monthly rainfall anomaly at one station in mm, is the station's mean annual rainfall in mm, and N is the number of stations

Months were grouped in seasons: winter (JFM), spring (AMJ), summer (JAS) autumn (OND)

To study the effect of the climate shift, the data has been divided in two subperiods:
- 1951-1977
- 1978-2006

The series were linearly detrended and normalized by the corresponding standard deviation
The Pearson product-moment correlation coefficient
Student's t-test

The study was divided in:
- Years with Niño events (Niño 3>0.4)
- Years with Niña events (Niño 3<-0.4)

The extreme events of NWIPR were considered:
- Years with maximum extremes (NWIPR>1)
- Years with minimum extremes (NWIPR<- 1)

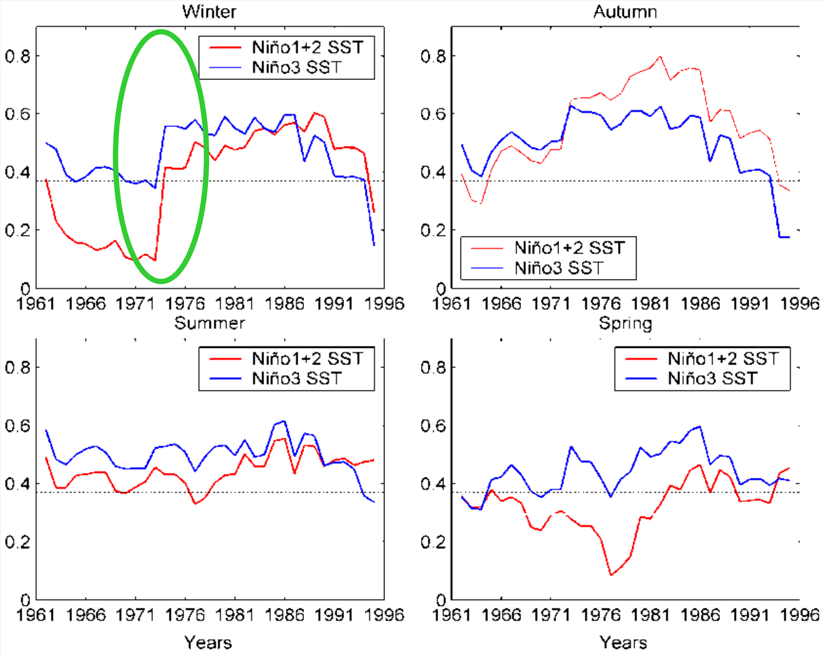
For the analysis of the SST behavior in the years with extreme NWIPR, the anomaly every three months was considered: January to March, February to April, March to May, April to June

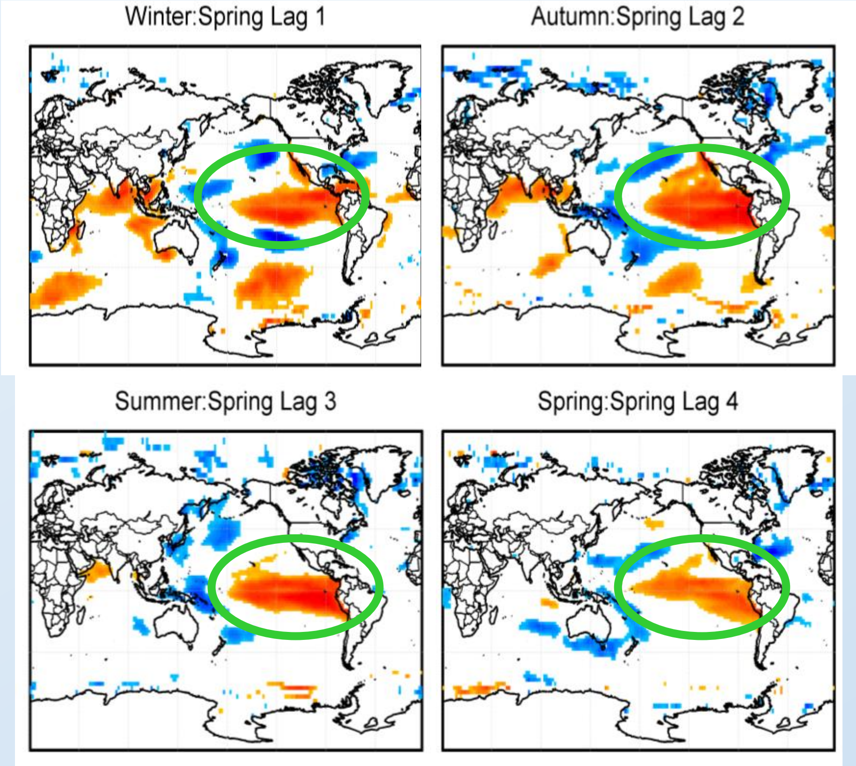
$$SSTA = \overline{SST_{extreme}} - \overline{SST_{period}}$$

*Lorenzo, M.N., I. Iglesias, J.J. Taboada, and M. Gómez-Gesteira (2009), ***Relationship between monthly rainfall in NW Iberian Peninsula and North Atlantic sea surface temperature****, Int. J. Climatol. 30 980-990. DOI: 10.1002/joc.1959.*

RESULTS

Seasonal SSTA:NWIPR correlations of seasonal mean SSTA and rainfall anomalies have been calculated for the 4 seasons. Only spring NWIPR fulfill the finiteness and interdependence criteria for several lags.





21-year sliding means were used to calculate the evolution of the correlation between Niño3 and Niño1+2 and spring NWIPR.

Lorenzo M.N., J.J. Taboada, I. Iglesias and M. Gómez-Gesteira (2011): ***Predictability of the spring rainfall in North-west of Iberian from sea surfaces temperatures of ENSO areas****. (Climatic Change 107: 329-341) DOI: 10.1007/s10584-010-9991-6.*

RESULTS

The ENSO state was analyzed based on the Niño indices (Niño 1+2, Niño 3, and Niño 3.4).

To identify the change that occurred in the atmospheric circulation and in the influence of the ENSO mechanism over the IP, the extreme events of the spring NWIPR were calculated.

Niño 1+2		Niño 3		Niño 3.4	
Niño	Niña	Niño	Niña	Niño	Niña
1952	1954	1953	1955	1958	1951
1953	1955	1958	1956	1959	1955
1957	1956	1966	1968	1966	1956
1958	1962	1969	1971	1969	1962
1959	1964	1970	1974	1970	1963
1961	1967	1973	1976	1973	1965
1965	1968	1977	1981	1980	1971
1969	1971	1983	1984	1983	1974
1972	1974	1987	1985	1987	1975
1973	1975	1992	1986	1988	1976
1977	1978	1998	1989	1990	1984
1983	1981	2003	1996	1991	1985
1987	1982		1997	1992	1989
1992	1984		1999	1995	1996
1998	1985		2000	1998	1999
	1994			2002	2000
	1996			2003	2001
	1999			2004	
	2000				
	2003				
	2004				

RESULTS

Years with negative NWIPR events => Neutral ENSO and negative PDO index (PDO in a cool state)
Years with positive NWIPR events => Positive ENSO events (El Niño) and PDO index (PDO in a warm state)

The potential for precipitation extremes is higher when ENSO and PDO are in the same phase. 3 years (grey boxes) not fit this pattern.

Minimum NWIPR events										
Year	1954	1962	1965	1975	1976	1982	1990	1991	1995	2006
Niño 1+2	-	-	*	-	-	-	*	*	*	*
Niño 3	*	*	-	-	-	*	*	*	+	-
Niño 3.4	*	*	*	-	-	*	+	+	+	-
ENSO	*	*	*	*	-	*	*	*	+	*
PDO	C	C	C	C	C	W	C	C	C	C
Maximum NWIPR events										
Year	1958	1961	1966	1969	1983	1988	1993	1997	1998	2000
Niño 1+2	+	*	*	*	+	*	+	*	+	-
Niño 3	+	*	+	+	+	*	*	-	+	-
Niño 3.4	+	*	+	+	+	+	+	*	+	-
ENSO	+	*	+	+	+	+	+	*	+	-
PDO	W	W	C	C	W	W	W	W	W	C

*Years with extreme NWIPR events between 1950 and 2006 and the winter Niño index, ENSO state, and PDO phase in these years. –, La Niña events; +, El Niño events; *, neutral state; C, cool PDO state; and W, warm PDO state.*

1976: La Niña and PDO cool phase. Both are in phase, less rainfall occurred.
1966 and 1969: ENSO and PDO not in phase Positive NWIPR events when ENSO and PDO were not in phase.
Why? Changes in the AMO and PDO signs (1966-1969 and 1976 respectively).
Previous work has found that the correlation between the interannual rainfall mode and El Niño could be modulated by the AMO and PDO (López-Parages and Rodríguez-Fonseca, 2012). The ENSO teleconnection with Europe is more effective with negative AMO. This work also found opposite teleconnections between positive and negative PDO.

Minimum NWIPR events										
Year	1954	1962	1965	1975	1976	1982	1990	1991	1995	2006
Niño 1+2	-	-	*	-	-	-	*	*	*	*
Niño 3	*	*	-	-	-	*	*	*	+	-
Niño 3.4	*	*	*	-	-	*	+	+	+	-
ENSO	*	*	*	*	-	*	*	*	+	*
PDO	C	C	C	C	C	W	C	C	C	C
Maximum NWIPR events										
Year	1958	1961	1966	1969	1983	1988	1993	1997	1998	2000
Niño 1+2	+	*	*	*	+	*	+	*	+	-
Niño 3	+	*	+	+	+	*	*	-	+	-
Niño 3.4	+	*	+	+	+	+	+	*	+	-
ENSO	+	*	+	+	+	+	+	*	+	-
PDO	W	W	C	C	W	W	W	W	W	C

*Years with extreme NWIPR events between 1950 and 2006 and the winter Niño index, ENSO state, and PDO phase in these years. –, La Niña events; +, El Niño events; *, neutral state; C, cool PDO state; and W, warm PDO state.*

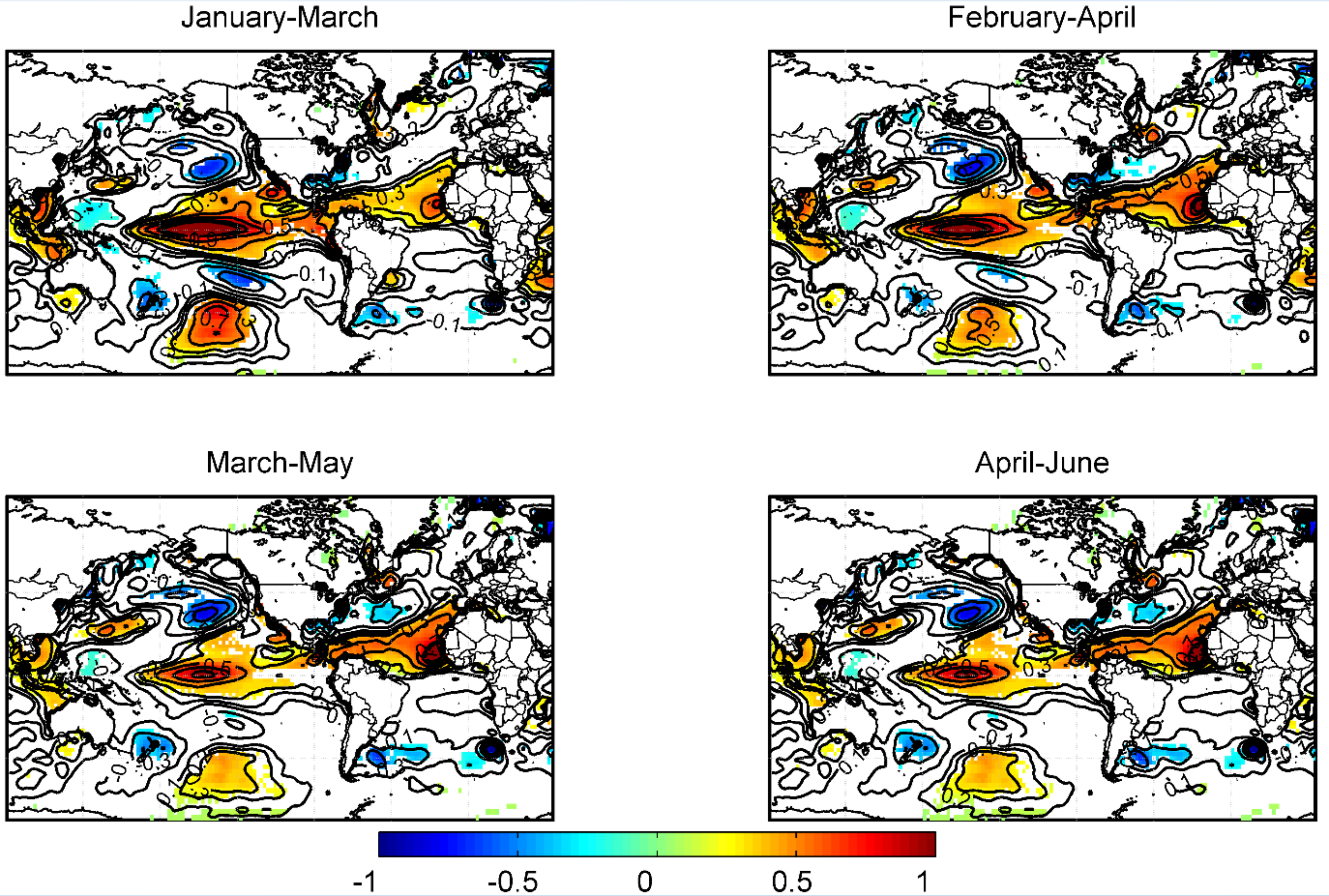
RESULTS

Before the CS:

<u>Extreme positive rainfall events</u> were related to a tropical Pacific and northern tropical Atlantic warming pattern => Extreme rainfall events related to El Niño or positive PDO.

Higher positive anomaly centre in the Equatorial Pacific related to a central El Niño event and the negative anomaly in the North Pacific that may be the two poles of the PDO.

Lags => The oceanic pattern is becoming weaker with time.



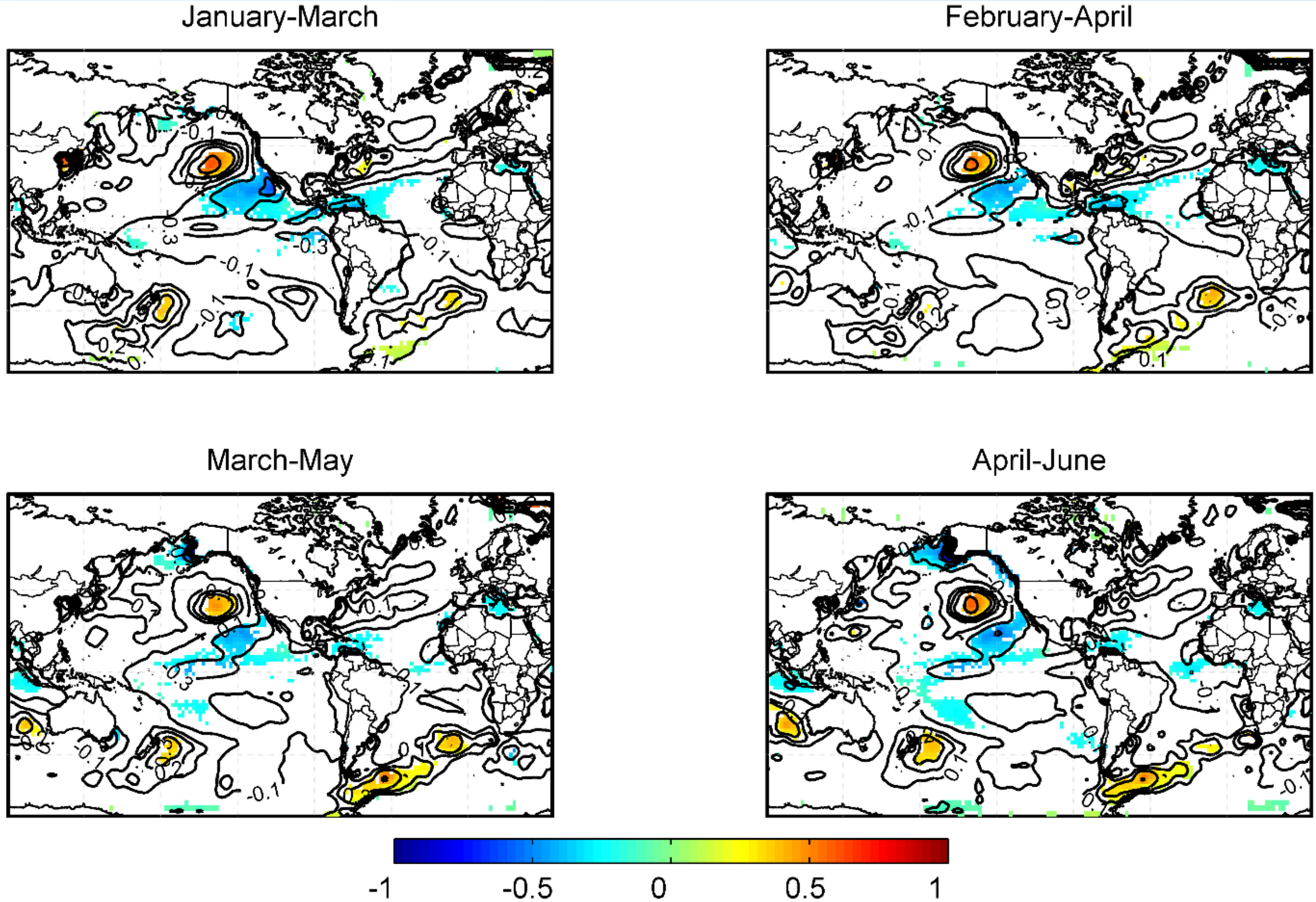
RESULTS

Before the CS:

<u>Extreme negative rainfall events </u>show lower and smaller SSTA centres .

Positive centre in the North Pacific region with some negative anomaly areas in the central equatorial Pacific.

That the extreme negative events are associated with weaker cooling over the Pacific.



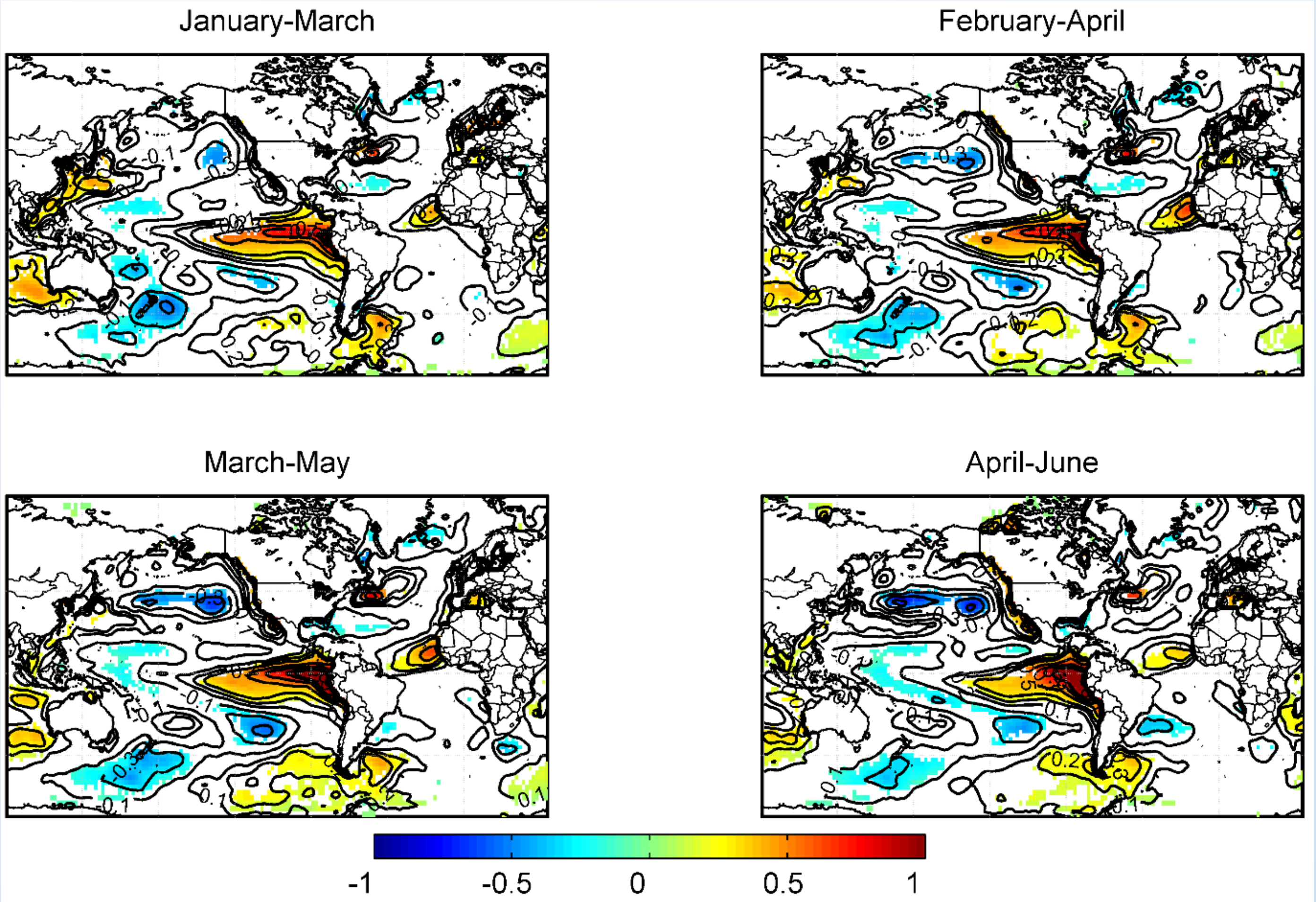
RESULTS

After the CS:

Extreme positive rainfall events were related to an eastern El Niño event in the Equatorial Pacific.

Positive anomalies can also be observed over the northern tropical Atlantic.

Persistence of the centers.

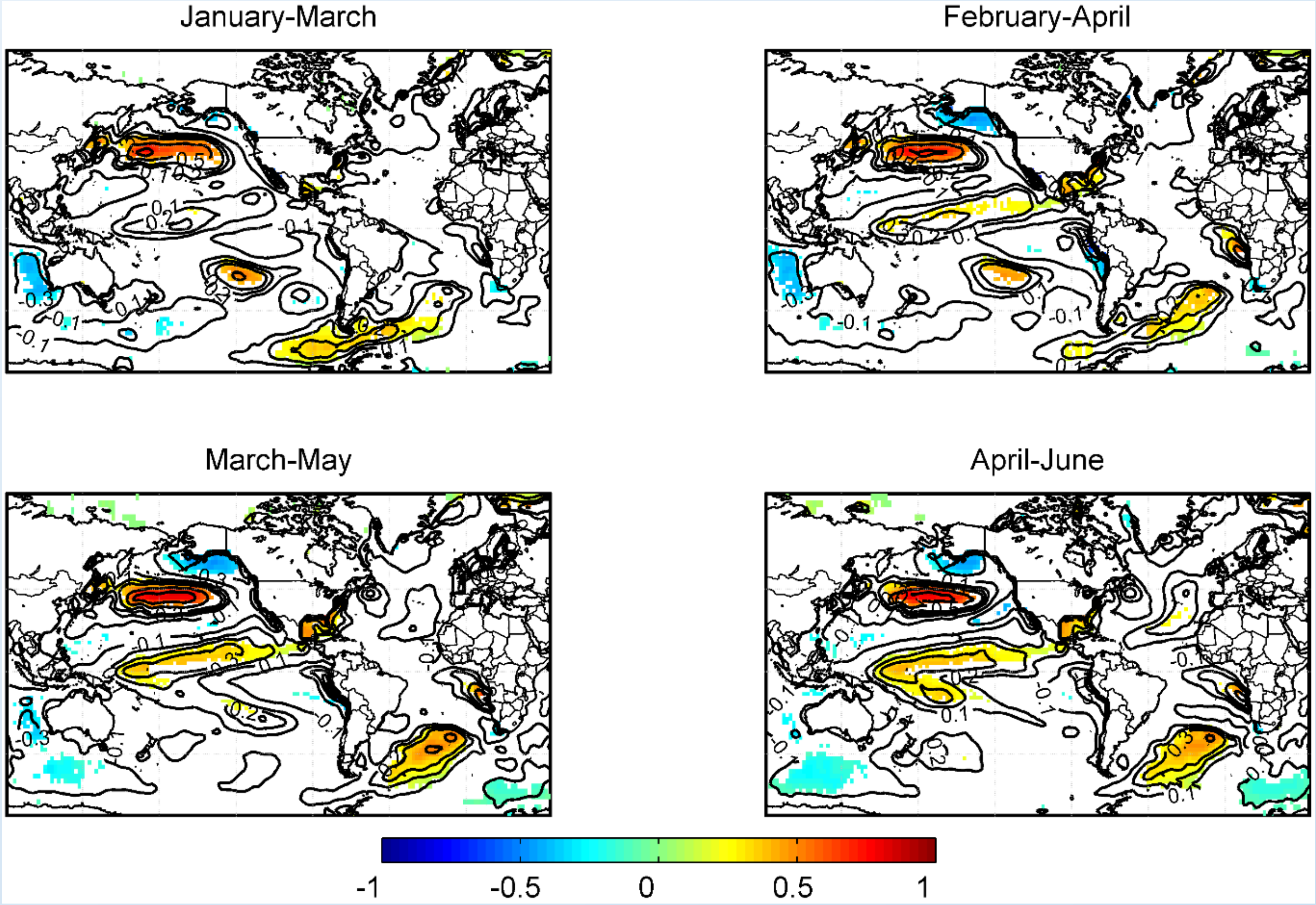


RESULTS

After the CS

Extreme negative rainfall events represent the development of a central Pacific El Niño.

Persistence of the centres.



RESULTS

Lopez-Parages et al (2015) used sensitivity experiments to show how the central Pacific El Niño events have a strong signal over Europe, obtaining central Pacific ENSO events before the CS (positive AMO) and eastern Pacific ENSO events after the CS (negative AMO). No significant signal was found for La Niña events.

Using the NWIPR index, the present results are similar, indicating that the analysis performed depends significantly on the type of ENSO considered before and after the CS. Therefore, the type of ENSO that produce wet springs over the IP was more central before and more eastern after the CS. There is no evidence that the La Niña events produced dry or wet springs over Galicia; the maximum extreme events of the NWIPR were always associated with different types of El Niño episodes: central and eastern.

To understand how the ENSO signal is transmitted to the European area, it was analyzed the streamfunction anomalies at 200 hPa. The positive extreme events of NWIPR were selected based on the intensity and persistency of the SSTA centres observed in the previous analysis.

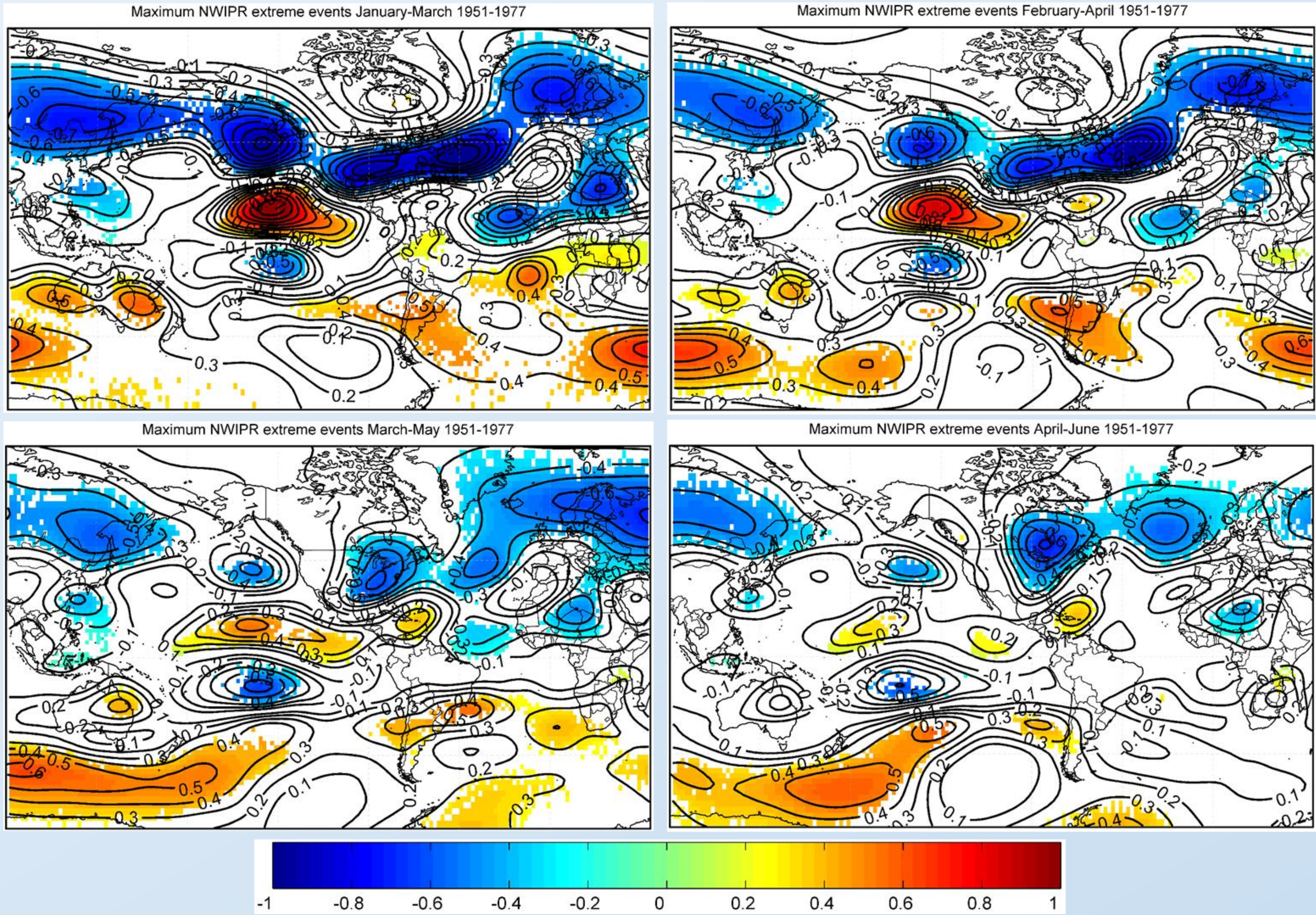
RESULTS

Before the CS:

Negative anomalies of streamfunction over Europe and Northern Hemisphere. Positive anomaly centre in the Equatorial Pacific related to the positive SSTA centre.

Pattern is becoming weaker with time

Persistent arching pattern from centre of the Equatorial Pacific with baroclinic Gill response at both sides of the Equator and west of the equatorial warming, and a barotropic structure through the east in the extratropics alternate centres of opposite signs. => Rossby waves reaching the NWIP with a negative streamfunction anomaly causing an increase in the rainfall in the region.
A signal over the tropical Atlantic is also evident, revealing a Walker–Hadley mechanism.



RESULTS

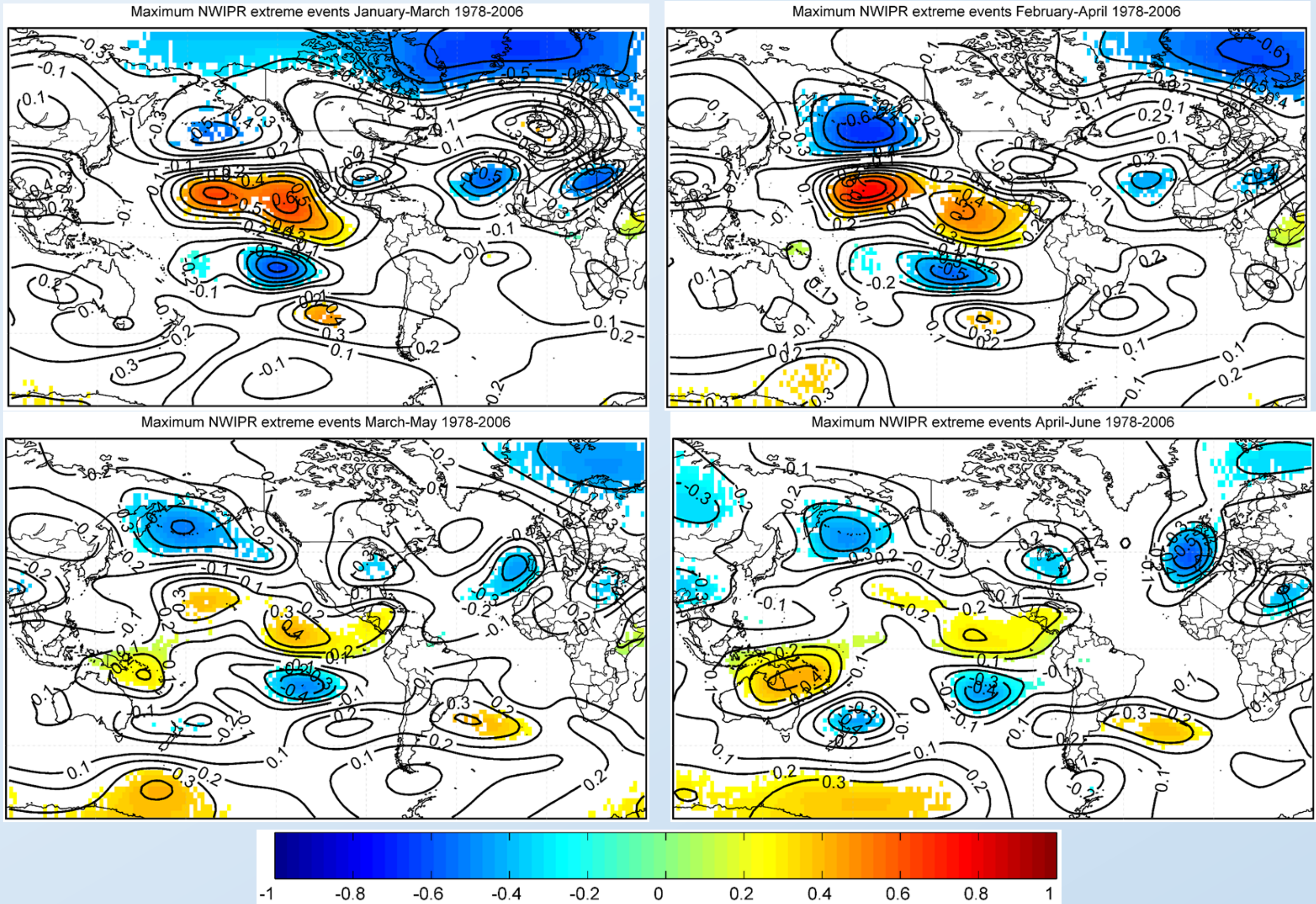
After the CS:

Positive streamfunction centre near South America during the April–June season, coinciding with the positive SSTA centre.

An arching Rossby wave pattern beginning next to the Chilean coast and moving to the east reaching the south-western Europe with a negative streamfunction centre.

The observed persistence therefore implies that this pattern appears to be the way that the signal reaches Europe.

No Walker–Hadley mechanism was found in this case.



CONCLUSIONS

The present study demonstrates that positive winter ENSO events are related to an increase in rainfall over Galicia. However, this relation is neither stationary nor linear.

Before the CS, rainy springs in the NWIP were related to positive winter central ENSO events; whereas after the CS positive extreme events were related to a more Eastern Pacific ENSO configuration. No conclusive oceanic signal was found for the negative NWIP rainfall events.

The anomalies of the streamfunction show negative anomalies over the IP before and after the CS and demonstrate that the ENSO signal appears to travel through the Pacific and Atlantic Oceans via Rossby waves and the Walker–Hadley mechanism. Before the CS, the ENSO effects arrived in Europe through the Atlantic Ocean with a northern displacement (Walker–Hadley mechanism). After the CS, this influence reached the European continent directly from the Pacific Ocean due to a general atmospheric circulation modification at the mid-latitudes (Rossby waves).

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