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North Atlantic Oscillation (NAO) and precipitation in Galicia (Spain)

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RESUMEN

En este artículo se investiga en qué escala temporal la OAN y ENOS se encuentran asociados con la precipitación en Galicia (noroeste de España), realizando una búsqueda de posibles predictores climáticos. Se analizó la posible existencia de frecuencias referentes utilizando SSA (análisis espectral singular), mientras que la significatividad estadística de los resultados se comprobó utilizando el método de Monte-Carlo. Los resultados sugieren que la OAN y la precipitación en Galicia podrían estar relacionados en una escala temporal de 8 años, mientras que la influencia de ENSO no es significativa.

ABSTRACT

In this study we investigate the time-scale at which NAO and ENSO are associated with the precipitation in Galicia (Northwestern of Spain), looking for possible climate predictors. The existence of preferred frequencies in all series was analyzed by using SSA (Singular Spectral Analysis), whereas the statistical significance of the results was checked by using the Monte-Carlo method. Results suggest that NAO and precipitation in Galicia could be related at a time scale of 8 years whereas the influence of ENSO is not significant.

Key words: ENSO, NAO, precipitation, Galicia, Spain.

1. Introduction

Changes in the atmospheric circulation have an important role in the interannual and interdecadal variability of precipitation. Rainfall patterns can change in midlatitudes through a shift in storm tracks associated with teleconnections. A dipole pattern of change over Europe has been widely documented, with lower rainfalls over southern Europe and wetter conditions in Scandinavia associated to the positive phase of the North Atlantic Oscillation (NAO) (Hurrell 1995, Hurrell and van Loon, 1997; Giannini *et al*., 2000). El Niño Southern Oscillation (ENSO) and the Pacific North America Oscillation (PNA) are associated to changes in storm tracks over the North Pacific leading to a dipole pattern of precipitation anomalies over California and the southeastern United States (Trenberth and Hurrell 1994). Furthermore, due to the global effect of ENSO on the general circulation of the atmosphere, floods and droughts in different locations around the globe are associated with ENSO through teleconnections (Ropelewski and Halpert, 1987, 1989a,b; Dai *et al*.1998).

The precipitation regime in the Iberian Peninsula has a highly irregular behavior in both the spatial and temporal dimensions (Esteban-Parra *et al*., 1998; Serrano *et al*., 1999; Trigo and DaCamara, 2000). It is important to notice that winter and spring precipitation variability can be explained as a function of changes in large-scale modes at a monthly scale, especially over the western sector of the Iberian Peninsula (Rodríguez-Puebla *et al*., 1998; Trigo and Palutikof, 2001). Among these modes, the North Atlantic Oscillation is largely the most important element to model the winter precipitation regime over the Iberian Peninsula (Rodó *et al*., 1997; Rodriguez-Puebla *et al*., 1998; Corte-Real *et al*., 1998; González-Rouco *et al*., 2000; Trigo and Palutikof, 2001). The typical pressure dipole pattern that characterizes NAO is clearly associated with changes in the vorticity field, so the maximum value of positive vorticity is moved a few degrees northwards for positive NAO respect to negative NAO. Positive vorticity is associated to low level convergence and uplift, so the condensation of perceptible water content is clearly related to NAO

The main aim of this work is to study the relationship between NAO and precipitation amounts in Galicia, a region located in the Northwest of Spain, focusing the study on the search of the preferred time scale of the relationship.

We will also try to find out if there is also a relationship with ENSO, a phenomenon located in the tropical Pacific that has implications in the climate all over the globe. Spectral analysis (SA) and singular spectral analysis (SSA) were computed following Vautard *et al*. (1992), whereas statistical significance was checked using the Monte-Carlo method by means of a first order autoregressive model, AR(1) (Allen and Smith, 1996).

2. Data

In order to measure NAO and ENSO phenomena, two pressure indices were used: NAO index (Jones *et al*., 1997) and the Southern Oscillation Index (SOI), both available at http: www.cru.uea.ac.uk. Precipitation data were provided by the Spanish National Meteorological Institute (Table1).

Table 1. Precipitation stations used.

Nº	Station	Lat. N	Long. W	Period
1	Boñar	42.86	5.32	1914-1998
2	Cervera	42.86	4.50	1913-1998
3	Grado	43.38	6.06	1942-1998
4	La Coruña	43.38	8.38	1931-1998
5	Puenteareas	42.18	8.49	1939-1998
6	Requejo	42.03	6.75	1943-1998
7	Santiago de Compostela	42.90	8.43	1944-1998
8	Sarría	42.78	7.41	1946-1998
9	Villameca	42.64	6.07	1931-1998
10	Zamora	41.50	5.76	1920-1998

SSA was used to look for periodicities and to determine the spatio-temporal structure of the data in the interannual frequency band. This technique is based in principal components analysis. When two phenomenon have the same periodicities, there is a high probability of one phenomenon forcing the other. In order to assure the significance of the spectral peaks, a Monte-Carlo method was used, starting from a first order autoregressive model.

3. Results

A SA was calculated for SOI (Fig. 1) and NAO index (Fig. 2), looking for significant periodicities. For both magnitudes, the spectra show few peaks above noise, with no coincidence between them. Cycles found in NAO index correspond to periods of 8.0, 5.8, 2.4 and 2.2 years, whereas those

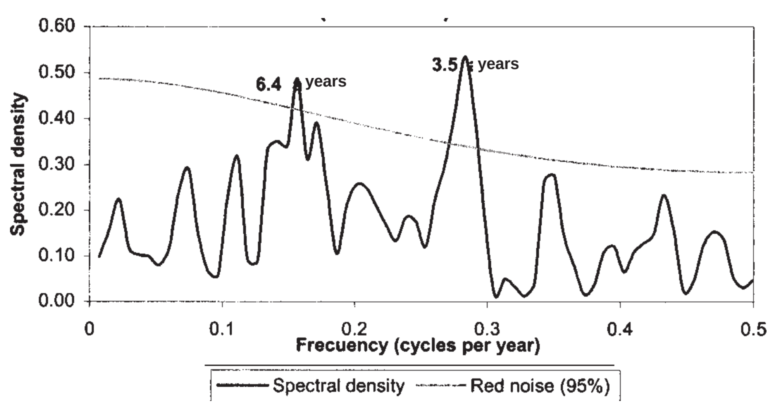

Fig. 1. Southern Oscillation Index (SOI) (1866-2000).

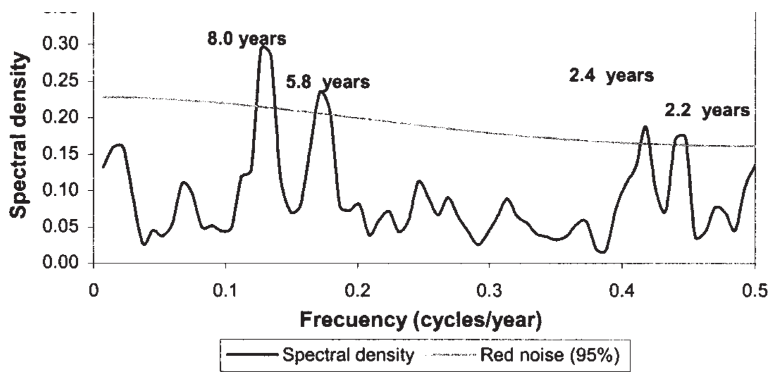

Fig 2. NAO Spectrum (1866-2000).

found in SOI correspond to 6.4 and 3.5 years. The only common characteristic is the high degree of red noise. This result is slightly different to that reached by García *et al.* (2000) who found a significant common oscillation of 6-8 years that represents about 20% of the SOI variance and about 25% of the NAO variance. However these authors advised of the limitations of the results due to the length of the used series. Results obtained using SSA for NAO index and SOI are shown in Table 2 for the first eigenvalues. The lack of coincidence between the indices is also evident in this case, although in some cases the difference is small. Obviously, the oscillation modes in NAO and SOI are not the same. Applying the Monte-Carlo method to the NAO index (Fig. 3), it is found that none of the cycles is significant at 95% significance level, although the significance of the 8 years cycle is good enough to consider it as a real cycle. This result is clearly in agreement with other studies looking for spectral peaks in the NAO series (e.g. Pozo-Vázquez *et al.*, 2000).

The results of SSA for precipitation using hydrological years are shown in Table 3. Five stations share a common oscillation period of 8.4 years, very similar to that of 8.3 years found in NAO

Table 2. Dominant periods and explained variance.

Index	Period (years)	Explained variance (%)
NAO	8.2	17.9
	2.9	16.1
	5.0	12.1
	13.0	10.8
SOI	6.4	20.8
	3.5	17.4
	4.7	13.0

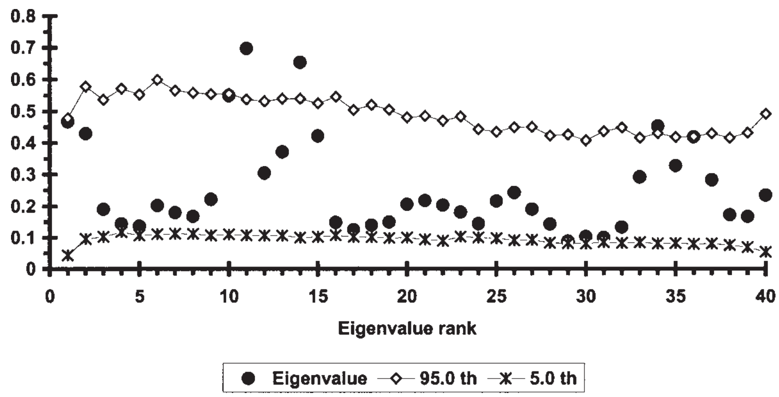

Fig. 3. SSA (M = 40) of NAO Index. Null hypothesis test derived from covariance matrix. Substitute ensemble size: 1000.

Table 3. Dominant frequencies of precipitation for all the hydrological years (October-March).

Index	Period (years)	Explained variance (%)
La Coruña	8.4	36.0
	4.2	25.6
	3.0	16.3
Santiago de Compostela	8.4	42.5
	2.6	17.6
	3.9	15.0
Ponteareas	4.2	31.1
	2.6	25.7
	8.4	21.0
Sarría	5.3	25.8
	8.4	18.9
	3.0	11.7
Requejo	3.8	39.8
	2.6	21.7
Grado	8.4	35.5
	4.2	23.5
	3.0	9.5
Villameca	3.2	19.4
	2.7	11.3
	5.2	
	9.0	

(Continues in the next page.)

Table 3. Dominant frequences... (continued)

Index	Period (years)	Explained variance (%)
Boñar	4.2	35.3
	6.0	21.4
	2.8	7.9
Cervera	6.0	31.6
	3.5	26.8
	2.8	20.1
Zamora	2.6	24.3
	5.3	21.0
	3.8	16.9

Table 4. Dominant frequencies of precipitation for the hydrological years in which NAO index is positive.

Index	Period (years)	Explained variance (%)
NAO	8.3	28.9
	4.1	16.8
	3.2	14.7
La Coruña	8.4	33.4
	2.6	18.6
	3.2	15.3
Santiago de Compostela	8.4	31.4
	2.6	23.6
	3.5	13.5
Ponteareas	2.6	28.8
	4.2	20.9
Sarría	8.4	31.4
	2.6	22.9
	3.0	11.7
Requejo	6.0	33.6
	2.6	25.9
	3.8	17.4
	3.8	12.1
Zamora	8.4	23.2
	5.3	19.2
	2.6	13.2

index. The 2.6 years cycle seems to have physical significance, since it appears in most of the precipitation series. The link with NAO is even more clear when using only years corresponding to positive phases of NAO (Table 4). In this case, the 8 years cycle is present in all the stations except Ponteareas, Requejo y Villameca. The other repeated cycle (2.6 years) is not related to NAO, however it appears in almost all the stations, so we have to consider it as an important feature in Galician precipitation.

4. Conclusions

In this work, relevant aspects of the relationship between NAO and Galician precipitation are shown, which could be useful for seasonal prediction, however results showed a lack of coincidence between SOI and Galician precipitation.

The results obtained for precipitation show a high level of coincidence near the coast, whereas variability increases with the distance to the sea, when the whole hydrological year is used. There is a common oscillation in NAO and precipitation with a period of around 8 years, very important for positive NAO phases. This suggest that both NAO and precipitation in Northwestern Spain could have a preferred time domain of relationship (about 8 years) being this effect more accused during positive phases.

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