Precipitation variability in the Peninsular Spain and its relationship with large scale oceanic and atmospheric variability

María Beltrán Peralta

Master's Degree in Geophysics and Meteorology, University of Granada

Abstract. In the present study, the influence of oceanic and atmospheric variability at large scale over the seasonal precipitation (autumn and winter) on the peninsular Spain was evaluated. First, regions which shared similar precipitation climatology were identified in both seasons, by means of a Principal Component Analysis. Multiple linear regression models for each principal component (predictand) were constructed using only the significant and stably correlated teleconnection indices identified throughout the study as potential predictors. Three linear models were found to explain a *significant* amount of the total variation in the main mode of variability of the precipitation of autumn, and in the two main modes of the precipitation of winter. Being, the SCAND, WeMO and El Niño1+2 the indices related to the precipitation in autumn; and, the NAO, EA, PEP, AO and WeMO the indices related to the precipitation in winter. On the other hand, low capacity of predictability of the climate patterns at large scale over the seasonal precipitation was shown.

Keywords: Iberian Peninsula, Principal Component Analysis, PCA, spatial variability, precipitation, teleconnection indices.

INTRODUCTION

Due to its geographic location (both latitudinal and with respect to the water and land masses that surround it) and its complex orography, Spain presents a wide climatic variability. Such variability, both spatial and temporal, is one of the reasons why the precipitation is the most important meteorological phenomenon, not just from a climatic point of view, but also as a resource. An overview over the territory shows an extreme pluviometric contrast between Galicia and Almeria [1]. Furthermore, precipitation may also be influenced, spatially and temporally, by certain climatic variability patterns representing variations that may be associated with oscillations at large scale of the dynamical processes occurring in the atmosphere and the ocean, resulting in variations in the weather and climate over widely separate points of the Earth (teleconnection patterns). Such phenomena are recurrent and persistent. To study the temporal evolution of such patterns, indices are defined such that they summarize the phase and intensity of the oscillation in a compact manner.

The aim of this study is to contribute to the understanding of the variability presented by the precipitation of the two wettest seasons in the peninsular Spain, using an updated version of a high-resolution database, MOPREDAS [2], related to several teleconnection indices chosen for this study. These patterns are: the Arctic Oscillation (AO), the Atlantic Multidecadal Oscillation (AMO), the East Atlantic pattern (EA), the East Atlantic / West Russia pattern (EAWR), El Niño Modoki (EMI), El Niño – Southern Oscillation (ENSO (E1 Niño 1+2, El Niño 3, El Niño 3.4 and El Niño 4) and SOI), the East Pacific – North Pacific pattern (EPNP), the North Atlantic Oscillation (NAO), the North Pacific Gyre Oscillation (NPGO), the Polar / Eurasia pattern (PEP), the Pacific / North American pattern (PNA), the Scandinavia pattern (SCAND), the Western Mediterranean Oscillation (WeMO) and the West Pacific pattern (WP).

METHODOLOGY

Both the precipitation data (covering the period 1951 – 2010) and the teleconnection indices were seasonally averaged, such that precipitation in autumn corresponds to September, October and November, precipitation in winter corresponds to December, January and February, and the teleconnection indices are grouped, in the same way, so that the coetaneous and with a time lag of up to four seasons indices (depending on the precipitation) are considered.

Principal Component Analysis (PCA)

The PCA [3,4] is a useful tool to reduce the dimensionality of the data, identifying modes of variability. In this study, a PCA was applied to the autumn and winter precipitation datasets with the goal of identifying the main modes of variation of the precipitation field over the Spanish Iberian Peninsula. In order to detect the number of principal components to be considered as significant, t*he North Rule* [5] and the *scree plot* [6] were used. The significant eigenvectors selected were rotated, using the Varimax rotation [7], an orthogonal rotation, to obtain an alternative and possibly better interpretation of the results, to try and get physically coherent spatial patterns which have the lowest possible spatial variance.

Selection of predictors and multiple linear regression

The identification of the teleconnection indices that can be used as predictors for seasonal precipitation was carried out by evaluating the significance and stability in time of the linear correlations between the principal components of seasonal precipitation and the teleconnection indices, for both autumn and winter seasons.

Using such seasonal indices as potential predictors, a multiple linear regression analysis was performed for each principal component of the precipitation, for both seasons, constructing linear models using the stepwise method [8]. To measure the goodness of fit of each formulated model, the R-squared and root mean squared error (RMSE) statistics were used.

RESULTS AND DISCUSSION

Spatial Variability

For both cases, autumn and winter, three significant modes of variability were retained. Accounting for, approximately, 77% of the total variance in the case of autumn and gathering approximately 85% of the total variance in the case of winter.

Autumn

The first mode of variability (which explains 54.91% of the total variance) groups the center and south, until approximately 1ºW by its right, including part of Aragon. The second mode groups together part of the north coast and southeast of the peninsular Spain, explaining 12.82% of the total variance. Finally, the third mode, which explains a total of 9.58% of the variance, corresponds to some regions from the west and northeast.

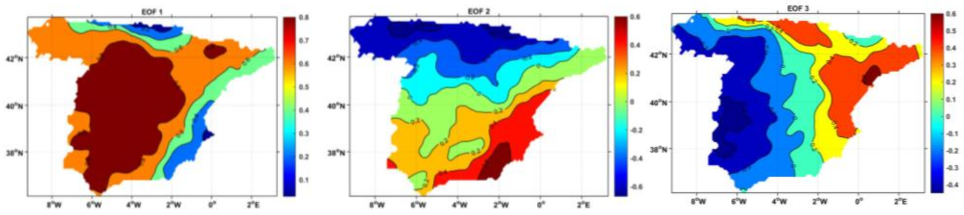

FIGURE 1. Maps of the first three EOFs corresponding to the autumn precipitation.

Winter

The first and main mode of variability able to explain 67.14% of the total variance, corresponds to almost the whole study area, with the exception of the north and east parts. The second mode groups together part of the north coast and southeast of the peninsular Spain, explaining 12.32% of the total variance. The third mode, which explains a total of 5.03% of the variance, corresponds to the regions of Cantabria and the Basque Country, approximately.

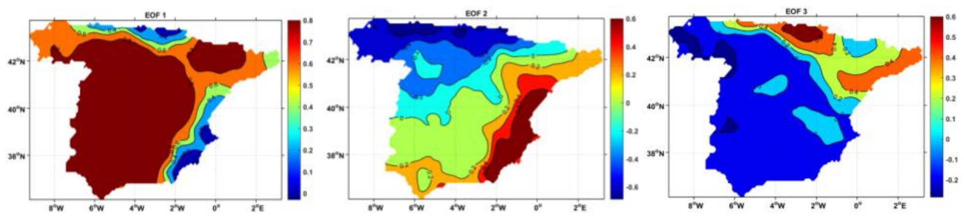

FIGURE 2. Maps of the first three EOFs corresponding to the winter precipitation.

Potential predictors and linear modeling

The principal components for each season are correlated with the teleconnection indices, and the ones presenting significant correlations at the confidence level of 95% or higher are selected. With the purpose of finding whether or not such correlations remain stable over time, 30-years moving correlation windows were plotted, considering as stable those for which 90%, or more, of moving correlations are above the threshold of the 95% level of significance. Table 1 shows a summary of the results about the relations studied. For both seasons, it is worth noticing the correlation between the second PC and the coetaneous WeMO, which remain highly (and negatively) correlated over time, especially in winter. Also in those seasons, the coetaneous AO and NAO are also highly (and negatively) correlated with the first PC of the precipitation.

TABLE 1. Significant and stable correlations between the PCs of the precipitation, of autumn and winter, and the seasonal teleconnection indices.

otoño	**PC1**	**PC2**	**PC3**	**invierno**	**PC1**	**PC2**	**PC3**
EAson1	-	-	0.40	**AOdjf**	-0.67	-	-
EPNPson	0.30	-	-	**EAdjf**	0.29	-	-0.39
EPNPjja	-	-	0.32	**EAjja1**	-0.28	-	-
Niño1+2son	0.43	-	-	**EAWRdjf**	-0.26	0.37	-
Niño1+2jja	0.33	-	-	**NAOdjf**	-0.71	-	-
Niño3son	0.45	-	-	**Niño3.4djf1**	-	-	0.27
Niño3jja	0.45	-	-	**PEPjja1**	-	0.36	-
Niño3son1	-0.30	-	-	**PEPdjf1**	0.26	-	-
Niño3.4son	0.46	-	-	**SCANDdjf**	0.33	-	-
Niño3.4jja	0.45	-	-	**SOIjja1**	-	0.30	-
Niño3.4son1	-0.29	-	-	**WeMOdjf**	-	-0.72	-
Niño4son	0.40	-	-				
Niño4jja	0.32	-	-				
SCANDson	0.48	-0.48	-				
SCANDjja	-	-	-0.29				
SOIson	-0.35	-	-				
SOIjja	-0.50	-	-				
SOIson1	0.29	-	-				
WeMOson	-0.33	-0.52	-				

Teleconnection indices to explain / predict the autumn and winter precipitation variability

An approach based on linear relationship, via the construction of multiple regression models, was followed, with the goal of evaluating the ability of teleconnection indices as predictors of seasonal precipitation.

Thereby, the results of the study about the predictability of seasonal precipitation (conducted using only the seasonal indices with a time lag in the construction of the models) showed a reduced capacity of prediction of the climatic variability at large scale over the precipitation of autumn and winter in the peninsular Spain. However, three linear combinations, between certain indices, were found to explain significant amount of the total variation in the first PC of autumn and the first and second PCs of winter.

The estimated model for the first PC of the autumn precipitation includes as predictors the WeMO, SCAND and El Niño1+2 coetaneous indices. The last two presented positive correlation with the PC, so positive phases of those patterns would be associated with rainy periods; unlike with the WeMO pattern, which correlated negatively with the PC. This model is able to explain 56.1% of the variation in the autumn precipitation in the center and south of the Peninsula. For the first PC of the winter precipitation, a model was estimated, such that explains 67.14% of the variation the precipitation of winter over almost the whole territory of the Spanish Iberian Peninsula. It includes as predictors the NAO, EA and AO coetaneous indices, plus the PEP index from the previous winter. In this case, both the NAO and AO indices correlate negatively with the PC, so their positive phases would contribute to less rainy periods. Whilst the opposite would occur with the EA and PEP indices, which correlate positively with that PC. For the second PC of the winter precipitation, the estimated linear model includes only the coetaneous WeMO, index which positively correlates with that PC, contributing then to periods with less rain. Such model was able to explain 51.9% of the total variation in the winter precipitation in parts of the north coast and southeast of the Peninsula.

CONCLUSIONS

Three linear models were found to explain a *significant* amount of the total variation in the main mode of variability of the autumn precipitation, and in the two main modes of the winter precipitation. The SCAND, WeMO and El Niño1+2 indices being included in the modeling of the autumn precipitation; and, the NAO, EA, PEP, AO and WeMO indices, related to the winter. On the other hand, low capacity of predictability of the climate patterns at large scale over the seasonal precipitation was shown.

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