Department of Physical Geography and Regional Geographical Analysis
Faculty of Geography and History
University of Barcelona

PhD Thesis

The Western Mediterranean Oscillation and Rainfall in the Catalan Countries

Memory presented by
Joan Albert López i Bustins
(*Summary*)

PhD Director

Prof. Dr Javier Martín Vide
University de Barcelona

Barcelona, June 2007

INTRODUCTION

0.1. PRESENTATION

The Catalan Countries are mostly in a Mediterranean climate domain. The atmospheric circulation regimes in the Mediterranean basin show a seasonal cycle, linked to the wet temperate circulation in winter and to the strictly subtropical one in summer. This produces rainy winters and dry summers. The Mediterranean climate thus shows the geographical transition situation between the wet mild domain of the mid-latitudes and the arid and desertic area of the tropical anticyclone belt. However, the highly geographic complexity of the Mediterranean basin composed of three peninsulas with a remarkable surface in its northern versant, and its singularity, almost closed over the Atlantic, diversifies its general Mediterranean climate, yielding a great variety of atmospheric behaviors, mainly pluviometric. When geographical factors interfere in circulation dynamics, they cause a seasonal distribution of rainfall in certain scopes of the basin, which differs from the typically Mediterranean one. Specifically, in the eastern façade of the Iberian Peninsula, leeward of the Atlantic influence, autumn is the rainiest season whereas winter is relatively dry (Martín-Vide and Olcina Cantos, 2001). Especially illustrative is the pluviometric calendar, on a daily resolution, obtained from observatories located on the coast of the Catalan Countries (Figure 1) showing an annual regime that differs from the typically Mediterranean one. Therefore, the maxima are equinoctial both in frequency and in quality, with autumn standing out in terms of quantity and winter barely surpassing summer (Soler and Martín-Vide, 2002).

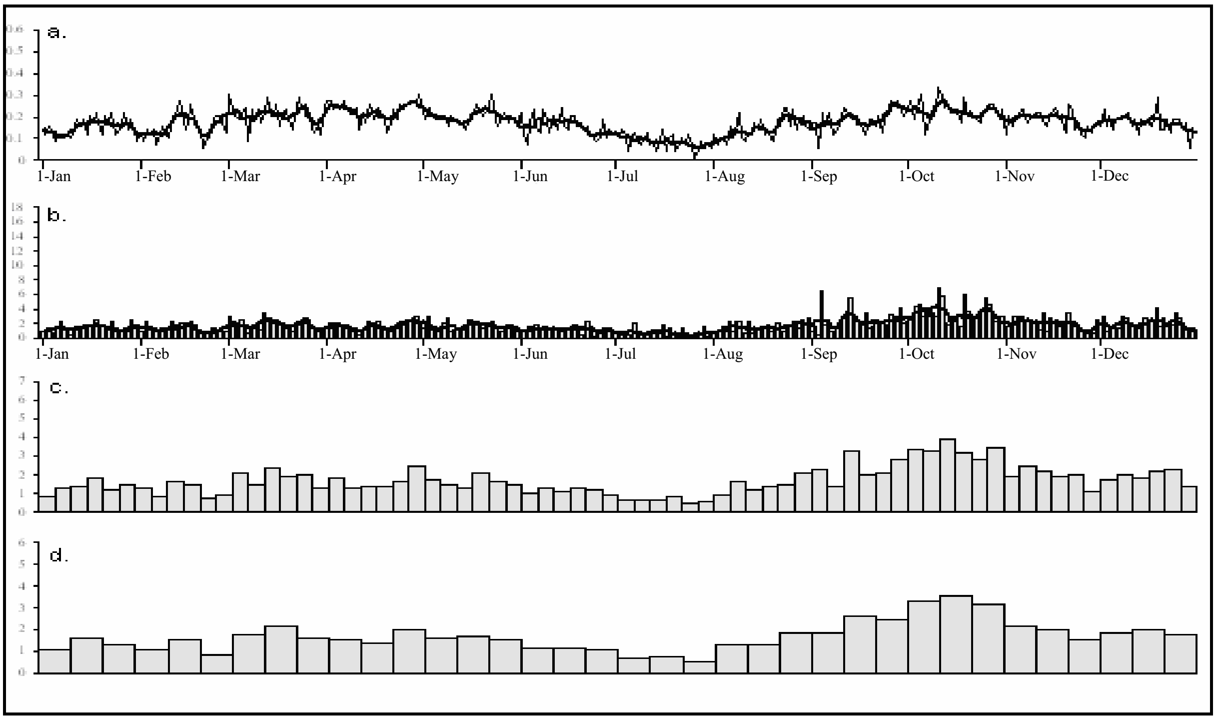

Figure 1. Pluviometric calendar of Sant Feliu de Guíxols, Baix Empordà (Costa Brava) (1927-1995). **a.** Relative frequencies of rainy days. **b.** Daily amount averages (mm). **c.** Daily amount averages in 5 days (mm). **d.** Daily amount averages in 10 days (mm). (From Soler and Martín-Vide, 2002).

0.2. MOTIVATIONS

The Western Mediterranean Oscillation (WeMO) is a new concept presented in this thesis as a regional teleconnection pattern. The Catalan Countries are that eastern façade of eastern Iberia where the precipitation is weakly explained by the European patterns as the North Atlantic oscillation (NAO) or Arctic oscillation (AO). A database was published in 2002 by the European project IMPROVE, in which very long pressure series were reconstructed. During the research period, Dr. Martín-Vide (University of Barcelona) and Dr. Camuffo (University of Padua) thought about creating a new pattern for the western Mediterranean basin. The series selected to calculate the WeMO index (WeMOi) were Padua (Veneto, Italy) from the Specola Tower Observatory and San Fernando (Cadiz) from the Naval Observatory. This study tries to continue the preliminary definition of this new pattern. The main duty has been the index redefinition and validation by means of the Catalan rainfall pluviometry at different temporal resolutions. Furthermore, the phases and cycles detection on the WeMOi and the main trends are analysed. Finally, the influence of external factors as solar activity, quasi-biennial oscillation (QBO) or El Niño Southern Oscillation (ENSO) on the WeMOi and the Catalan Countries' rainfall is also considered.

0.3. STUDY AREA: THE CATALAN COUNTRIES

After the first essays between the WeMOi and the Iberian rainfall (Martin-Vide and Lopez-Bustins, 2006), the eastern façade of the Iberian Peninsula was where the WeMO had the largest influence. It was an area very similar to the Catalan Countries region. The Catalan Countries are a cultural region with a certain national identity. They are located in south-western Europe and divided into four different countries (Figure 2): Andorra, Spain (Catalonia, Valencian Country, Balearic Islands and eastern Aragon named *Franja de Ponent* –Western Strip–), France (Eastern Pyrenees Department known as Northern Catalonia –Perpinyà–) and Italy (l'Alguer, a town in Sardinia). This last one is not included in this study. An administrative division comprising of a number of municipalities named *comarca* (county) is used to establish a high coverage of meteorological stations. The total area study covers about 70.000 km^2 and is limited by the following coordinates: (42º53'N-37º51'N, 01º32'W-04º18'E). The most important orography is the Pyrenees which divides Northern Catalonia from Southern Catalonia or Catalonia. The highest mountain in the study area is in the western Pyrenees (Pic d'Aneto). Between the Pre-Pyrenees and the coastal mountain ranges there is the Catalan central plain. In the Valencian Country, the highest mountains are over north-western and northern Alacant. In the Balearic Islands, the highest peak is over northern Mallorca. The most relevant rivers flowing north to south are: Tet, Llobregat, Segre, Ebre; Túria, Xúquer and Vinalopó (Figure 3).

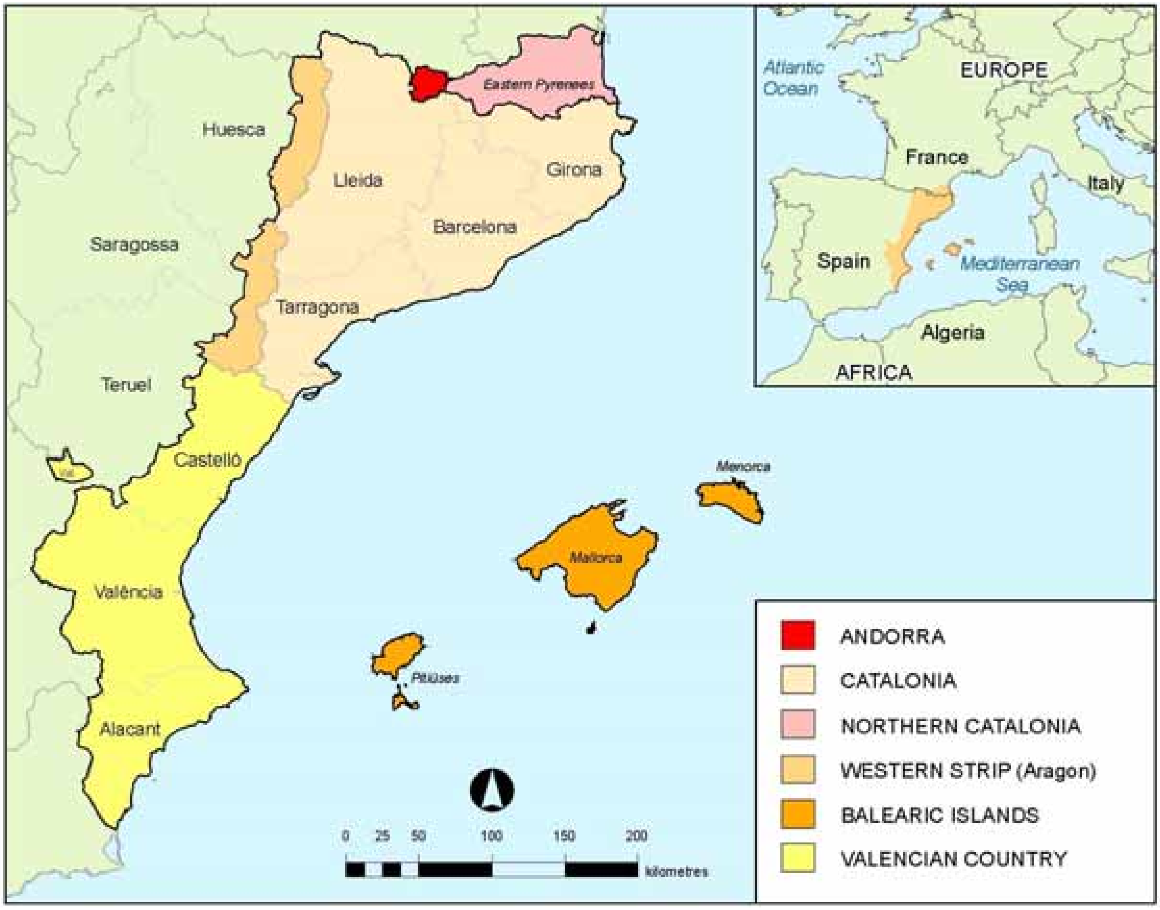

Figure 2. Political map of the Catalan Countries and their location in Western Europe.

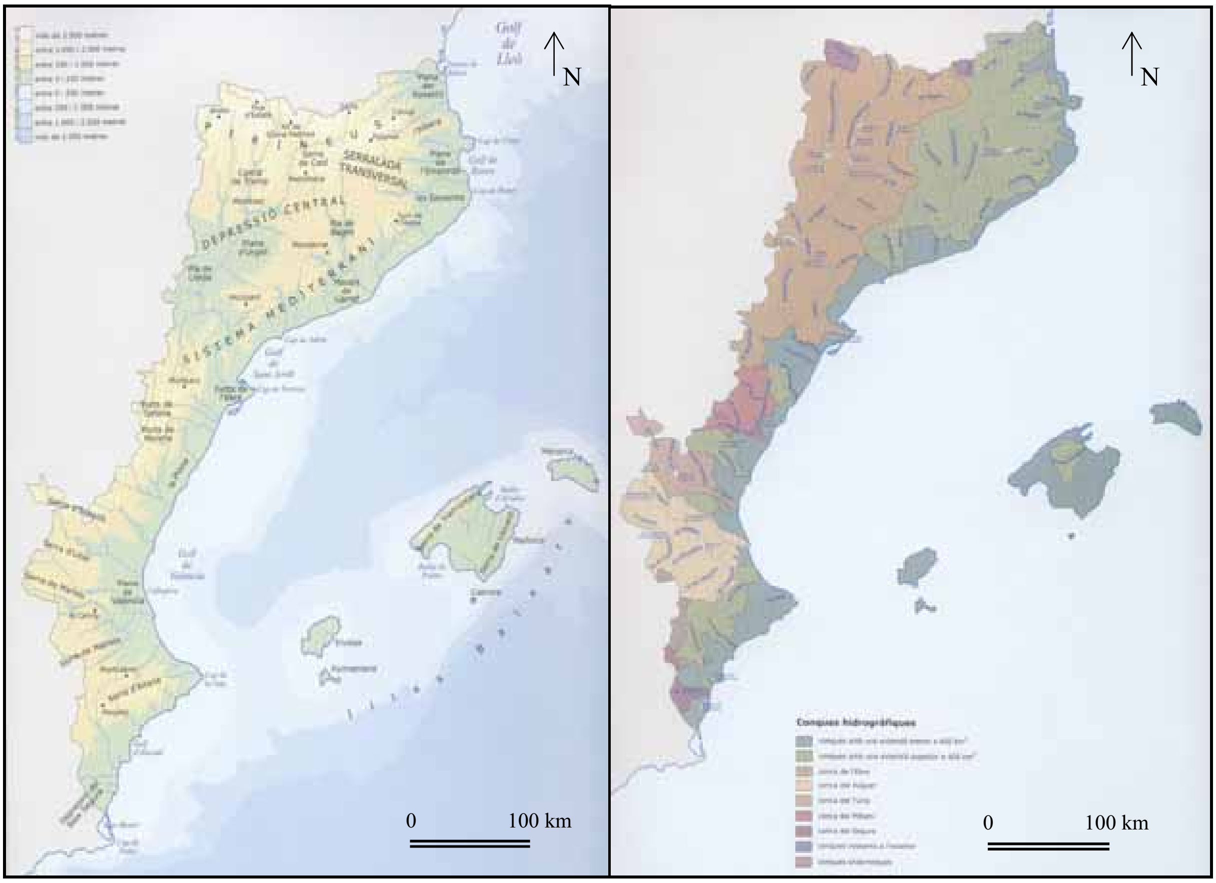

Figure 3. Relief (left) and catchments (right) in Catalan Countries. (Source: *Atles dels Països Catalans* –Catalan Encyclopaedia, 2000–).

0.4. STUDY PERIOD

The study period to validate the WeMO pattern is the second half of the 20th century, 1951-2000. From a climatological point of view, 30 years are usually the minimum to carry out analyses and trends. This study period comprises a period with a very notorious climatic variability, with a more noticeable anthropogenic influence during the second half of the study period, and the beginning of a climatic change at the end of the 20th century.

Other study periods are employed for several reckonings, for instance, the WeMOi has values since 1821 to be analysed. The 1961-1990 period is taken as reference in most analyses, above all, for the standardization procedure.

0.5. MAIN OBJECTIVES

This study has two main goals:

1) To know the WeMO influence on the Catalan Countries' rainfall variability.
2) To assess the WeMO potentiality to predict the daily rainfall.

Having known the WeMO variability, I search the variability and trends of the pattern to foresee the rainfall behaviour over eastern Iberia in the near future. Furthermore, torrential rainfall is very frequent over the coastal areas in Catalan Countries, therefore, I try to relate its occurrence to daily extreme WeMO phases.

0.6. THE MOST IMPORTANT HYPOTHESES

This study basically contains three hypotheses:

1) The WeMO is the regional pattern of the western Mediterranean basin and feasibly explains the rainfall variability on the Catalan Countries.
2) The rainfall over the Catalan Countries in the near future depends on the cycles and recent trends of the WeMOi.
3) Daily WeMOi is a very useful tool to predict torrential events in the Catalan Countries.

In addition, it would be very interesting to study the role that the WeMO plays on the Catalan Countries' rainfall variability in the current climate change.

0.7. MAIN METHODS

The Pearson's correlation coefficient (*r*) is used to analyse the relationship between these patterns of low frequency variability and climatological variables. Other analyses are trends, spectral analysis, synoptic classifications, etc.

For the synoptic classification, I used a manual method to describe the sea-level pressure (SLP) maps and the geopotential height maps. I also used an automatic and objective one by means of the principal components analysis (PCA) in the 4th chapter. Anyway, there are currently high difficulties in establishing a correct synoptic classification for the Mediterranean scope due to its complex physical geography on the terrain (Martin-Vide, 2001).

Downscaling is applied to detect rainfall anomalies in Catalan Countries associated with some of the obtained circulation patterns.

0.8. DATABASE

The Catalan Countries' precipitation database is formed by meteorological stations. A grid is not recommendable for this study, because of the main role of the local factors. The WeMO influence will be demonstrated to be very dependant on the local orography. Some validation and homogenisation problems remain in the database, but it is compensated by the high coverage of the study area by over 120 observational points. The main database sources are the NESAP (North-Eastern Spain Adjusted Precipitation dataset) data (Climate Change Research Group –CCRG– at the Rovira i Virgili University) (Saladié *et al.*, 2005) and the Spanish Meteorological Office (INM).

The WeMOi is calculated using two surface pressure series: San Fernando and Padua. In the 1st chapter, the details of the characteristics of both series and the paths to calculate the WeMOi are exposed.

I only use an SLP grid from the NCEP/NCAR reanalysis (Kalnay *et al.*, 1996) when I carry out an objective synoptic classification.

0.9. THESIS STRUCTURE

The thesis consists of five chapters which follow a logical chronology according to the improvement, development and knowledge of the WeMO.

1st Chapter: *The Western Mediterranean Oscillation (WeMO) definition and its index calculation (WeMOi).*

2nd Chapter: *The study area definition and WeMO application to its precipitation.*

3rd Chapter: *WeMO trends and cycles analysis: the effects on the Catalan Countries' rainfall variability.*

4th Chapter: *The Stratosphere and the WeMO.*

5th Chapter: *Application of the WeMOi at daily resolution.*

0.10. MATTERS TO BE IMPROVED

This thesis just pretends to let this new pattern come to light and its several applications and uses. The novelty is that its spatial resolution is regional and its temporal resolution is daily. This study does not imply ceasing further research about it. This thesis is open to rectifications regarding the calculation and definition of the WeMOi.

Moreover, the first step after obtaining my PhD will be to update the WeMOi to the present. Monthly WeMOi data are available for the 1821-2000 period at the web site of the Group of Climatology (University of Barcelona):

http://www.ub.es/gc/English/wemo.htm