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

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5TH CHAPTER

APPLICATIONS OF THE WEMOI

AT DAILY RESOLUTION

5.1. POTENTIALITIES OF THE REGIONAL TELECONNECTION PATTERNS AT DAILY RESOLUTION

The potentialities of the WeMO, as a new regional teleconnection pattern, have already been mentioned along the current thesis. The calculation of the daily index of a pattern of low variability is a challenge to the 'low' adjective. The daily WeMOi application is a very new method among the studies about teleconnection patterns. Very few studies have already applied this daily temporal resolution on teleconnection indices (Baldwin and Dunkerton, 2001; Beniston and Jungo, 2002; Camuffo *et al*., 2006; Peña *et al*., 2006b). Once satisfactory results are obtained, it might be able to carry out a methodological extrapolation to other teleconnection patterns.

Most of the works I present here are the result of different contributions to national and international Meetings. They are 4 short communications which show a daily WeMOi application to determine different features of climatic variables such as local wind circulation, temperature anomalies and, obviously, precipitation episodes. The studies are focused on different points or regions of the Catalan Countries.

The first one derived to a research contribution to the 4th Meeting of the Spanish Climatological Association in 2004 (López-Bustins and Azorín-Molina, 2004). It talks about the different precipitation episodes to be classified according to pluviometric types, previously established and defined by Azorín-Molina and López-Bustins (2004), according to the daily value of WeMOi. This classification is very similar to the one established by CEAM (Estrela *et al*., 2002). The second study is my project of the Applied Climatology Master (López-Bustins, 2004). It adjusts the very torrential events (≥200 mm/ 24 h) in Catalonia and in the Valencian Country to the WeMO calendar during the second half of the 20th century.

In 2005, the Group of Climatology from the University of Barcelona contributed to the 5th European Meteorological Society (EMS) Meeting in Utrecht with the application of the daily WeMOi to predict the occurrence of sea-breeze (Sb) days in the western Mediterranean basin (Lopez-Bustins and Azorin-Molina, 2005). In 2006, this research group showed the positive relationship between the WeMOi and the urban heat island (UHI) in Barcelona in the 6th International Conference on Urban Climate in Göteborg (Lopez-Bustins *et al*., 2006b).

5.2. APPLICATIONS

5.2.1. PLUVIOMETRIC CLASSIFICATION OF RAINFALL EPISODES ACCORDING TO THE WEMO PHASE

In this work, the WeMOi is applied to the atmospheric types of rainfalls in the Alacant province. The first goal of this research is based on the definition of the daily index values for the atmospheric episodes with rainfalls ≥10 mm in six meteorological observatories (Alacant, Dénia and Torrevella in shoreline; Alcoi, Tibi and Villena inland; map of Alacant region is only displayed in Catalan version) in the course of the 1991-2000 decade. Among the results obtained, the part played by the neutralization of this barometric dipole (neutral phase: index values around 0), that is to say, the importance of the synoptic configurations of scarce baric gradient in superficial tropospheric levels (flat barometer), at the outbreak of convective rainfall episodes in the south-east of the Iberian Peninsula. The classification of backdoor cold fronts and Atlantic ones is also adjusted to daily WeMOi values. Once the episodes are classified according to their typology, the following comments were deduced:

a) Atlantic precipitations

They are frequent when the daily WeMOi is over 1.50, i.e., extremely positive (Figure 1). Nevertheless, an important exception takes place when most of the Atlantic episodes are related to negative values. It occurs when these episodes are linked to polar lows over western Iberian Peninsula.

b) Mediterranean precipitations

They tend to take place in WeMOi negative values. Notwithstanding, an exception was also found in the [-0.50, 0.50] interval; they are meteorological situations with a clear north-east component (Figure 1), which are associated to backdoor cold fronts with slight negative WeMOi values.

c) Convective precipitations

They usually take place when daily WeMOi values are between -0.50 and 0.50, which groups over 60% of the total episodes of ≥10 mm of the 6 observatories. In the neutral WeMO phase, when the WeMOi values are around 0, synoptic situations with a low pressure gradient at surface level (flat barometer) occur. They often lead to the local winds circulation which can cause thunderstorms.

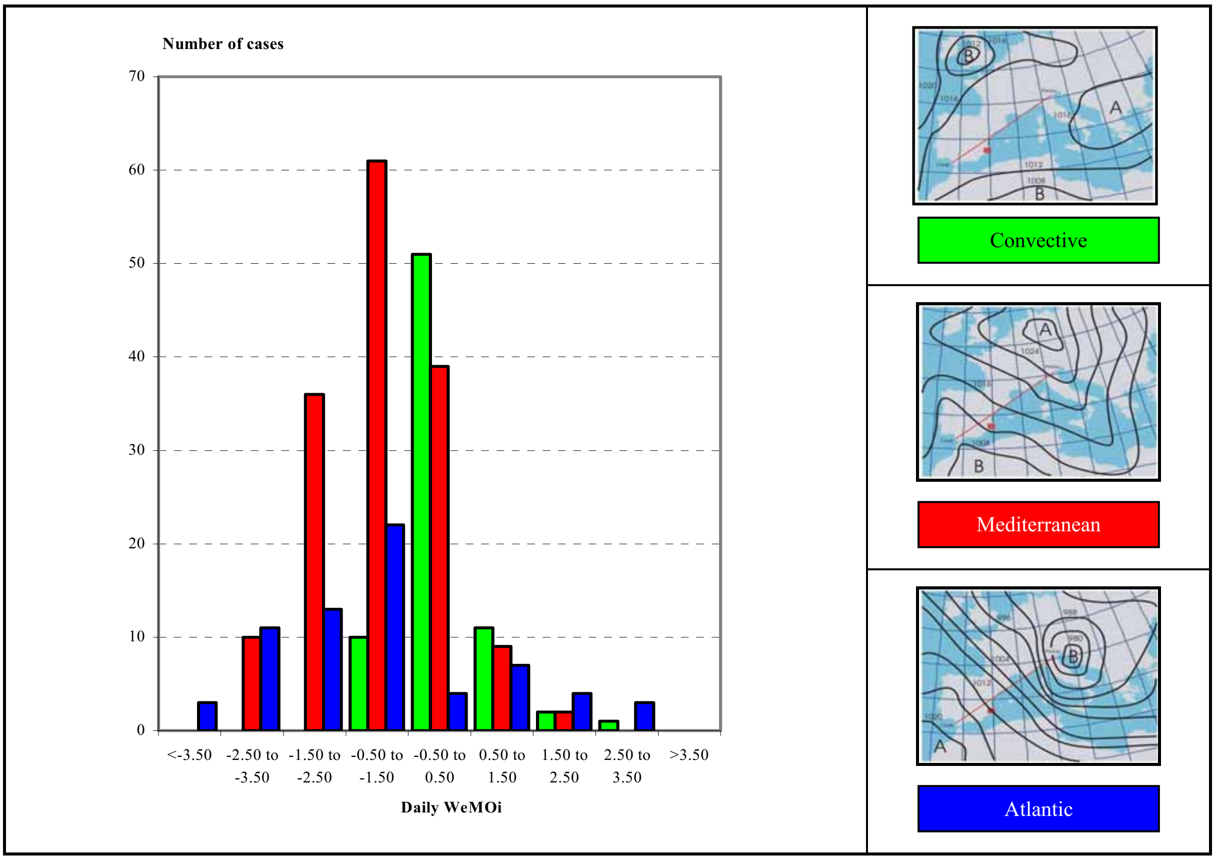

Figure 1. Total number of cases of convective, Mediterranean and Atlantic precipitation of ≥10 mm/ 24 h in at least one of the six meteorological stations considered in the Alacant province grouped in daily WeMOi intervals for the 1991-2000 period.

5.2.2. The WeMO calendar and the temporal evolution of extreme torrential episodes

5.2.2.1. <u>Catalonia (1951-2000)</u>

The compilation of the 200 mm/ 24 h events was done by Gázquez *et al*. (2004). The number of cases is not very large (32 episodes) because this extreme torrentiality is more frequent in the Valencian Country as it can be seen in the next subsection.

It must highlighted that autumn is the season of the year where torrential events are more probable, above all, during the 1st fortnight of October (>30% of the cases), which can be related to the period of the year with a lowest mean value of the WeMOi. Martín-Vide *et al*. (in press) detected a maximum occurrence of torrential episodes in Catalonia in October. Moreover, they obtained the 7 most frequent circulation patterns which favour this heavy precipitation to be associated to a negative WeMO phase. In other regions of the Catalan Countries, the Balearic Islands, a maximum of torrential rainfall is detected in October too (Grimalt *et al*., 2006). During the period of the year with a highest mean value of the WeMOi, the 1st fortnight of February, no event takes place (Figure 2).

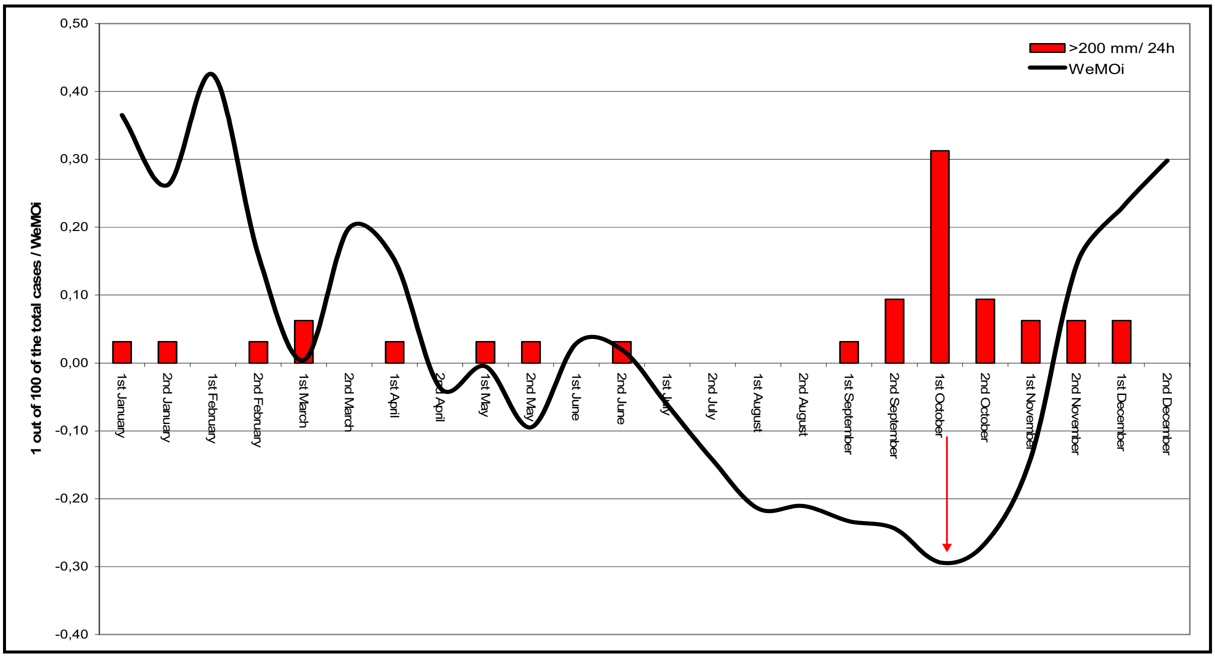

Figure 2. Intraannual evolution of the WeMOi by fortnights for the 1951-2000 period with their corresponding >200 mm episodes (32 cases) in Catalonia.

5.2.2.2. Valencian Country (1951-2000)

The concentration of cases is also in autumn, as it was expected, with a peak in the 1st fortnight of October in the 1951-2000 period (Figure 3) and with a certain accumulation of cases in early winter. It is not strange that some episodes take place in the transition between winter and spring.

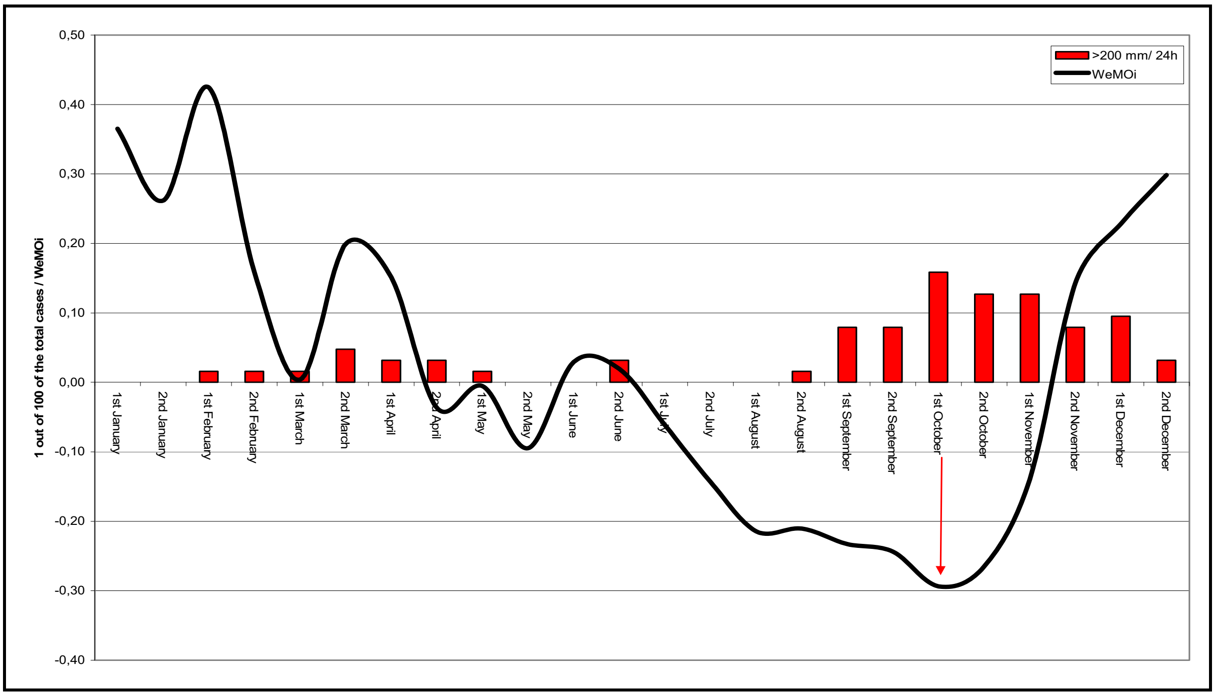

Figure 3. Intraannual evolution of WeMOi by fortnights for the 1951-2000 period with their corresponding >200 mm episodes (63 cases) in the Valencian Country.

5.2.3. The WeMOi: An objective primary filter for finding sea-breeze days in the south-east of the Catalan Countries

5.2.3.1. Abstract

The synoptic variability on a daily temporary scale is the primary factor that determines the occurrence of Sb. The presence of a weak surface pressure gradient favours the onset of a mesoescalar wind circulation caused by the role of sunshine and diurnal thermal forcing occurring between land and sea masses. The definition of a regional teleconnection pattern for the western Mediterranean basin such as the WeMO has allowed a quantification of the synoptic factor influence. The WeMOi is used as the first criterion for selecting Sb days. Its application as an essay on the objective and subjective databases created for Alacant during the 1999-2000 biennium, positively confirms the effectiveness of this objective primary criterion. The [-1, 1] interval of the daily WeMOi ensures stable synoptic conditions on the surface for the detection of Sb triggering on the coast of the Catalan Countries.

5.2.3.2. Objective, data and method

The aim of the study is to improve the selection method of Sb days and propose a universal criterion based upon the use of regional teleconnection patterns at daily resolution. The method is to cross daily WeMOi values with objective and subjective Sb databases. They are also crossed with daily NAOi values in order to make comparisons.

The study period is the 1999-2000 biennium. The experimental databases of Sb are: 1) Objective (370 days of pure Sb, automatic selection), and 2) Subjective (498 days of non-pure Sb, manual selection).

5.2.3.3. Results

The WeMOi explains better than the NAOi the occurrence of Sb in Alacant. A WeMOi around 0 (neutral phase), clear sky and intense solar radiation lead to a high probability of Sb occurrence in Alacant. The influence of the neutral phase of the NAO over stable meteorological conditions in the western Mediterranean is low. The NAO is not a valid pattern for selecting Sb days on the coast of the Catalan Countries. The WeMOi application to the subjective database is the only distribution which is Gaussian according to the Kolmogorov-Smirnov test (Figure 4).

It must be defined the WeMOi interval which might be used as a primary objective criterion to select Sb days using the subjective database. The threshold interval of the daily WeMOi was set as follows. First, eight class intervals increasing in length by 0.5, starting from the central value 0, were proposed: [-0.25, 0.25], [-0.5, 0.5], [-0.75, 0.75], [-1, 1], [-1.25, 1.25], [-1.5, 1.5], [-1.75, 1.75], [-2, 2]. For each class interval, the absolute number of Sb days (Sb $\sum n_i$) and non-Sb days (NSb $\sum n_i$) were collected, and the corresponding distributions of relative frequencies (Sb and NSb $\sum n_i$ %) were calculated for both. The relative rise in Sb days (Rise Sb $\sum n_i$ %) and non-Sb days (Rise NSb $\sum n_i$ %) was then estimated between the second class interval and the first, the third interval and the second, etc.

The relative difference obtained between both was used to set the WeMOi threshold interval that best selects weak surface pressure gradient situations for Sb development, subject to the condition that the relative difference (Rise Sb – Rise NSb) must be positive, as it ensures an increase in the selection of Sb days greater than the non-Sb days. The last class interval that matches this condition is the best threshold interval to identify ideal surface pressure gradient situations for a Sb to occur. The [-1, 1] threshold interval corresponds to the last one in which the difference in the relative rise is positive by 1.31% for Sb days (Table 1). Therefore, if the low-level component is too strong the WeMOi values range between [-∞, -1] and [1, ∞], and the Sb passage theoretically may be prevented altogether.

	Class	**Sb $\sum n_i$**	**NSb $\sum n_i$**	**Sb $\sum n_i$ (%)**	**NSb $\sum n_i$ (%)**	***Rise* Sb $\sum n_i$ (%)**	***Rise* NSb $\sum n_i$ (%)**	***Rise* Sb – *Rise* NSb**
1	**[-0.25 , 0.25]**	141	27	28.31	11.89			
2	**[-0.5 , 0.5]**	250	50	50.20	22.03	21.89	10.13	11.76
3	**[-0.75 , 0.75]**	348	77	69.88	33.92	19.68	11.89	7.78
4	**[-1 , 1]**	405	100	81.33	44.05	11.45	10.13	1.31
5	**[-1.25 , 1.25]**	440	124	88.35	54.63	7.03	10.57	-3.54
6	**[-1.5 , 1.5]**	457	140	91.77	61.67	3.41	7.05	-3.63
7	**[-1.75 , 1.75]**	472	157	94.78	69.16	3.01	7.49	-4.48
8	**[-2 , 2]**	480	176	96.39	77.53	1.61	8.37	-6.76

Table 1. Distribution of collated absolute ($\sum n_i$) and relative frequencies ($\sum n_i$, %) of the Sb days (Sb) and non-Sb days (NSb), grouped together in class intervals with a growing range threshold. The relative rise of Sb days (Rise Sb) and non-Sb days (Rise NSb) between the higher class interval (2) and the lower (1). The last column shows the difference in the relative rise between the Sb and the NSb in Alacant (1999-2000). (The most suitable class interval for selecting Sb days is highlighted).

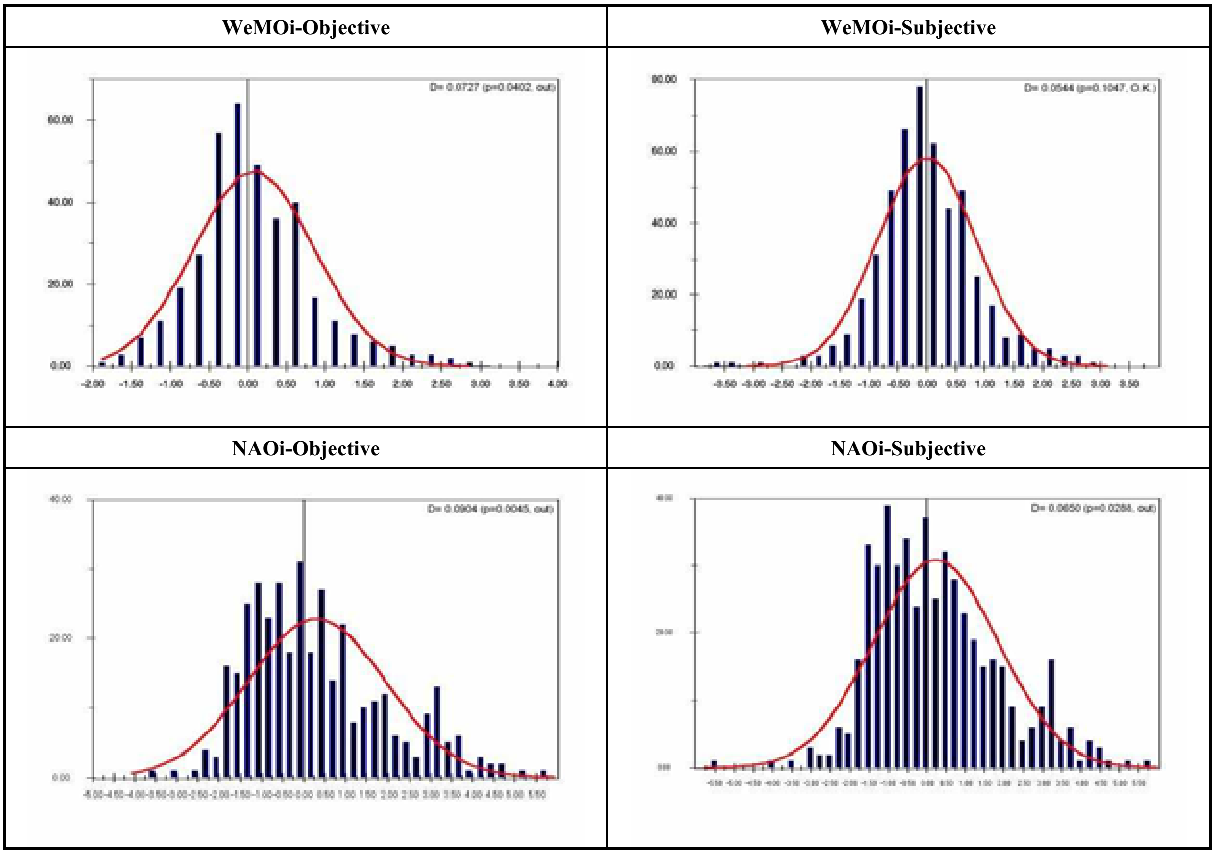

Figure 4. Graphics of Sb days distribution according to the daily value of WeMOi and NAOi for both databases, objective and subjective. D value of the Kolmogorov-Smirnov test for a normal distribution is shown (AnClim software –Stepanek 2005–).

5.2.3.4. Conclusions and future work

A regional teleconnection pattern such as the WeMO has been used as a new objective criterion to select those days with stable meteorological conditions with a low pressure gradient. The [-1, 1] interval has been defined as the first primary objective filter to select those days where Sb occurrence is probable. This method could be applied to the rest of the coast of the Catalan Countries, and be extrapolated to other study areas.

Future work is to define a precise objective method taking the new criterion of [-1, 1] interval into account together with other secondary filters (radiation, sunshine, cloudiness, geostrophic wind, etc.); with the purpose of widening knowledge of the characteristics and physical processes involved of this mechanism of winds (Azorin-Molina and Lopez-Bustins, submitted).

5.2.4. The WeMOi and the intensity of the urban heat island in Barcelona

5.2.4.1. Abstract

Even though synoptic conditions favour the event of an UHI, some northerly type advections also lead to an intense one in Barcelona (Moreno, 1994). This is demonstrated by using the WeMO at daily resolution, as its positive phase is mainly defined by north-west advections. The most significant correspondence is found in winter and autumn.

5.2.4.2. Introduction

It is well-known that some weather types and synoptic patterns (e.g. anticyclonic situations) enhance the UHI, especially its intensity. In this sense the synoptic and the local meteorological scales are linked. The annual mean temperature in Barcelona city is 1.5ºC over the corresponding one in its airport located southward.

5.2.4.3. Objective, data and method

The goal of this study is to demonstrate that north advections over Barcelona region increase its UHI intensity (Moreno, 1994) by means of a regional teleconnection pattern such as the WeMO at daily resolution.

For assessing the Barcelona UHI, minimum temperatures are used from two meteorological stations, one in the ancient centre next to the harbour, 'Drassanes'; and the other one, in 'El Prat' airport, located just outside Barcelona city. Both are close to the sea and at a similar height a.s.l. The distance between them is slightly over 15 kilometres. The period study is from 3rd July 1970 to 19th February 1984. Thus, 4,980 minimum temperature differences are calculated, and each one of these differences will be corresponded with one daily WeMOi value in order to find some relationship.

5.2.4.4. Analyses and results

The days with an intense UHI to be related to extreme positive WeMO phases must be selected. The fixed threshold is an UHI intensity ≥5 ºC. Consequently, the sample is reduced to 458 days.

Once a daily WeMOi value has been attributed to each day, two WeMOi values means are worked out. One is performed for the days of the whole period (4,980 cases), and another one for those days with an intense UHI (458 cases). The analysis is performed for the entire year, and for each season. In winter, the highest frequency of intense UHIs takes place (16.2 % of the winter days), doubling the number of cases in other seasons. The second season with a highest frequency of intense UHIs is autumn (7.6 % of the days).

It is in winter when the highest mean of the daily WeMOi values is obtained. Nevertheless, autumn has the largest difference between the means as the mean of the whole period is slightly negative due to the frequent occurrence of Mediterranean storms with easterly flows. These ones are characterised by overcast skies, high relative humidity and moderate or strong winds, which mitigate the UHI development.

For the entire year, there is also a significant difference. Summer is the only with means very close as north advections are not common in this season. Spring has a slight negative mean for the days with an intense UHI with a weak significance. To sum up, once again autumn and winter are demonstrated to be the most liable seasons to an intense UHI occurrence (Table 2).

	Days of the whole period		**Days with an UHI intensity ≥5ºC**		
	Cases	**WeMOi mean**	**Cases (% of the whole period)**	**WeMOi mean/ (Confidence interval at 95%)**	**Difference between the means**
Annual	4.980	0.0381	458 (9.2 %)	<u>0.3177</u> / (0.3124, 0.3230)	+0.2796
Winter	1.254	0.3074	203 (16.2 %)	<u>0.6293</u> / (0.6164, 0.6422)	**+0.3219**
Spring	1.196	0.0518	86 (7.2 %)	<u>-0.0349</u> / (-0.0646, -0.0052)	-0.0867
Summer	1.256	-0.0963	72 (5.7 %)	-0.0833 / (-0.1088, -0.0578)	+0.0130
Autumn	1.274	-0.1075	97 (7.6 %)	<u>0.2758</u> / (0.2522, 0.2993)	**+0.3833**

Table 2. Comparison of the WeMOi means of the days of the whole period and days with an intense UHI, annually and seasonally. The confidence interval of the sample mean is displayed (the underlined WeMOi means with an UHI intensity ≥5 ºC are those ones which are significantly different to the WeMOi means of the whole period; the differences between the means in bold are the largest ones).

5.2.4.5. <u>Conclusions</u>

An intense UHI is probable to occur under anticyclone conditions (neutral WeMO phase), but also under north-west advections (positive WeMO phase) as it is seen in the annual analysis. Although winter season reaches the most positive WeMOi mean with intense UHI days, it is in autumn when there is a largest difference between the means due to the Mediterranean cyclones being very frequent in this season (negative WeMO phase).