

Analysis of the behavior of the extreme values of minimum daily atmospheric pressure at ground level over the Spanish Central Plateau

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RESUMEN

Se realiza un estudio para establecer el comportamiento espacio-temporal de los valores extremos de presión mínima diaria a nivel del suelo, en una zona que comprende el centro de la península Ibérica (Meseta Central española). El estudio se desarrolla en el intervalo de tiempo comprendido entre 1961 y 2003. A partir de series de datos de valores mínimos de presión diaria, medidos en 14 observatorios meteorológicos de la zona en el intervalo de tiempo considerado se construyen, para cada uno de los observatorios y para la Meseta Central española, así como para cada una de las dos zonas en que puede dividirse, las series de anomalías diarias de presión (diferencia respecto de la media). Se establecen los valores extremos de esas anomalías considerando como valores umbrales los de los percentiles P_{05} , para los valores más bajos, y P_{95} para los valores más altos. Se construyen las series de frecuencias de anomalías extremas, anuales y estacionales y, por último, se analiza la tendencia de esas frecuencias, tanto para cada observatorio individual como para las regiones consideradas, con resultados concordantes en todos los casos. El análisis de tendencia de las series anuales de frecuencias de anomalías extremas en la Meseta Central española muestra que los valores más bajos de presión mínima diaria presentan una tendencia decreciente mientras que los más altos la presentan creciente. Es decir, entre 1961 y 2003 el número de días por año con valores más altos de presión mínima a nivel del suelo se incrementan, mientras que el número anual de días con valores más bajos disminuye. Además se analiza la tendencia de las series estacionales y de sus resultados se concluye que sólo el invierno es determinante en el comportamiento de las series anuales.

ABSTRACT

A study was undertaken to establish the spatio-temporal behavior of the extreme daily values of atmospheric pressure at ground level in a zone comprising the central part of the Iberian Peninsula (Spanish Central Plateau). The study involves the time period between 1961 and 2003. From the data series of minimum values of daily pressure, measured at 14 weather observatories in the zone over the time period considered, the series of anomalies in daily pressure (differences with respect to the mean) were constructed for each of the observatories and for the Spanish Central Plateau and for each of the zones into which this latter can be subdivided. The extreme values of these anomalies were established considering as threshold values those of the P_{05} percentile, for the lowest values, and of the P_{95} percentile for the highest one. The series of extreme, annual and seasonal anomaly frequencies were constructed and, finally, the trend of those frequencies was analyzed, both for each individual weather observatory and for the regions considered. In all cases, the

results proved to be in agreement. Analysis of the trend of the annual series of extreme anomaly frequencies over the Spanish Central Plateau revealed that the lowest values of minimum daily pressure at ground level follow a decreasing trend while for the highest ones the trend is increasing. That is, between 1961 and 2003 the number of days per year with higher of minimum atmospheric pressure values at ground level increased whereas the number of days per year with lower values decreased. Additionally, an analysis was made of the trend of seasonal series; from the results, it is concluded that only the winter is determinant as regards the behaviour of the annual series.

Keywords: Minimum daily pressure, Iberian Peninsula, extreme values, frequency, trend.

1. Introduction

The most recent reports on the Evaluation of Climate Change (IPCC, 2002, 2007) highlight the need to study the behaviour of the extreme events of the various components of the climate. Studies specifically addressing atmospheric pressure at sea level usually involve the reconstruction of series (Allan *et al.*, 2002) and their relationship with other climate variables (Kutiel and Paz, 1998; Gouirand and Moron, 2003; Zangvil *et al.*, 2003; Salinger *et al.*, 2005), but only a few have analyzed their temporal behaviour (Pinto *et al.*, 2001). Additionally, in recent years climate studies at smaller scales (regional and sometimes local) have been more frequent with respect to those carried out large-scale (global or hemispheric). The findings of these studies at scales smaller than global serve to check that the results obtained at global or hemispheric scale.

The aim of the present work was to perform an analysis of the temporal behaviour of daily minimum ground level pressures (MIGLP) from the series of data recorded at the weather observatories of the synoptic and climatological network of the Spanish Instituto Nacional de Meteorología, INM, (currently the State Agencia Española de Meteorología, AEMET) in the regions of Castilla-La Mancha, Madrid and Castilla and León, all three areas forming the Spanish Central Plateau. This work supplements the one carried out by Labajo *et al.* (2008) addressing the temporal behaviour of the extreme values of maximum ground level pressure, for the same study area and the same interval of time. A contrast of the results of both analyses should allow the trend of the extreme values of atmospheric pressure at ground level in the central area of the Iberian Peninsula to be confirmed. Additionally, this should allow it to be decided whether the temporal trend of the mean values of ground level pressure is due to the behaviour of its extreme values or not.

2. Data and methodology

The study zone is delimited by latitudes 38° 01' and 43° 14' N, and longitudes 0° 54' and 07° 02' W, affording an area of more than 180,000 km² on the central part of the Iberian Peninsula (Spanish Central Plateau-SCP). This is crossed from SW to NE by a mountain range that divides the zone into two almost equal parts. These two parts show sufficiently marked physical-geographic contrasts to enable them to be differentiated from each other, such that the SCP can be divided into two distinct regions: the northern zone (Northern Subplateau, NS), defined by latitudes 40° 05' and 43° 14' N and longitudes 1° 46' and 7° 02' W, and the southern zone (Southern Subplateau, SS), between latitudes 38° 01' and 41° 19' N and longitudes 0° 54' and 5° 24' W.

The data used for this study were provided by the AEMET. These data are values of minimum daily pressure (MIGLP) obtained from the bands of the barograph at the weather observatories of the synoptic and/or climatological network of the INM. The data used here were obtained from

continuous pressure recordings taken at 14 weather observatories: eight on the NS and six on the SS. The observatories selected were those of Ávila, Burgos (Villafria), León (Virgen del Camino), Salamanca (Matacán), Segovia, Soria, Villanubla (Valladolid), Zamora, Los Llanos (Albacete), Ciudad Real, Cuenca, Madrid (Retiro), Barajas (Madrid) and Toledo (Fig. 1). These observatories cover the study zone sufficiently well. They were selected on the basis of the percentage of gaps in the working series and with the condition that such series should be of the same length. In no case was the number of gaps in the series greater than 20% of the total number of data. The length of the working series was that encompassed between 1961 and 2003, and they included 15,695 data.

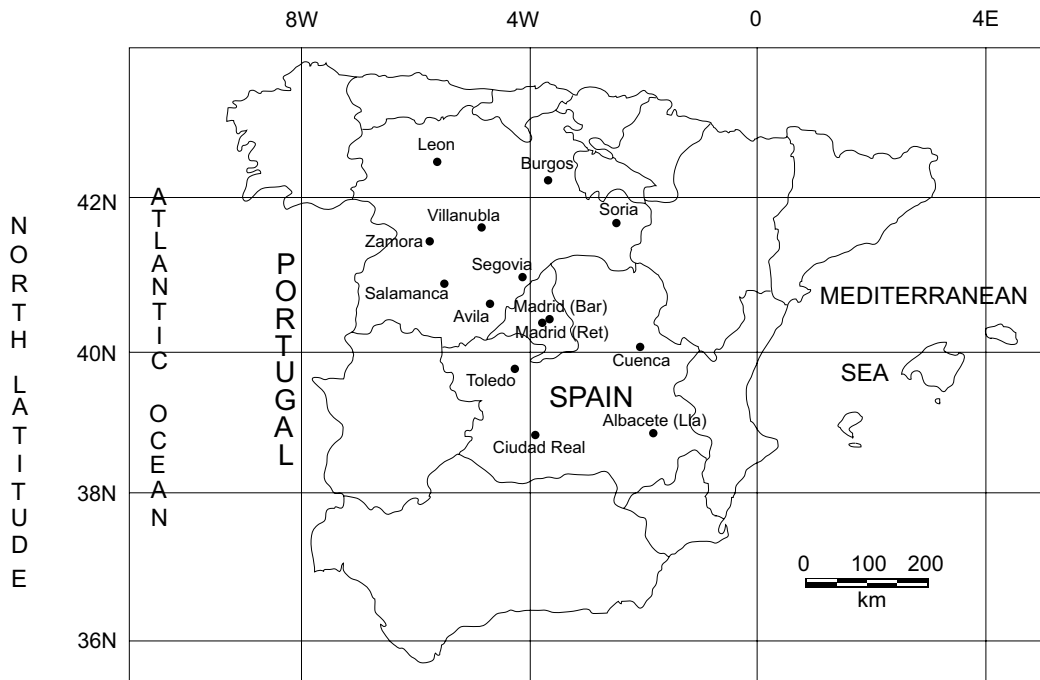


Fig. 1. Study zone. Location of the weather stations selected.

The data series were refined by applying a series of logical filters, and the gaps thus generated, together with those present initially, were filled in using linear regression techniques. Regarding homogeneity, given the initial quality of the data, we limited ourselves to checking the homogeneity of the variance in the working series, using the Levene test (Levene, 1960). A particular case is that of the observatory of Toledo, which was moved from its original site in 1982. Accordingly, it was necessary to reconstruct the part of the series of MIGLP values corresponding to the first location in order to homogenize the series as much as possible. The inclusion of Toledo among the observatories considered is justified owing to the need to complete the coverage of the observations in the study area. The process used to obtain the series of annual frequencies of extreme MIGLP values was as follows: with the daily database we constructed the series of anomalies in minimum ground level pressures (AMIGLP) for each station, in each case calculating the differences between the daily MIGLP values and each of the corresponding daily mean values obtained as averages, for each of the 365 days of the year, from the data of the original series.

As indicated in previous works (Labajo *et al.*, 2006, 2008) the fact of considering the series of daily anomaly values instead of the daily values of minimum pressure was mainly due to two aspects. First, because the former values do not depend on the altitude of the observatories and can therefore be compared directly with one another without having to make any kind of correction, which is not the case of the pressure values, and, second, because the use of anomaly data instead of daily observational data filters the annual periodicity that affects pressure values and minimizes the inhomogeneities not detected. From this anomaly series we constructed the regional series corresponding to the minimum pressures over the SCP. To construct these series, we employed those of the observatories selected, using the inverse distance weighting method (Jones and Hulme, 1996) for the spatial averaging in a cell between latitudes 38° and 43° N, and longitudes 1° and 6° W. Furthermore, taking into account the differences between both subplateaus (NS and SS) we constructed the regional series for each. These series were studied separately in order to be able to check the results obtained with those relative to the CSP.

2.1 Determination of thresholds

To determine thresholds that would enable us to define the AMIGLP values as extreme, the percentile criterion was used in the case of both the lowest and the highest values. This criterion is widely used by investigators (Brunetti *et al.*, 2001; Manton *et al.*, 2001; Salinger and Griffiths, 2001; Griffiths *et al.*, 2003; Labajo *et al.*, 2008). Here, we used the P_{05} percentile as a threshold for the lowest extreme values and the P_{95} percentile as the threshold for the highest extreme values.

The reason why we chose these two percentiles is that in order to determine the threshold values that would allow us to consider an AMIGLP value as extreme is based on the definition of the *tri-mean* statistical parameter. This is a mean established for the values of a series, excluding those that lie below the threshold established by P_{05} and those surpassing that established by P_{95} , thereby allowing one to remove the strong influence of extreme values on the mean and hence prevent distortion of this statistic. As a result, as the threshold of extreme values in our series we took those values corresponding to the P_{05} and P_{95} percentiles of each series.

By applying this criterion to the AMIGLP series, we determined the threshold values below or above which the daily anomalies of minimum pressure are considered as extreme values for the series from the weather stations at Ávila, Burgos, León, Salamanca, Segovia, Soria, Villanubla, Zamora, Los Llanos, Ciudad Real, Cuenca, Madrid, Barajas and Toledo), and for the partial and total regional series. These values are shown in Table I.

It also seemed appropriate to establish which daily minimum atmospheric pressure values could be considered extreme in the study zone. Accordingly, we determined the values corresponding to the P_{05} and P_{95} percentiles in the series of daily minimum pressure values (MIGLP) for each of the individual observatories. We did not include the thresholds of the extreme pressure values for the partial and total regional series because they were not significant, since the pressures at the observatories considered were not reduced to the same height above sea level. These threshold values are shown in Table I.

Having determined the thresholds of the extreme values, for each of the data series we established the number of cases per year, for each year, in which the AMIGLP values were above the P_{95} percentile and below the P_{05} percentile. We thus obtained the series of annual frequencies of extreme minimum pressure anomaly values (FAMIGLP).

Finally, we analyzed the temporal behaviour of the annual frequencies of extreme values, initially establishing their temporal evolution graphically and then determining the possible trends shown by them over the time period studied (1961-2003), applying the Spearman method (Sneyers, 1975).

Table I. Thresholds of extreme, lowest and highest values (percentiles P_{05} and P_{95}) of the AMIGLP anomaly series and of the daily pressure values (MIGLP) at each of the observatories in the study zone (hPa).

Observatories	AMIGLP		MIGLP	
	P_{05}	P_{95}	P_{05}	P_{95}
Ávila	-11.90	9.40	875.1	896.7
Burgos	-12.80	10.10	901.9	925.1
León	-13.40	10.50	897.2	921.4
Salamanca	-12.52	9.90	912.3	935.1
Segovia	-12.20	9.71	889.0	911.2
Soria	-12.60	9.80	879.9	902.7
Villanubla (Valladolid)	-12.62	10.10	905.6	928.7
Zamora	-17.30	6.00	926.5	950.1
Los Llanos (Albacete)	-10.68	9.22	923.5	944.1
Ciudad Real	-10.80	8.70	933.0	953.4
Cuenca	-11.10	9.45	895.7	917.0
Barajas (Madrid)	-11.60	9.50	936.2	958.3
Madrid (Retiro)	-11.20	9.90	927.7	949.4
Toledo	-12.80	11.10	939.8	962.8
<i>Northern Subplateau</i>	-12.97	9.41		
<i>Southern Subplateau</i>	-11.08	9.42		
<i>Central Plateau</i>	-11.91	9.54		

3. Results

From the values of the frequencies of anomalies in daily minimum pressure (FAMIGLP) obtained for each of the observatories, we constructed the plots showing the temporal evolution of those extreme events. The plots, seen in figures 2-5, include the corresponding trend lines.

Analysis of the plots revealed that at nearly all the observatories the observed trend was decreasing for the case of the lowest values (P_{05} threshold), while in the case of the highest values (P_{95} threshold) it was increasing. The slope of the trend lines was different for each of the plots, indicating that the level of confidence associated with the observed trend was different in each case.

In the plots shown in figures 2-5 it is possible to see the considerable variability of the series of FAMIGLP values. For the lowest extreme values (days with extremely low MIGLP values, threshold P_{05}) the highest frequencies were seen for 1963 and 1996 at nearly all the observatories. For the highest extreme values (days with extremely high MIGLP values, P_{95} threshold) there was a common outstanding maximum at all observatories in 1983, although at those of Ávila, Valladolid and Los Llanos the absolute maximum was seen for 1998 and in those at Soria and Barajas for 1990.

The trend lines included in the plots point to the existence of trends in all cases during the study period, although those corresponding to Burgos, Ciudad Real and Madrid (Retiro) are not very significant.

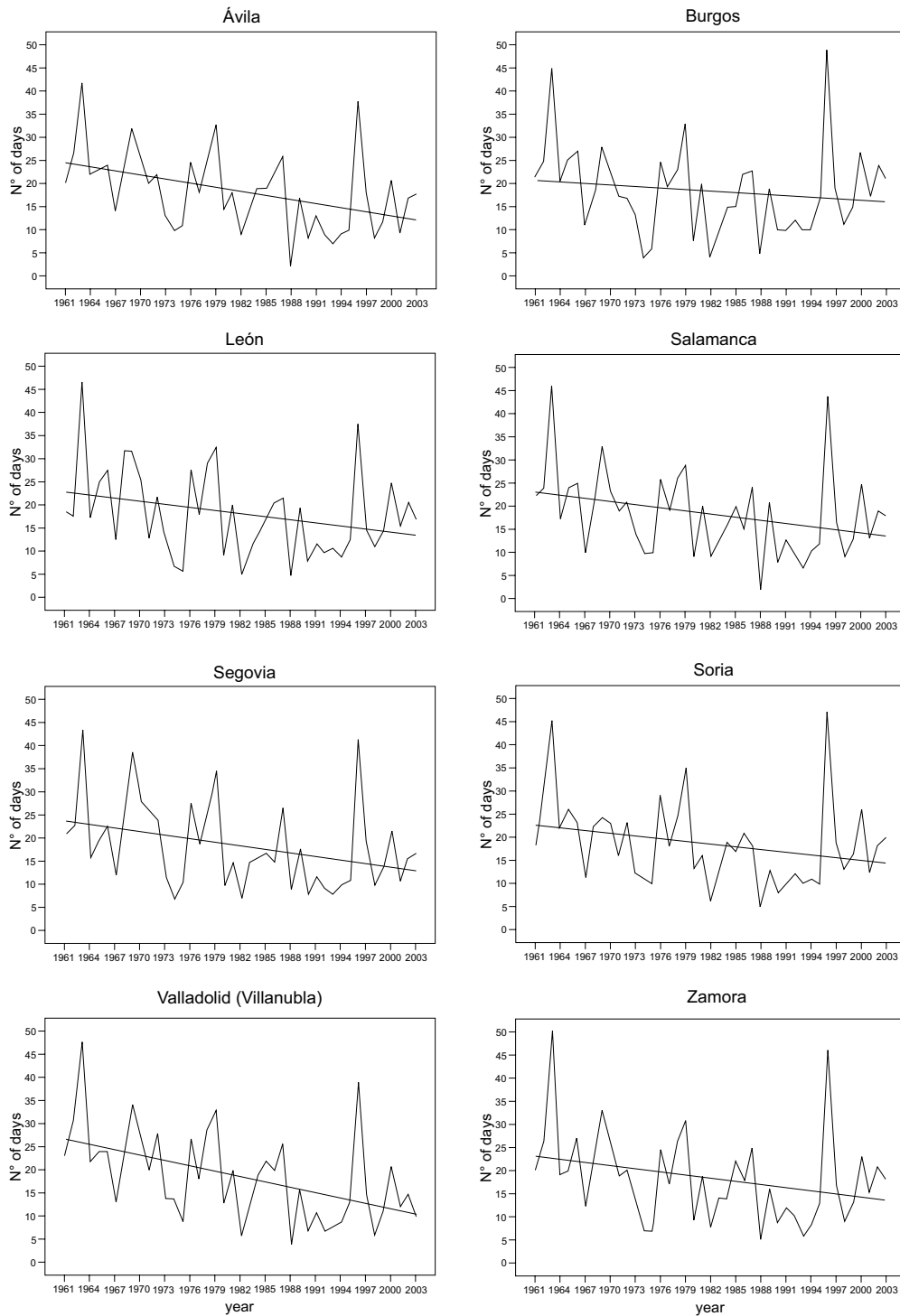


Fig. 2. Temporal evolution of the annual frequency of the lowest extreme events of AMIGLP smaller than P_{05} at each of the weather observatories of the Northern Subplateau.

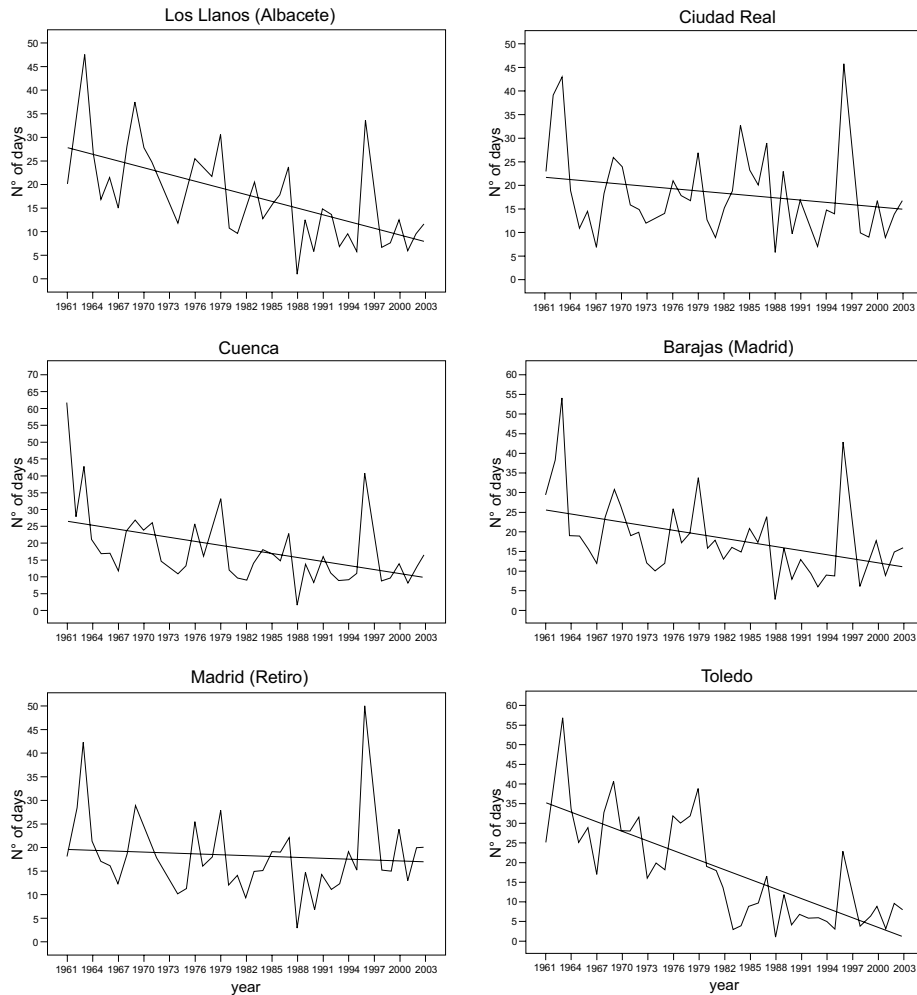


Fig. 3. The same as in Fig. 2 at each of the observatories of the Southern Subplateau.

To establish the degree of significance of the trends, the Spearman test (Sneyers, 1975) was applied to the FAMIGLP series obtained for each of the observatories. Sufficiently significant trends are those in which the confidence levels were greater than 90% ($\alpha_s < 0.1$). The results are shown in Table II.

The results offered in Table II indicate that the FAMIGLP series with the lowest extreme values show an appreciable trend in all cases studied, with the exception of the observatories at Burgos, Ciudad Real and Madrid (Retiro), in which the level of confidence was very low. For these latter observatories, the sign of the trend persisted. In general, for the rest of the observatories the annual frequency series of the lowest extreme values revealed decreasing trends at a level of confidence greater than 95%, except in the case of León (90%).

Regarding the FAMIGLP series of the highest extreme values, the trend of these was increasing, in most cases at a level of confidence greater than 95%. The exception was the Soria series, for

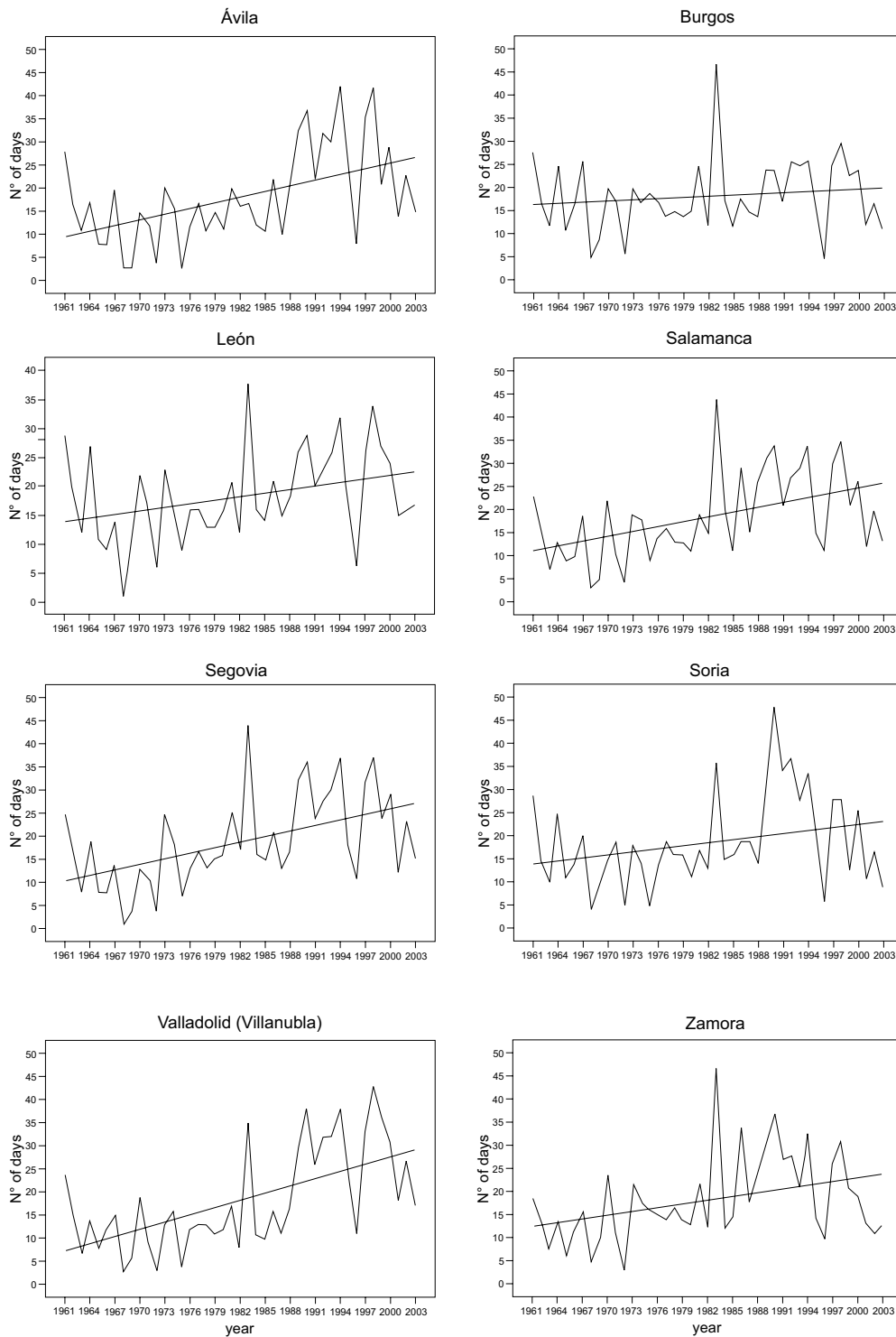


Fig. 4. Temporal evolution of the annual frequency of the highest extreme events of AMIGLP bigger than P_{95} at each of the observatories of the Northern Subplateau.

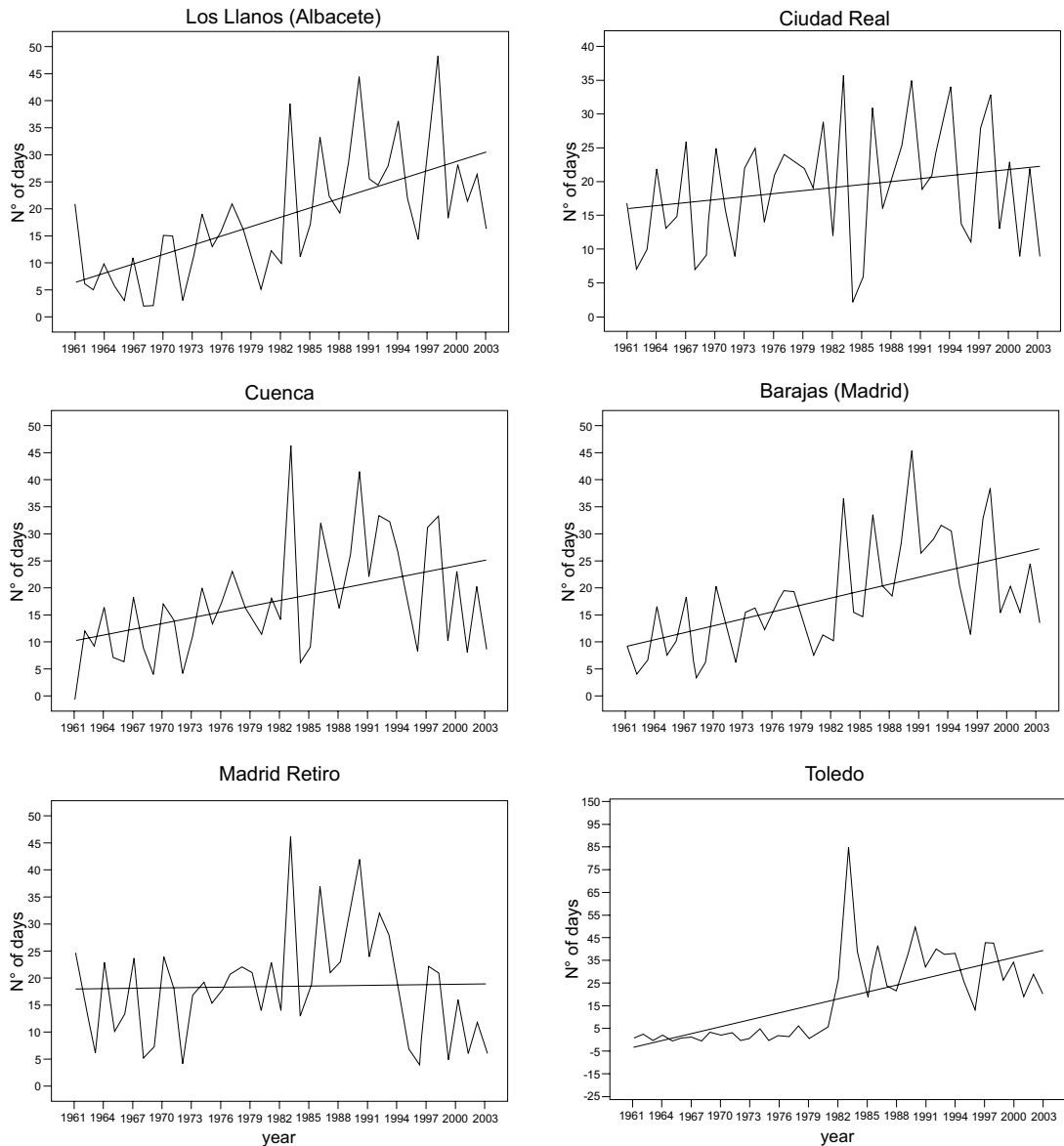


Fig. 5. The same as in Fig. 4 at each of the observatories of the Southern Subplateau.

which the level of confidence was greater than 90%. The series corresponding to Burgos, Ciudad Real and Madrid (Retiro) did not show any appreciable trend and in the case of Madrid (Retiro) the trend was of opposite sign to those of the other observatories, although its level of confidence was very small ($\alpha_s < 0.05$).

These findings suggest a modification of the behaviour of the pressure field at the surface along the year. This implies a variation in frequency and intensity of the cyclonic or anticyclonic perturbations affecting the Iberian Peninsula over the year.

Table II. Trends of FAMIGLP lower or higher than the threshold established with the P_{05} and P_{95} percentiles for the observatories of the study zone (for a level of confidence of 90% or greater. I = increasing, D = decreasing, NT = no significant trend (trend values in days per decade).

Observatories	FAMIGLP < P_{05}			FAMIGLP > P_{95}		
	r_s	α_s	Trend	r_s	α_s	Trend
Ávila	-0.502***	0.010	D (2.9)	0.494***	0.001	I (4.1)
Burgos	-0.205	0.187	NT	0.116	0.460	NT
León	-0.284*	0.065	D (2.2)	0.341**	0.025	I (2.0)
Salamanca	-0.368**	0.015	D (2.2)	0.477***	0.001	I (3.5)
Segovia	-0.387**	0.010	D (2.6)	0.488***	0.001	I (4.0)
Soria	-0.331**	0.030	D (2.0)	0.261*	0.091	I (2.3)
Villanubla (Valladolid)	-0.541***	<10 -3	D (3.9)	0.591***	<10 -3	I (5.2)
Zamora	-0.344**	0.024	D (2.3)	0.364**	0.017	I (2.7)
Los Llanos (Albacete)	-0.645***	<10 -3	D (4.7)	0.682***	<10 -3	I (5.7)
Ciudad Real	-0.243	0.016	NT	0.199	0.202	NT
Cuenca	-0.510***	<10 -3	D (4.0)	0.412***	0.006	I (3.4)
Barajas (Madrid)	-0.480***	0.001	D (3.5)	0.570***	<10 -3	I (4.3)
Madrid (Retiro)	-0.130	0.387	NT	-0.123	0.884	NT
Toledo	-0.764***	<10 -3	D (8.1)	0.712***	<10 -3	I (1.0)

*Level of confidence ≥ 90 and $\leq 95\%$ ($\alpha \leq 0.10$ and $\alpha \geq 0.05$). **Level of confidence ≥ 95 and $\leq 99\%$ ($\alpha \leq 0.05$ and $\alpha \geq 0.01$). ***Level of confidence $\geq 99\%$ ($\alpha \leq 0.01$).

Having analyzed the behaviour of the individual series of daily minimum pressure, we next explored the behaviour of the regional series in the same way. As in the case of the observatories, the FAMIGLP series were compiled as a function of the thresholds obtained for the AMIGLP regional series for the whole of the study zone (SCP), and its two differentiated parts (Table I).

The temporal behaviour of these regional series is shown in Figure 6. The trend line is also included. As in the case of the series from the individual observatories, in the regional series it may be seen that a trend is present in all of them –increasing in the case of the frequency series with the highest values and decreasing for those with the lowest values for the 1961-2003 period. These results are in agreement with those reported by Pinto *et al.* (2001) for the annual mean pressure series, obtained from mean monthly pressure values for the 1972-1994 period.

The level of significance of the trend observed in the analysis of the plots is shown in Table III.

From the results shown in Table III it is clear that, on average, the trend seen at the observatories has persisted throughout the study zone: a decreasing trend in the FAMIGLP, or in other words in the annual frequency of the lowest values of GLP, and an increasing trend in the case of the highest extreme values.

The trends of the FAMIGLP series, both in the case of the highest and the lowest values, are above the 99% confidence level for both subplateaus and for the SCP.

From all the above, it may be deduced that the temporal behaviour of the extreme GLP values as regards the frequency of their annual occurrence is similar in the northern part to what is observed in the southern part of the study zone, and that the results obtained for the whole zone are completely representative of their behaviour in it. Additionally, the annual frequency of the lowest extreme values of the minimum pressure anomalies observed for the SCP has tended to decrease along the interval studied (1961-2003), whereas that of the highest extreme values has tended to

increase. In other words, there has been a trend towards an increase in the number of days in the year with very high minimum pressures and a decrease in the number of days per year with very low minimum pressures. This suggests a possible increase in the frequency and/or intensity of anticyclonic situations at the expense of a decrease in the frequency and/or intensity of cyclonic situations along the year.

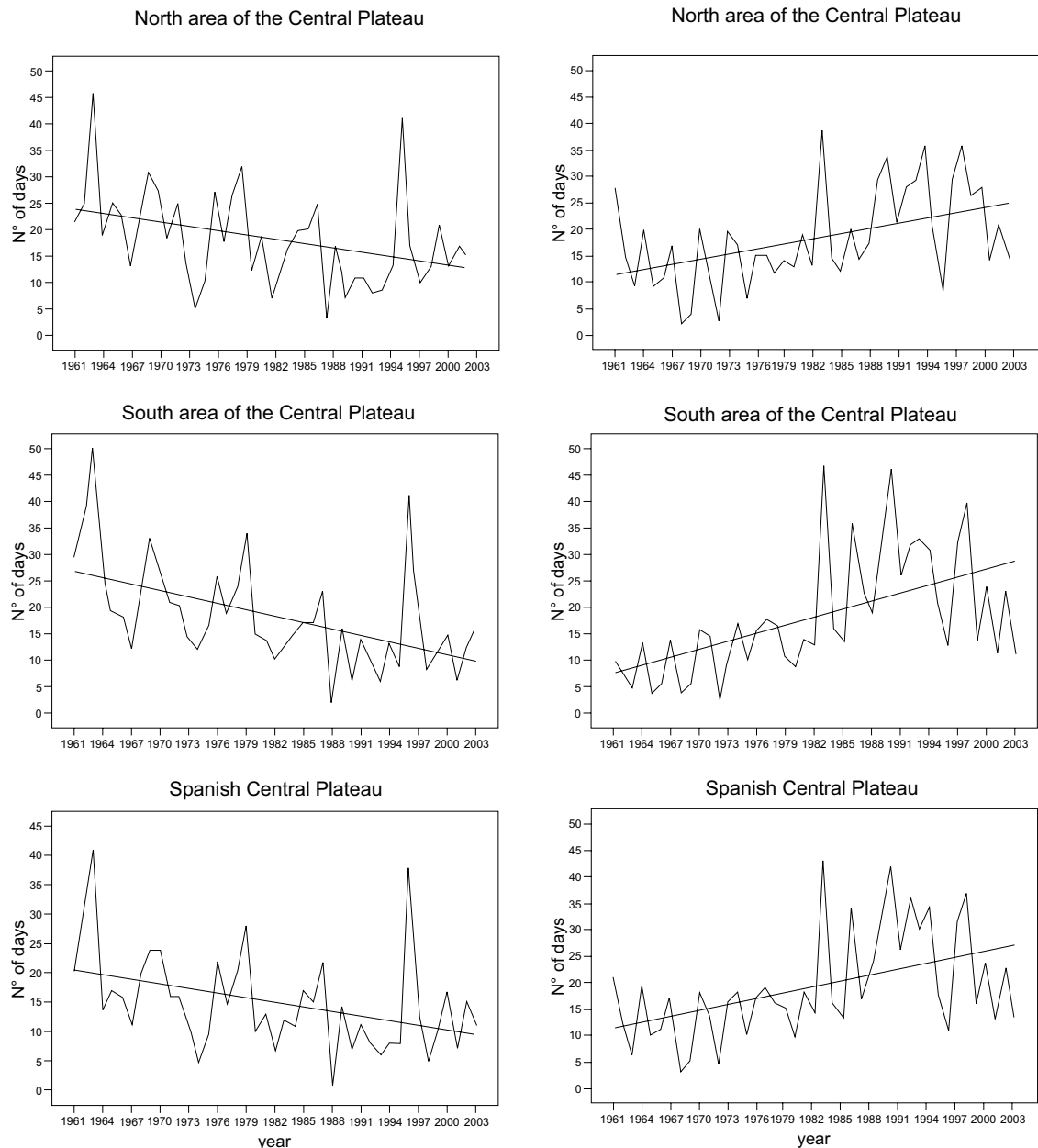


Fig. 6. Temporal evolution of annual frequency of the extreme AMIGLP events over the Spanish Central Plateau and at each of the subplateaus.

Table III. Trends of the FAMIGLP series lower than or higher than the threshold established by the percentiles P_{05} and P_{95} in the study zone for a level of confidence of 90% or greater. I = increasing, D = decreasing, NT = no significant trend (trend values in days per decade).

	FAMIGLP < P_{05}			FAMIGLP > P_{95}		
	r_s	α_s	Trend	r_s	α_s	Trend
Northern Subplateau	-0.428***	0.004	D (2.7)	0.447***	0.003	I (3.3)
Southern Subplateau	-0.457***	<10-3	D (4.0)	0.602***	<10-3	I (5.0)
Central Plateau	-0.454***	0.002	D (2.9)	0.437***	0.003	I (3.6)

*Level of confidence ≥ 90 and $\leq 95\%$ ($\alpha \leq 0.10$ and $\alpha \geq 0.05$). **Level of confidence ≥ 95 and $\leq 99\%$ ($\alpha \leq 0.05$ and $\alpha \geq 0.01$). ***Level of confidence 99% ($\alpha \leq 0.01$).

These findings are in agreement with those reported in studies of the temporal behavior of other climate variables; in particular, the mean annual temperature of the air. An increase in the annual frequency of anticyclonic events affecting the Iberian Peninsula implies an increase in the solar radiation reaching the earth's surface along the year. This contributes to the increase in air temperature detected in recent years in the CSP (Galán *et al.*, 2001; Morales *et al.*, 2005).

It is also possible to confirm the validity of the results obtained by comparing them with the index behavior of the North Atlantic Oscillation (NAO) over the same period of time (1961-2003). On applying a statistical study similar to that performed with the FAMIGLP series to this series of NAO index values, the following results were obtained. The Spearman coefficient was 0.41, with a level of confidence of 99%, implying that during the 1961-2003 period the NAO index underwent a highly significant increasing trend. This implies an increase in its positive values and a decrease in the negative ones during that period, in agreement with the annual trends of the extreme MIGLP values on the SCP.

Once the temporal behaviour of the annual frequencies of the extreme AMIGLP values in the study zone had been established, it was considered of interest to know which seasons affect this behavior most. To accomplish this, we elaborated, in the same way as for the annual series, the FAMIGLP series for spring (March, April and May), summer (June, July and August), autumn (September, October and November) and winter (December, January and February). The trend was determined in each of them, and the results are shown in Table IV.

From the results shown in Table IV, it may be deduced that the mean behavior of the extreme pressure values in winter in the study zone and in each of its two parts is what determines their annual behavior. In the other seasons no trend is seen, and in some cases, such the highest extreme values in summer, the trend is opposite to that seen in other seasons.

4. Conclusions

From the results obtained in this study the following conclusions may be drawn. The thresholds of the highest and lowest extreme values of the AMIGLP are defined, in each data set, by the values of the P_{05} and P_{90} percentiles respectively. These values are very similar in all cases, ranging between -10.08 and -17.30 hPa for the lowest values and between 6.00 and 11.10 hPa for the highest ones.

The FAMIGLP series from all the observatories studied show great variability, but a clear agreement in the structure of all of them should be noted. 1963 and 1996 can be considered as the years in which the frequency of days with very low maximum pressures show the highest maxima

in the study zone. Also, 1983 is the year in which the frequency of days with the highest daily minimum pressures shows an absolute maximum at most of the observatories analyzed. The exceptions are those located at Ávila, Valladolid (Villanubla) and Los Llanos (Albacete), where the absolute maximum is seen for 1998, and those at Soria and Barajas (Madrid), where the absolute maximum is observed for 1990.

Table IV. Trends of the seasonal AMIGLP frequencies below or above the P_{05} and P_{95} thresholds in the study zone (I = increasing; D = decreasing; NT = No trend trend values in days per decade).

Zone	Percentiles	Variables	Winter	Spring	Summer	Autumn
Northern zone of Central Plateau	FAMIGLP <P05	r_s	-0.367*	-0.199	-0.250	-0.066
		α_s	0.057	0.201	0.106	0.676
		Trend	D (2.3)	NT	NT	NT
	FAMIGLP >P95	r_s	0.408***	0.183	-0.110	0.044
		α_s	0.007	0.241	0.481	0.780
		Trend	I (2.9)	NT	NT	NT
Southern zone of Central Plateau	FAMIGLP <P05	r_s	-0.431***	-0.208*	-0.174	-0.158
		α_s	0.004	0.061	0.266	0.281
		Trend	D (2.9)	D (0.9)	NT	NT
Spanish Central Plateau	FAMIGLP <P05	r_s	-0.388**	-0.240	-0.174	-0.012
		α_s	0.011	0.122	0.266	0.940
		Trend	D (2.4)	NT	NT	NT
	FAMIGLP >P95	r_s	0.517***	0.129	-0.258*	0.088
		α_s	<10-3	0.409	0.095	0.576
		Trend	I (3.3)	NT	D (0.04)	NT

*Level of confidence $\geq 90\%$ and $\leq 95\%$ ($\alpha \leq 0.10$ and ≥ 0.05). **Level of confidence $\geq 95\%$ and $\leq 99\%$ ($\alpha \leq 0.05$ and $\alpha \geq 0.01$). ***Level of confidence $\geq 99\%$ ($\alpha \leq 0.01$).

From the results of the trend analysis of the annual frequency of the highest extreme AMIGLP values obtained at each of the observatories studied, and throughout the study zone and in each of its parts, it may be inferred that between 1961 and 2002 the number of cases per year with pressures much higher than normal seems to have increased, while in the case of the lowest extreme values the trend has been towards a decrease.

The comparative seasonal study suggests that in the SCP and in each of its two parts (NS and SS) between 1961 and 2003 the trends of the annual frequencies of extreme values of daily mean minimum pressure at ground level have been determined by the behavior in winter. As regards the other seasons, spring (with the exception of the Northern Subplateau, where an appreciable trend is seen), summer and autumn have no effect.

From the analysis of the total number of cases of extreme events that occurred monthly in the study zone during the 1961-2003 period, it may be seen that the months in which there was a greater probability of such events occurring are December, January and February (i. e., the winter), which are those with the greatest incidence of Atlantic perturbations over the study zone.

The behavior of the frequency of extreme MIGLP events during the summer months can be explained by taking into account that during that period, the SCP is under the influence of a thermal low. This thermal low is a determinant factor in the change of sign of the trend of the highest FAMIGLP values.

The results obtained here are in complete agreement with those obtained for the case of the extreme values of daily maximum pressure (Labajo *et al.*, 2008). This means that the increasing trend in mean annual pressure, previously established for Castilla and León (Pinto *et al.*, 2001), would mainly be due to the increase in the annual frequency of the highest extreme MIGLP cases and the decrease in that of the lowest extreme cases. They also suggest that between 1961 and 2003 there has been a variation in the frequency and/or in the intensity of perturbations that affect the SCP along the year, anticyclonic episodes and decreasing cyclonic ones increasing.

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