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Article

Recovering climatic data from documentary sources: a case study of the climate in southern Spain from 1792 to 1808

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Abstract: New data on the climate in southern Spain from 1792 to 1808 are analyzed in this work. The data source is the newspaper *Correo Mercantil de España y sus Indias*, where summaries of the weather conditions in Spain were published at weekly resolution. The study is focused on southern provinces, providing 2788 new records, some of them corresponding to areas without data previously recorded. The analysis indicates the predominance of cold-dry winters, cold-wet springs, warm-dry summers, and variable conditions in autumn, from west (cold-wet) to east (warm-dry). Some examples of these situations are presented.

Keywords: Historical climatology, Spain, Dalton Minimum, temperature, rainfall

1. Introduction.

The period 1790-1830 is known as Dalton Minimum of solar activity [1]. During this period there was an intense volcanic activity, with eruptions of Lakagígar (Island) in June 1793, Etna (Italy) in July 1787, St. Helens (USA) in January 1800, and Tambora (Indonesian) in April 1815 [2]. Therefore, it is a historical moment in which natural radiative forcings might have affected the global climate in an important way [3].

The Mediterranean Basin, and, in particular, the Iberian Peninsula (IP) has been recognized as a hot spot area for climate change [4]. The climate of the IP, due to its geographical and latitudinal situation in the western end of the Mediterranean Basin, is governed by flows from the Atlantic Ocean and the Mediterranean Sea, modulated by a varied topography, with abrupt altitude gradients in a relatively small area [5]. In consequence, the study of IP climate during a natural climate change period, such as the Dalton Minimum, could be particularly interesting.

The objective of the historical climatology is the reconstruction of long and continuous series of climatic data, overlapping with instrumental series, to obtain an appropriate calibration and validation [6]. However, the value and utility of short series is recognized today [7]: they allow to generate useful reconstructions of concrete years (for instance, the "year without summer" 1816), contribute to a better understanding of extreme events, and processes such as the transition between different climatic episodes, the impact of volcanic eruptions, the intra-annual and interannual variability, as well as the connection of climatic events with impacts and social responses.

The main data sources of this period are early meteorological data (EMD), taken by individual efforts and following the initiatives of scientific societies, interested on the relationships between climatic conditions, sailing, medicine, and agriculture [8]. However, EMD is a heterogenuous, fragmentary, and dispersed data set, without metadata in many cases, and only a few cities in the IP (Cádiz, Madrid, Barcelona) have long and continuous meteorological series [9]. Therefore, it is still necessary to find new data sources reporting climatic conditions during the historical period.

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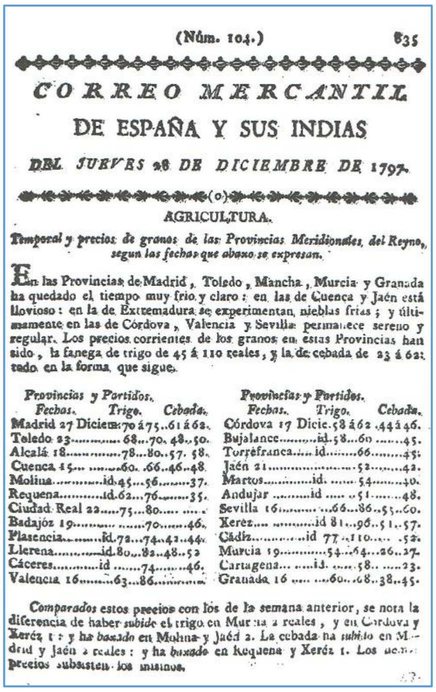
Recently, a new data source on the IP climate during the period 1792-1808 has been described [10]. It is the newspaper *Correo Mercantil de España y sus Indias* (Mercantile Mail of Spain and its Colonies, henceforth denoted as CMEI, Figure 1). The editors established a network of correspondents to obtain information from most of Spanish provinces. The newspaper was published twice a week, and included news, articles on local commerce, statistical data, economy, sea ports, gobernmental regulations, change, etc. The newspaper began to publish on 1st October 1792, until 30th June 1808, when the Napoleonic invasion interrupted its production. Copies of this newspaper have been digitized and are available online at the National Library of Spain website [11] except two gaps, from July to November 1798, and from July 1804 to July 1806 (unfortunately, we have not found the missing copies).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CORREO MERCANTIL

DE ESPAÑA Y SUS INDIAS

DEL JUEVES 28 DE DICIEMBRE DE 1797.

AGRICULTURA.

Temporal y precios de granos de las Provincias Meridionales, del Reyno, segun las fechas que abaxo se expresan.

En las Provincias de Madrid, Toledo, Mancha, Murcia y Granada ha quedado el tiempo muy frio y claro: en las de Cuenca y Jaén está llovioso: en la de Extremadura se experimentan nieblas frias; y últimamente en las de Córdova, Valencia y Sevilla permanece sereno y regular. Los precios corrientes de los granos en estas Provincias han sido, la fanega de trigo de 45 á 110 reales, y la de cebada de 23 á 62: todo en la forma que sigue.

Provincias y Partidos. Fechas.	*Trigo.*	*Cebada.*
Madrid 27 Diciem.	70 á 75	61 á 62.
Toledo 23	68...70.	48...50.
Alcalá 18	78...80.	57. 58.
Cuenca 15	60. .66.	46..48.
Molina id.	45...56	37.
Requena id.	62...76	35.
Ciudad Real 22	75...80	.....
Badajóz 19	70	46.
Plasencia id.	72...74.	42..44.
Llerena id.	80...82	48..52
Cáceres id	74	46.
Valencia 16	63...86	.....

Provincias y Partidos. Fechas.	*Trigo.*	*Cebada.*
Córdova 17 Dicie.	58 á 62	44 á 46.
Bujalance id.	58...60	45.
Torreéfranca id.	66	45.
Jaén 21	52	42.
Martos id.	54	40.
Andujar id	51	48.
Sevilla 16	66...86	55..60.
Xeréz id	81...96	51..57.
Cádiz id	77...110	52.
Murcia 19	54...64	26..27.
Cartagena id.	58	23.
Granada 16	60...68	38..45.

Comparados estos precios con los de la semana anterior, se nota la diferencia de haber *subido* el trigo en Murcia 2 reales, y en Córdova y Xeréz 1: y ha *baxado* en Molina y Jaén 2. La cebada ha *subido* en Madrid y Jaén 2 reales: y ha *baxado* en Requena y Xeréz 1. Los demas precios subsisten los mismos.

Figure 1. Front page of the issue 104 (28/12/1797) of CMEI.

All the editions began with a report on agriculture, with qualitative descriptions of weather conditions and grain prices in each province. The interest of this data source is that yields information at weekly timescale on meterorological events in Spain during the central years of the Minimum Dalton, with reports on areas without information to date, and with large spatial coverage. In a first approach, this work is focused on southern provinces (Seville, Córdoba, Jaén, Granada, and Murcia, Figure 2, [12]), to complete a previous work dedicated to EMD in this area [13]. However, information of other areas in the IP will be used during the study.

Among the different tools used in historical climatology to reconstruct the past IP climate we can highlight the use of rogations [14-16], which defines rainfall indices from information on pro-pluvia and pro-serenitate rogations recorded in eclessiastical archives, and the content analysis method [17], which analyses the descriptions of meteorological events found in historical documents of varied origin. The objective is to establish an index series that may be contrasted with modern instrumental series. A different method, based on the inference of distribution

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Figure 2. Spanish provinces in 1789 according to the Atlas Nacional de España [12]

functions of past climate variables from the frequency of extreme events, and their comparison with modern distribution functions, has been used to reconstruct the conditions of the climate in Granada during the first third of the 18th century [18]. Recently, it has been described a new method, called COST (Cost Opportunity for Small Towns), based on the analysis of the amount of paper used in the original documents to describe hydroclimatic events [19]. The underlying hypothesis is that the greater the amount of paper used to describe a climate event, the greater the intensity and duration of such an event. In our case, due to the nature of the data source (an edited neswspaper), the weekly resolution, and the general character of reports, with information not only on extreme events, but also on 'normal' conditions, it seems more appropriate the analysis of the different terms used to describe the meteorological events.

The scheme of the paper is as follows: the section 2 shows a description of the meteorological information obtained and the study methods used; in section 3 the main results obtained are shown; these results are discussed in the section 4, and, finally, in the section 5, some conclusions and research challenges are outlined.

2. Data and methods.

In this section terms used by the data source to describe the meteorological events are briefly described (a more detailed description may be found in [10]). All the issues of the newspaper began with a report on agriculture, qualitatively describing general weather conditions and indicating the grain prices. The information wass classified by province, taking into account the territorial division of Spain during those years. Reports are a brief summary where the editors transmit the information correspondent to different locations within each province. Therefore, we can consider that the information is a spatial "average", although sometimes differences are specified between several localities within the same province.

The weekly resolution ensures that the records not only inform on extreme events, but also on the 'normal' conditions for the period of study. It is frequent the appearance of comments such as "weather typical of the season", or "appropriate for the season". In these cases we can admit,

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at least, the absence of relevant extreme events. The meteorological information was directly related to the crop production, in particular wheat, from the autumn planting to harvesting at the beginning of the summer, although the correspondents were interested also on other plants (olive, fruits, pastures). Different crops have different climatic requirements, and for any given crop, depend on the phenological phase of plant growth. So, comments such as "weather appropriate fot plants", or "favourable for plants", were not used in the study, due to the difficult to establish precisely what the predominant meteorological conditions were in these cases.

Fortunately, many comments are direct descriptions of meteorological events, focusing mainly on the thermopluviometric regime, although other phenomena, such as fogs, winds, storms, and cloudiness are also recorded. Table 1 shows a summary of main descriptors used. Each record related to the temperature was indexed with the values i_t=+2 (very warm), +1 (warm), 0 (mild), -1 (cold), and -2 (very cold). In the case of rainfall, it was possible to obtain a ranking from absence of rain (i_r =0), slight and/or dispersed rainfalls (+1), moderate rainfall (+2), and intense rainfalls (+3). Some descriptores are vague, such as the references to "wet", "unsettled", "varied", or "regular" weather. In these cases, only by comparing with other contemporaneous and independent data sources can the true meaning of these concepts be clarified. These terms were not indexed to avoid circularity problems in the comparison with EMD data.

Sometimes information is not provided for all the provinces, probably due to the lack of responses from local correspondents, problems with the mail or tansportation, lost information or editorial errors. In addition, the information is not simultaneous between different provinces, with some days of lag from one province to another. This circumstance compels to study each province individually. In a first approach, it was decided to study the records corresponding to southern provinces (Seville, Córdoba, Jaén, Granada, and Murcia), because there are EMD series for the same area and similar time period [13]. So, it is possible to compare reports from independent data sources, and add areas (Córdoba, Jaén) without data on this period, to the best of our knowledge. Records were extracted from the data source, tabulated and indexed. As a first result, the data base on early meteorological observations in South Spain [20] was enlarged. The total number of new records was 2788, distributed in the following way: Seville 518, Córdoba 548, Jaén 599, Granada 598, and Murcia 565.

A monthly temperature (rainfall) index I_t (I_r) was defined as the average for the i_t and i_r indices assigned to each invidual record. Monthly indices were calculated only when the number of weekly records was ≥3, and considering that some weeks belog to two consecutive months [21]. In the time series obtained, the 13 months moving average was calculated to filter intra-annual seasonal variations, and to obtain an initial overview of the time evolution of each variable.

The climate in Spain experiences clear seasonality, with marked differences between winter (December to February), and summer (June to August), while spring (March to May), and autumn (September to November) are transitional seasons. Therefore, the study was carried out separately for each season of the year (in the following, winters are identified by the year corresponding to January and February). For each year, the optimal number of seasonal records was set at ≥9, considering that 3 or more weekly records/month were sufficient. Figure 3 shows the methodology used to study the meteorological information, using the spring data for Córdoba as an example. In this case, considering our criterion for the optimal number of seasonal records, the years 1795, 1802, 1803, 1805, and 1806, were removed from the analysis (Fig. 3a). The next step

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Table 1. Terms used in CMEI to describe weather conditions and indices assigned (it = temperature index, ir = rainfall index; ambiguous terms (category "other") were not indexed).

Category	i_t	i_r	Descriptors (Spanish)	Descriptors (English)
Very warm	+2		Calores vehementes/fuertes/excesivos Muy/excesivamente/bastante caluroso Soles muy picantes/Ardiente	Vehement/excessive/strong heats Very/excessively/quite warm Very spicy suns/Burning
Warm	+1		Caluroso/algo caluroso	Warm/some warm
Mild	0		Templado/suave/bueno/fresco	Mild/soft/good/cool
Cold	1		Hielos/escarchas/nieve Vientos fríos	Ices/frosts/snowfalls Cold winds
Very cold	2		Muy/excesivo/extraordinario/ bastante frío	Very/excessive/extraordinary/ quite cold
Clear		0	Sereno/serenidad/seco/árido/ sequedad Soles/claro/despejado Se necesita el agua	Quiet/serenity/dry/arid/ dryness Suns/clear/cloudless Water is necessary
Cloudy (without rainfalls)		0	Nubes/nuboso/cubierto Aparatos de lluvia/nieve	Clouds/cloudy/overcast Apparatus of rain/snow
Slight rain		1	Ha llovido algo/a veces/en algunas partes Ha llovido un poco Ligeras lluvias/chubascos	It has rained something/sometimes/somewhere It has rained a bit Slight rainfalls/squalls
Moderate rain		2	Lluvias/lluvioso Ha llovido moderadamente/suficiente	Rainfalls/rainy It has rained moderately/quite
Heavy Rain		3	Ha llovido copiosamente/abundantemente/ excesivamente Aguas excesivas/continuas/ constantes	It has rained copiously/abundantly/excessively excessive/continuous/constant waters
Fog			Nieblas	Fogs
Wind (direction)			Vientos (solanos/levantes; nortes; sur; ponientes)	Winds (east; north; south; west)
Other			Revuelto/vario/húmedo/ regular/favorable	unsettled/variable/humid regular/favourable

was to count the percentage of records related to cold or warm weather (i_t<0, i_t>0, respectively, Fig. 3b), and the absence or presence of rain (i_r=0, and i_r>0, respectively, Fig. 3c). Our hypothesis here is that the general character of a given season (warm/cold and/or dry/wet) is indicated by the highest percentage. Note that this classification indicates the average weather conditions for each season and province, not the extremes possible for a particular season.

It is interesting to study the combined effect of thermal and rainfall regimes [22-23]. Therefore, differences between percentages corresponding to wet and dry (warm and cold) weather were calculated for each year, and represented as it is shown in Figure 3d. In this figure each point represents the combined character of a particular season. If the point is located in the

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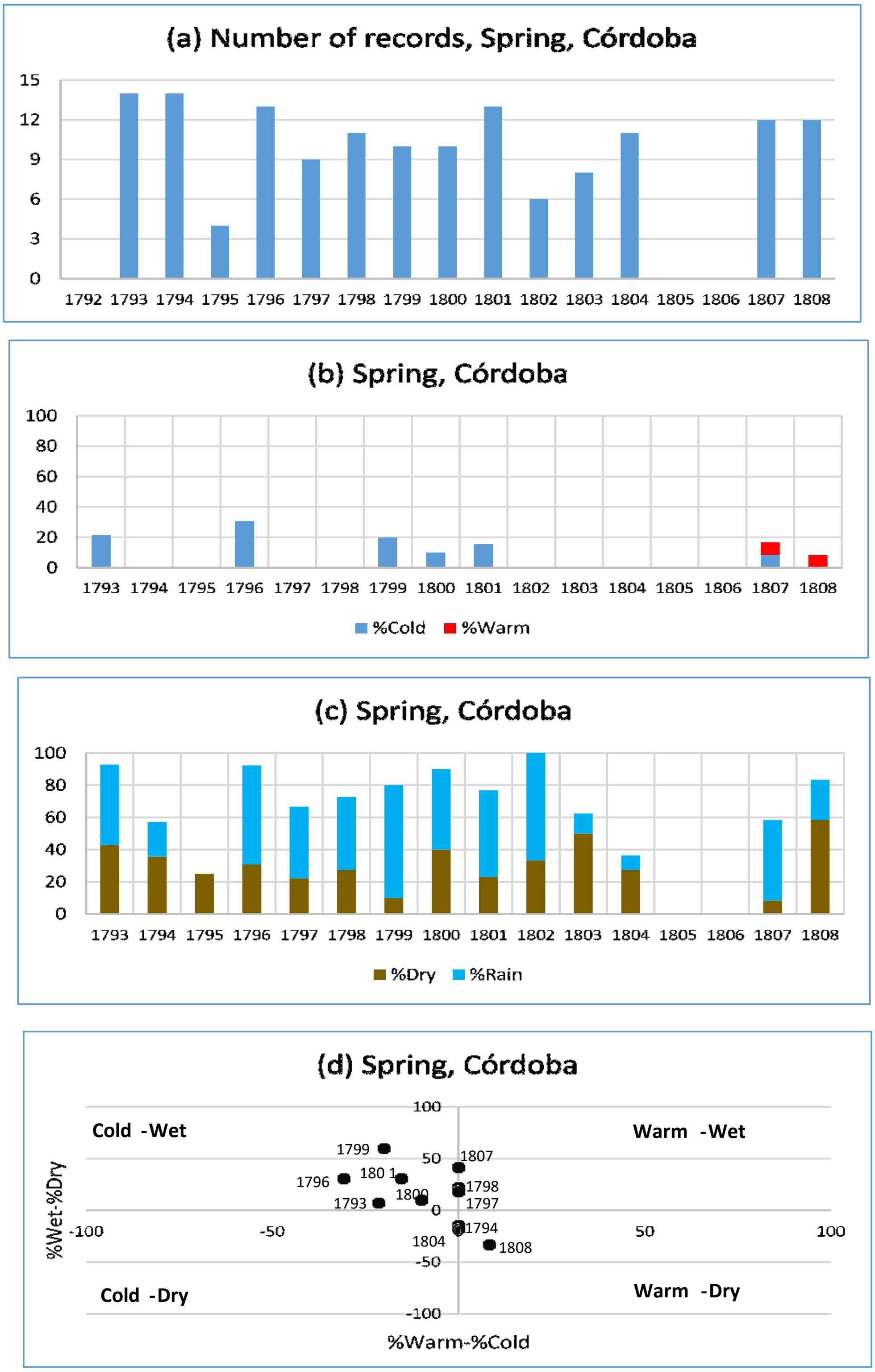

Figure 3. (a) Number of spring records in Córdoba from 1792 to 1808. (b) Percentage of records indicating cold (blue) and warm (red) conditions. (c) Percentage of records indicating dry and wet conditions. (d) Characterization of the combined temperature and rainfall conditions in Córdoba from 1792 to 1808. Years are indicated.

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first quadrant, it corresponds to the predominance of warm-wet conditions, cold-wet conditions in the second quadrant, cold-dry conditions in the third quadrant, and warm-dry conditions in the last quadrant. If the point is located on the horizontal (vertical) axis, these percentages are equal, and rainfall (temperature) conditions may be considered as average level (mild). In our example, springs of 1793, 1796, 1799, 1800, and 1801 may be considered cold-wet, meanwhile spring of 1808 was warm-dry, springs of 1797, 1798, and 1807 mild-wet, and springs of 1794 and 1804 mild-dry. Therefore, during the period of study, cold-wet springs predominated in Córdoba. This analysis was made for each season of the year and for the five provinces analyzed (Supplementary Material).

A feature of this data source is that it allows one to perceive the spatial coverage of different events, enlarging the information beyond individual provinces. This is specially interesting in the case of extreme events, and it allows to use those records non-considered to obtain the indices. Records may map to describe the general conditions in the whole country for a given week. This analysis allows to infer the underlying atmospheric dynamics. In the study, due to lags between provinces, records were grouped with lags up to ±1 day around the chosen central day. In the following section, some examples are shown.

3. Climatic conditions in southern Spain from 1792 to 1808.

3.1. Monthly indices.

Figure 4 shows the time series of the monthly indices I_t and I_r in the five provinces studied. The 13 months mean average allows to overview the indices time evolution filtering the intra-annual seasonal variations. Although the existence of gaps, particularly around 1805, prevents the establishment of conclusive results, it is evident the increase of the index I_t from 1799 onwards. The indices mean value during the complete period 1792-1808 (along with their standard errors) are -0.08±0.08 in Seville, -0.10±0.07 in Córdoba, +0.03±0.07 in Jaén, -0.05±0.08 in Granada, and +0.15±0.10 in Murcia, suggesting the existence of a temperature gradient from west (coldest conditions) to east (warmest conditions). The index I_r shows a maximum around 1799-1800, and a clear decrease in the eastern provinces, in Granada since 1799, and in Murcia since the beginning of the series. I_r mean values are +1.12±0.08 in Seville, +0.98±0.07 in Córdoba, +0.91±0.07 in Jaén, +0.86±0.06 in Granada, and +0.72±0.06 in Murcia. This result suggests a decrease of rainfall along a west-east axis, from provinces more affected by atlantic flows (Seville, Córdoba) to the eastern end (Murcia), where mediterranean mechanisms are more important.

3.2. Combined modes of variability.

Figure 5 shows the distribution of years classified as warm-wet, warm-dry, cold-wet, and cold-dry for each season and province. There was a marked seasonality (common to the five provinces), with cold winters, warm summers, and spring and autumn as transitions seasons. It is evident the predominance of cold-dry winters (for instance 1793, 1796, 1798, 1801, and 1808), warm-dry summers (1796, 1803, 1807), and cold-wet springs (1796, 1799). Main differences appear in autumn, indicating in this season a transition from west (wet conditions in Seville and Córdoba) to east (warm-dry conditions in Murcia), with Jaén and Granada as transition provinces. So, autumn 1794 was cold-wet in Seville, and cold-dry in the eastern provinces, and autumn 1801 was cold-wet in Córdoba, and warm-dry in Murcia.

3.3.Examples.

There was a predominance of cold-dry winters in the area during the period 1792-1808. Figure 6a shows an example of this situation. Records dated between 18 and 20 January 1799 were used to make this map (Table S1 of Supplementary Material indicates comments from each province). Due to the weekly resolution of records, these conditions correspond to the period

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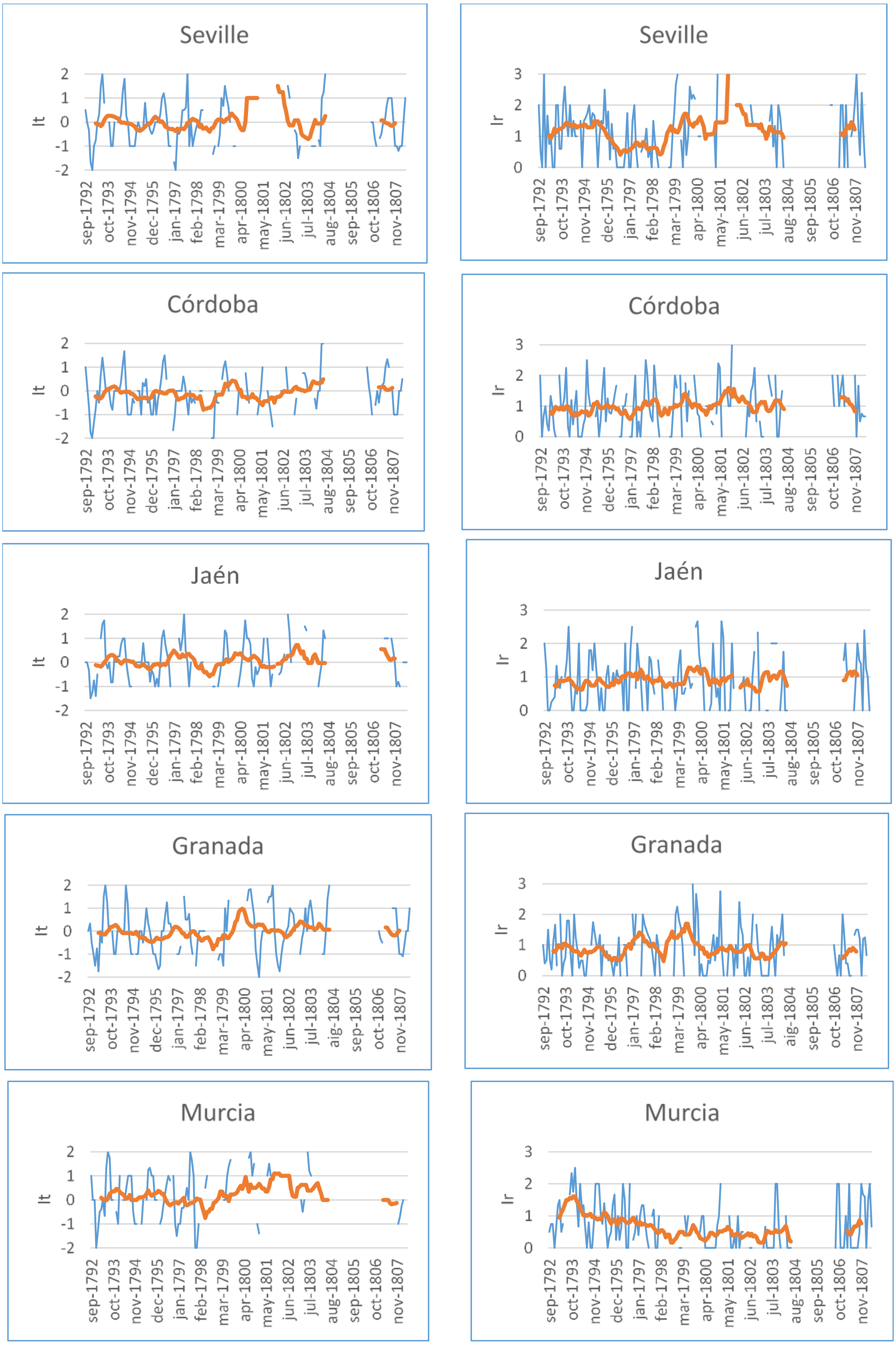

Figure 4. Thin line: time series of the monthly indices I_t (left), and I_r (right) for the five provinces studied. Thick line: 13- months moving average.

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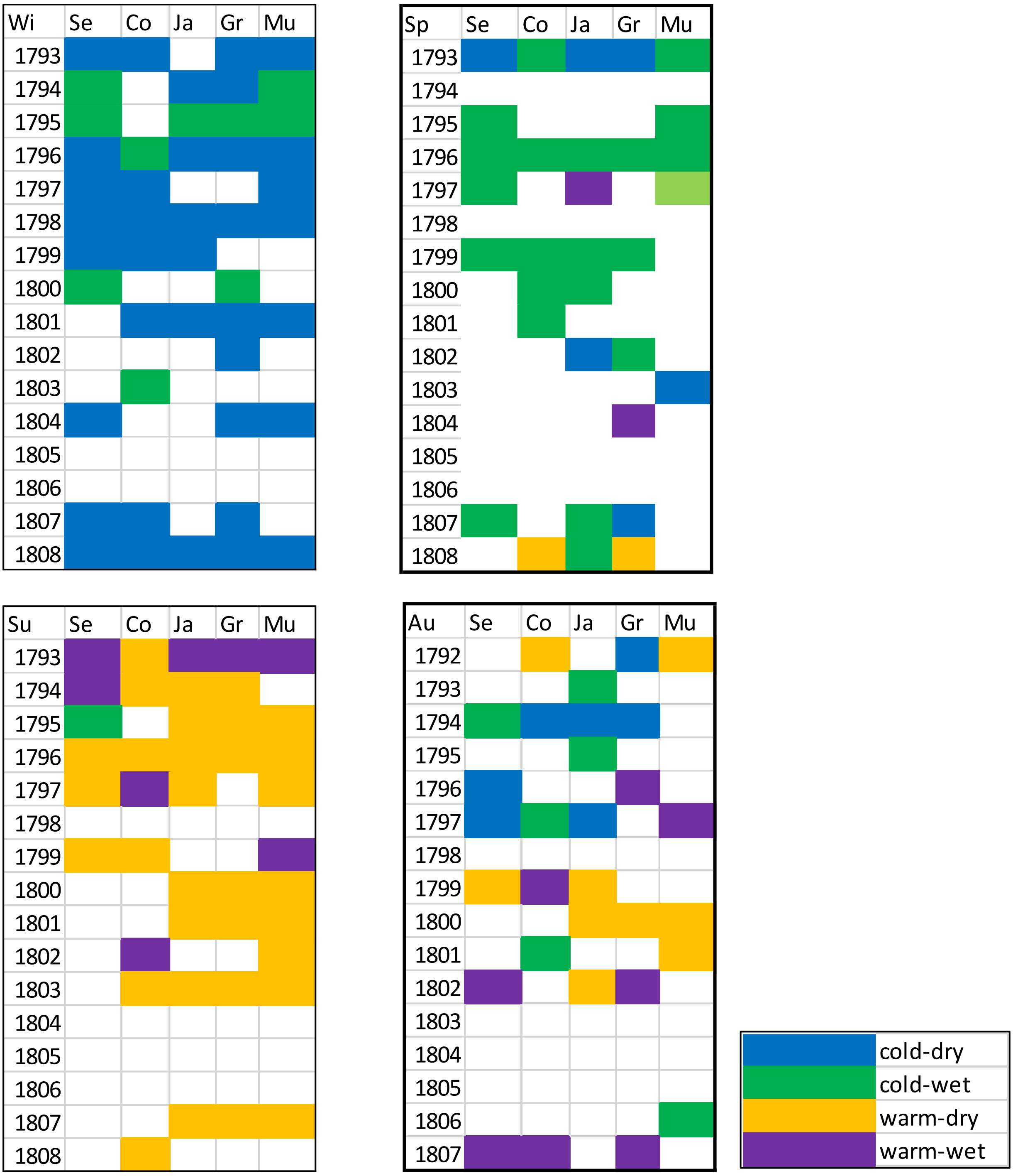

Figure 5. Combined temperature-rainfall character of the four seasons of the year (Wi=winter, Sp=spring, Su=summer, Au=autumn) and the five provinces studied (Se=Seville, Co=Córdoba, Ja=Jaén, Gr=Granada, Mu=Murcia).

between 11 and 19 January 1799. It can be seen that references to cold and sunny weather are recorded in all the provinces with information, including the reference to the appearance of fogs in the central area of the country. These conditions are often related to the predominance of anticyclonic conditions in winter [24]. This situation is reflected in Figure 6b, which shows the mean value of the sea level pressure (SLP) field corresponding to January 1799, according to the independent reconstruction by Luterbacher et al [25-26].

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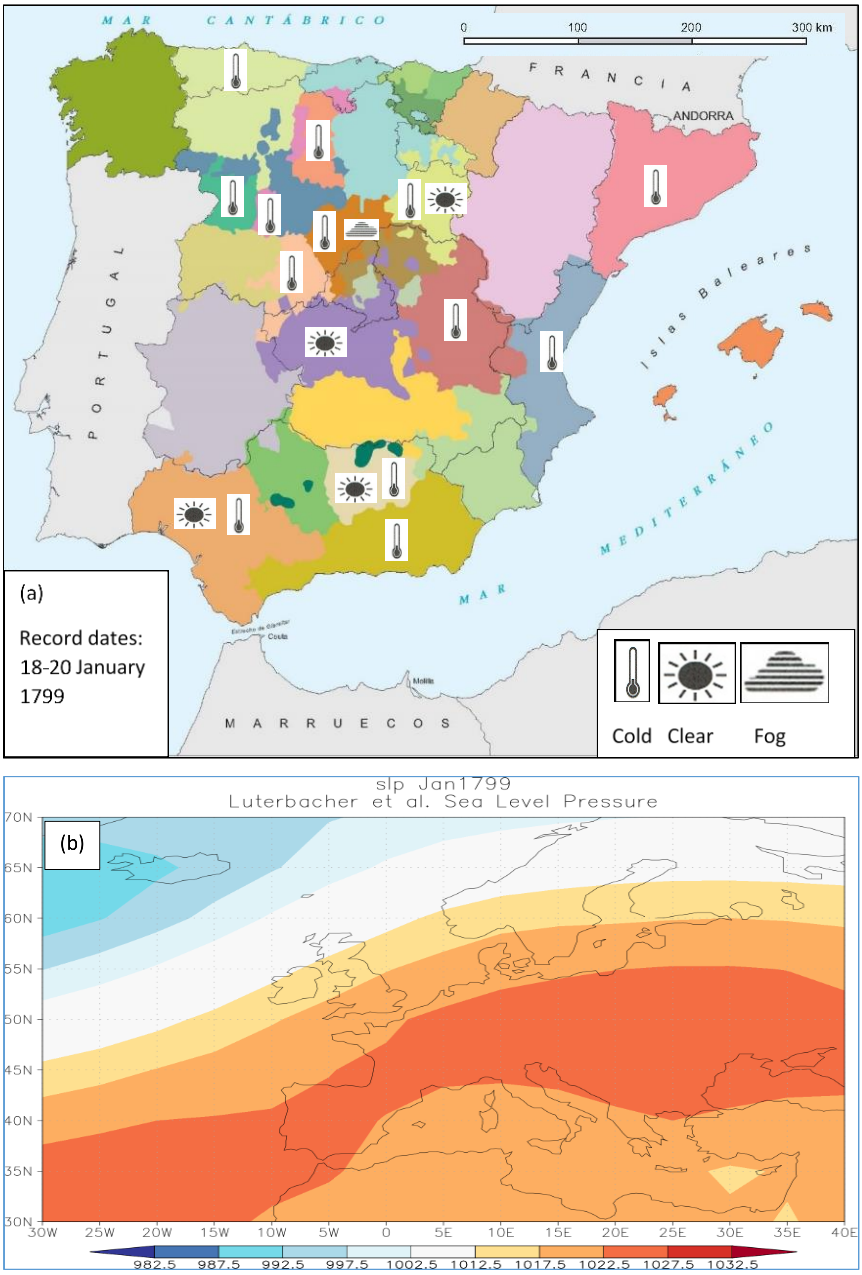

Figure 6. (a) Weather information corresponding to 11-19 January 1799 (reports dated from 18 to 20 January 1799, issues 6-11, 1799, CMEI). (b) SLP field in January 1799.

Figure 7a shows an example of cold-wet springs. In this case, records were dated between 12 and 14 April 1793, reflecting conditions corresponding to 5-13 April 1794 (Table S2, Supplementary Material). Records from Seville and Málaga indicate abundant rainfalls. Intense rainfalls and snowfalls were generalized in the IP, except in the eastern provinces Murcia and Cuenca. This map may be interpreted as prevailing cyclonic conditions, with atlantic northwest flows, a typical situation in spring [27], as it can be seen in the mean value SLP field reconstruction for April 1793 (Figure 7b).

Figure 8a shows an example of warm-dry summers. In this case, the record dates are 15-17 July 1796 (conditions of 8-16 July 1796, Table S3, Supplementary Material). It is notorious the information on east winds in the province of Burgos, and the mild character of temperatures in the mediterranean coast (Valencia province). These conditions are probably the consecuence of an anticyclone provoking east flows from the Mediterranean, which would cool the weather in

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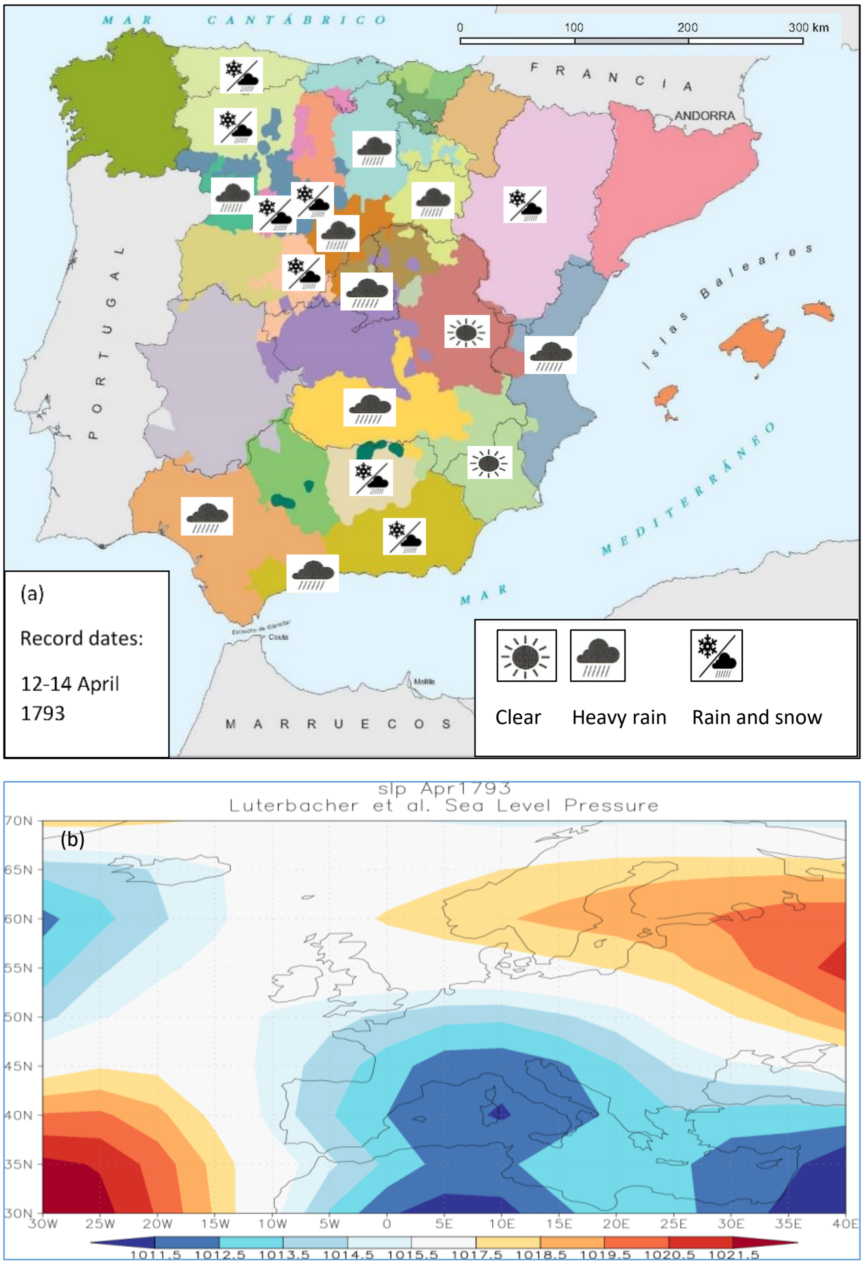

Figure 7. (a) Weather information corresponding to 5-13 April 1793 (reports dated from 12 to 14 April 1793, issuexs 8-11, 1793, CMEI). (b) SLP field in April 1793.

the mediterranean areas [28]. Figure 8b shows the reconstruction of the mean value SLP field in July 1796. Figure 9a shows an example of autumn conditions. It corresponds to records dated on 21-23 Novemeber 1794 (conditions of 14-22 November 1794, Table S4, Supplementary Material). There were rainfalls in western provinces, especially abundant to the southwest, and dry weather to the East, in Aragón and Murcia provinces, with cold weather to the north, in Galicia and Catalonia. These conditions seem reflect the advection of wet air masses from the Atlantic [27], as it can be seen in the mean value of the SLP field corresponding to November 1794 (Figure 9b), which shows the predominance of zonal circulation over the IP. These situations would explain the differences found along the west-east axis in this season of the year.

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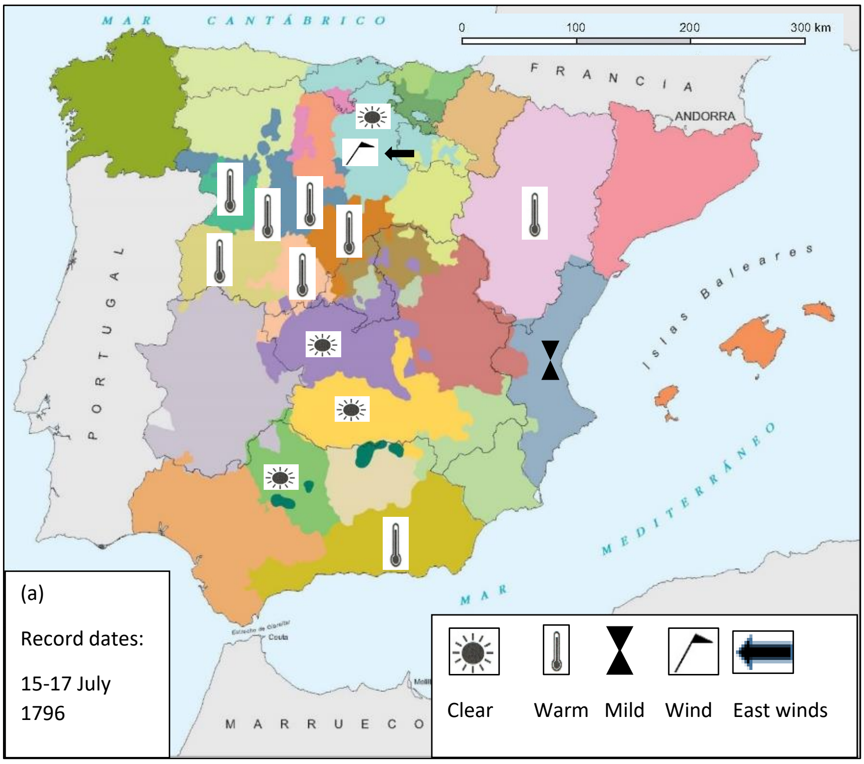

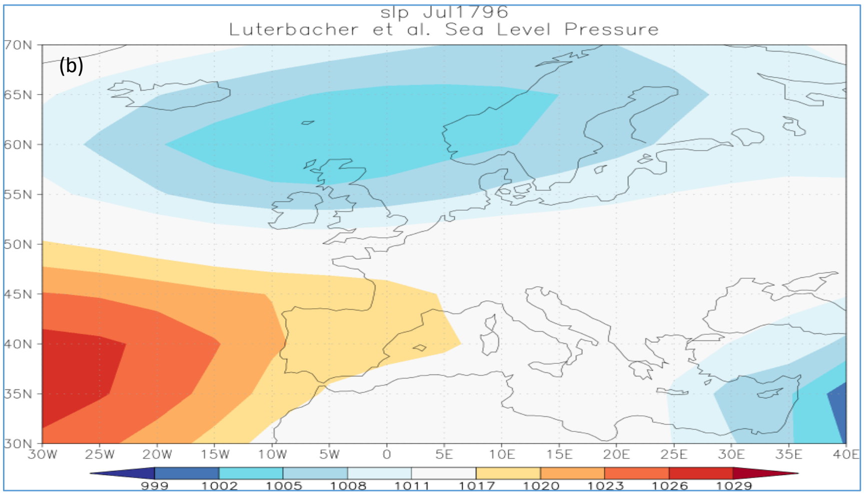

Figure 8. (a) Weather information corresponding to 8-16 July 1796 (reports dated from 15 to 17 July 1796, issues 57-60, 1796, CMEI). (b) SLP field in July 1796.

4. **Discussion.**

The best proof for the reliability of these results is to check other evidences from independent data sources to see if they show similar characteristics. A first exercise of comparison has been made in the previous section, comparing the observations from CMEI with the independent reconstructions of the SLP field. In addition, we can find in the literature some references to the IP climate during the studied period. So, for instance, Fernández-Fernández et al [21] analyse the correspondence between the majordomo of the county of Zafra (Extremadura province, near Seville and Córdoba) and the landowner from 1750 to 1840. These authors find a dry period from 1796 to 1799, and a wet period between 1799 and 1807 [29], coinciding with the evolution of our index I_r in Seville and Córdoba provinces (Fig. 4). In relation to temperature, these authors

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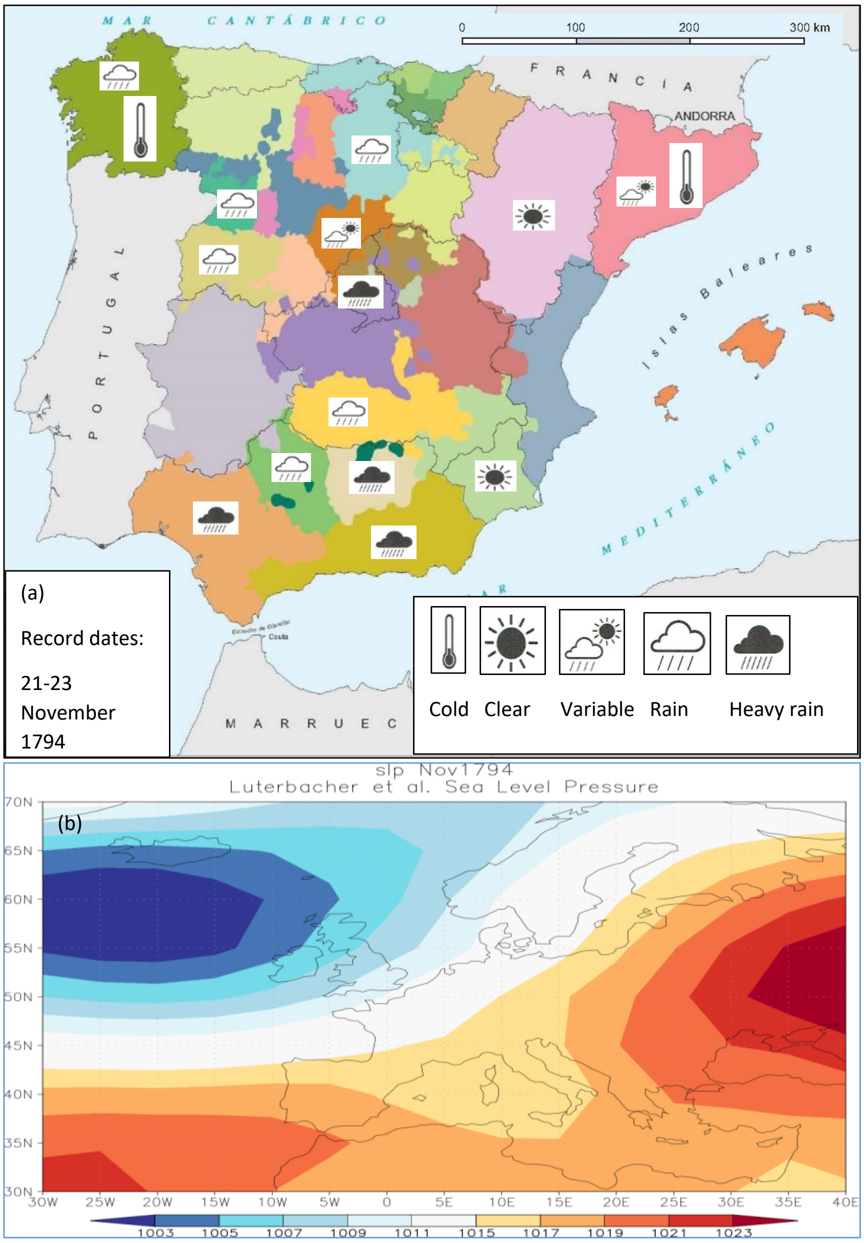

Figure 9. (a) Weather information corresponding to 14-22 November 1794 (reports dated from 21 to 23 November 1793, issues 94-99, 1794, CMEI). (b) SLP field November 1794.

highlight the seasonal dependence of thermal conditions [30], with high percentages of cold weeks in winter 1807, spring 1799 and 1807, and warm weeks in winter 1794, autumn 1797, and summer 1800, coinciding with our results in Seville and Córdoba (Figure 5, Figures S1, and S2, Supplementary Material). In relation to dry conditions in Murcia, Alberola Romá [31] underscores the performs of many pro-pluvia rogations in this province between 1800 and 1807.

On the other hand, there are other data sources that were explored in a previous work, and collated in the EMOSSv2 data base [20]. This is a set of qualitative descriptions and EMD series from Cádiz, Seville, Málaga, Granada, and Murcia. The comparison is difficult because the length of common periods is short, the time resolution is different (weekly in CMEI, daily/monthly in EMOSSv2), as well as the spatial resolution (areal average in CMEI, local in EMOSSv2). However, a comparison exercise was attempted, comparing the monthly index I_t with the monthly mean value of temperature in EMOSSv2. Figure 10 shows results of this comparison in three cases: Granada from June 1796 to September 1797 (Fig. 10a, Gr1796-1797 in EMOSSv2), Cádiz from

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January 1799 to December 1800 (Fig. 10b, Ca1799-1800 in EMOSSv2), and Seville from October 1803 to December 1806 (Fig. 10c, Se1803-1806 in EMOSSv2, Cádiz and Seville belonged to the same province in the studied period). In all the cases the temperature was measured at noon. The monthly average of midday temperature may be considered as a good proxy of the monthly mean value of daily maximum temperature [32]. If we accept the calibration shown in the Figure 10, the application of the regression equation to the mean value of the index I_t allows to estimate the mean value of the maximum temperatures according to CMEI data. Results are 20±2 °C in Granada, 18±1°C in Cádiz, and 21±1°C in Seville. We can compare these values with mean values corresponding to the reference modern period 1961-1990 [33]: 22.5±0.1°C in Granada, 21.3±0.1°C in Cádiz, and 24.7±0.1°C in Seville. These results indicate that the studied period, inside the Dalton Minimum of solar activity, was around 2-3°C colder than the modern period.

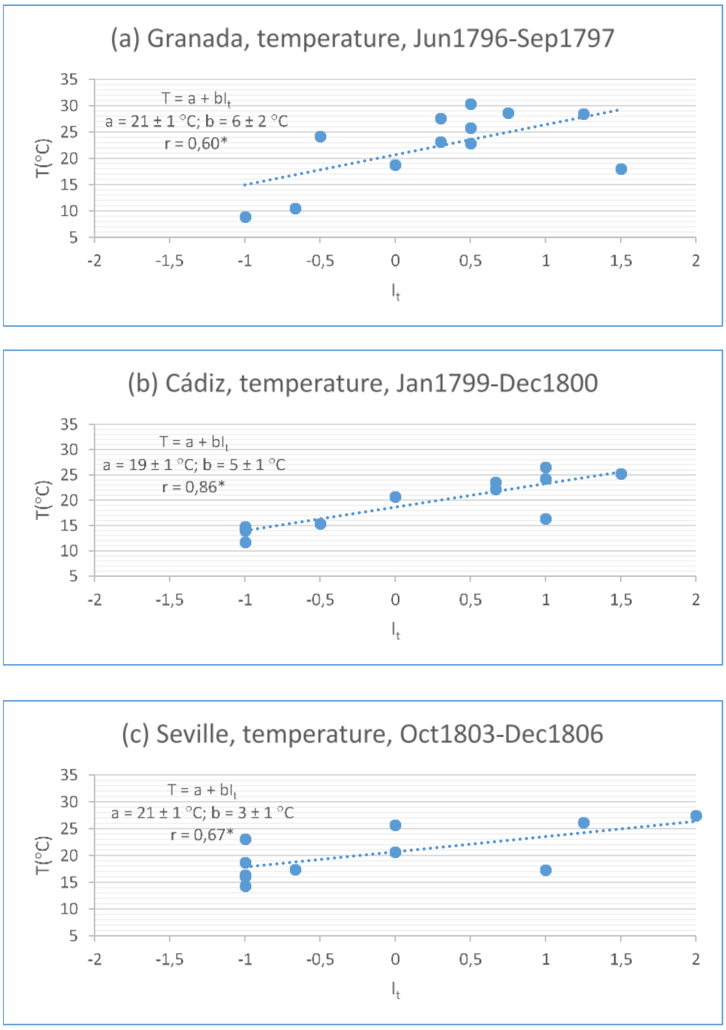

Figure 10. Comparison beteen monthly indices I_t from CMEI and monthly mean temperature at midday from EMD (EMOSSv2) in (a) Granada, June 1796 to September 1797, (b) Cádiz, January 1799 to December 1800, and (c) Seville, October 1803 to December 1806. Linear regression equations and correlation coefficients are included (* = significant at the 95% confidence level).

There is scarce quantitative information on rainfall amount in EMOSSv2. In EMD series, the variable related to precipitation is the number of rainy days (RD). RD has a strong correlation with the amount of cummulated rainfall, but the comparison with the index I_r is difficult because this index is an average, and therefore it is related to the rainfall intensity more than to the rainfall

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amount. In the case of rainfalls, an added problem is that CMEI data are spatial averages, meanwhile EMOSSv2 data are local. We can expect a similar thermal behaviour in nearby cities, but the rain is a discrete and discontinous variable, with high spatial variability, especially in the case of convective rainfalls. Therefore the study of rain is particularly problematic and needs major research, outside of the scope of this work. However, a first approach was made in [10], obtaining that the correlation coefficient between I_r from CMEI and RD from Ca1799-1800 (EMOSSv2) is 0.64, statistically significant at the 95% confidence level.

These results must be interpreted cautiously. The period 1792-1808 is short, and there are gaps due to lost issues or insufficient number of records. Anyway, a certain overview on the climate in southern Spain during this period can be obtained. Results suggest the existence of temperature and rainfall gradients along a west-east axis. In a previous work [34], these differences were explained as a result of the decreasing (increasing) influence of atlantic (mediterranean) disturbances from west to east.

The relationship between winter rainfall in the IP and the North Atlantic Oscillation (NAO) is well-known [35]: the positive phase of the NAO is related to an intensification of high pressure in the western IP, producing dry conditions and droughts over the area [36], meanwhile the negative phase of the NAO shifts atlantic cyclones southward, invading the IP and generating intense rainfalls, which sometimes may provoke river floods [37]. Although our period of study is short, it is possible to compare our results with the independent reconstruction of the NAO by Luterbacher et al [38-39]: dry winters 1793, 1796, 1798, and 1801 correspond to positive values of the NAO index (+0.60, +0.83, +0.51, and +0.12, respectively), and wet winters 1794, 1795, and 1800 correspond with negative values of the NAO index (-0.23, -0.84, and -1.27, respectively), reflecting this negative relationship in our data.

Results suggest a positive (negative) correlation between temperature and rainfall in winter (spring, summer, and autumn). Therefore, the pattern would be the predominance of cold-dry or warm-wet winters, meanwhile the other seasons of the year would be charactized by cold-wet (or, alternatively, warm-dry) conditions. This pattern was found in a previous study on the covariability between seasonal temperature and rainfall in the IP during the instrumental period 1951-2016 [40], as well as in an analysis of the climate variability in Europe since 1766 [41]. Results suggest the predominance of cold-dry winters, cold-wet springs, and warm-dry summers. In autumn, the pattern is less clear, in agreement with Casty et al [41], who find that the temperature-rainfall relationship is weaker in autumn than in spring in the Mediterranean Basin.

The period 1792-1808 coincides with the central years of the Dalton Minimum of solar activity. In addition, it has been recorded a frequent volcanic activity during this period [42]. The reduced shortwave radiation would explain the cooling detected in winter and spring. On the other hand, a possible consequence would be the predominance of the positive NAO phase in winter, with anomalous dry conditions over the IP [43], and the negative phase of the East Atlantic pattern (EA) in spring, yielding an increase of rainfall over the Mediterranean Basin [44]. The interplay between these patterns of climate variability could explain the variability of the climate observed in the IP [45], although it is necessary more research before obtaining definitive conclusions.

5. Conclusions.

The main objective of this work is to present a new data source with climatic information on Spain during the period 1792-1808. This brief period is interesting because it is included inside the Dalton Minimum period of solar activity. Therefore, these data may help to understand the climate fluctuations in the IP during historical periods dominated by natural radiative forcings. The analysis has focused on southern IP, showing the potential utility of this data source. In

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particular, it allows to obtain an overview on the spatial distribution of the meteorological events at weekly time scale. In addition, this data source yields information on areas without instrumental data recorded (Jaén, Córdoba).

In general terms, results are in good agreement with previous results on climatic conditions in southern IP, cold conditions, and variable rainfall regime, dry in winter, wet in spring. However, there are a lot of work to do: to enlarge the study to the rest of Spanish provinces, to prepare a catalogue of extreme events, considering their intensity and spatial coverage; and to calibrate and validate monthly indices. All these challenges will be the object of future research.

Supplementary Materials: The following are available online at www.mdpi.com/xxx/s1, Figures S1 to S5, Tables S1 to S4.

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