Cuadernos de Investigación Geográfica *Geographical Research Letters*	2021	Nº 47	pp. 143-162	EISSN 1697-9540

Copyright © 2021, The authors. This work is licensed under a Creative Commons Attribution 4.0 International License.

http://doi.org/10.18172/cig.4696

SYNOPTIC CAUSES OF TORRENTIAL RAINFALL IN SOUTH-EASTERN SPAIN (1941–2017)

JAVIER MARTÍN-VIDE*, MARÍA C. MORENO-GARCÍA, JOAN A. LÓPEZ-BUSTINS

Department of Geography, Universidad de Barcelona, 08001 Barcelona (Spain).

ABSTRACT. The weather types of 68 dates with torrential rainfall (≥200 mm/day) recorded at any weather station in the provinces of Alicante or Murcia during the period between 1941 and 2017 were determined using the Martín-Vide's 1984 manual synoptic classification. Other relevant synoptic characteristics, as well as the surface pressure, and the value of the Western Mediterranean Oscillation index (WeMOi) on which those dates fell were also considered. The results show the high percentage of the Advection from the East with DANA (isolated high-altitude depression) or 'gota fría' type, which is present in more than 50% of the events, followed by the Trough type at 500 hPa and the Dynamic or Cold-core Low type, in the torrential rainfalls of South-eastern Spain. Except for the latter type, the average air pressure is close to or higher than normal. The WeMOi was negative for all events, which is consistent with the nature of this teleconnection pattern.

Causas sinópticas de las precipitaciones torrenciales en la región del Sureste, España (1941-2017)

RESUMEN. Se han determinado los tipos sinópticos, a partir de la clasificación manual de Martín-Vide (1984), de 68 fechas con precipitación torrencial (≥200 mm/día) en alguna estación meteorológica de las provincias de Alicante y Murcia durante el período 1941-2017. Se han considerado otras características sinópticas relevantes, así como la presión en superficie, y el valor del índice de la Oscilación del Mediterráneo Occidental (WeMOi) de las citadas fechas. Los resultados muestran la importancia porcentual en las precipitaciones torrenciales del Sureste de España de las advecciones del este con DANA ("gota fría"), presentes en más del 50% de los casos, seguida por las vaguadas en 500 hPa y las borrascas dinámicas o frías. Salvo en este último tipo, la presión atmosférica media es próxima o superior a la normal. En todos los casos el WeMOi fue negativo, lo que es consistente con la naturaleza de este patrón de teleconexión.

Key words: DANA, South-eastern region (Spain), synoptic situation, torrential rainfall.

Palabras clave: DANA, región del Sureste (Spain), situación sinóptica, precipitación torrencial.

Received: 25 May 2020

Accepted: 13 October 2020

*Corresponding author: Javier Martín-Vide, Department of Geography, Universidad de Barcelona, 08001 Barcelona (Spain). E-mail: jmartinvide@ub.edu

1. Introduction

Rainfall in the South-eastern region of Spain is known to be extremely irregular both spatially and temporally. In particular, its high daily concentration of rainfall (Ayala Carcedo and Olcina, 2002; Martín-Vide, 2004; Cortesi *et al.,* 2012; Monjo and Martín-Vide, 2016; Serrano-Notivoli *et al*., 2018) and degree of variability from one year to the next, indicated by a coefficient of variation of up to 40% among annual pluviometric series (Martín-Vide, 2011), combined with the marked aridity of the region which is due to its sparse precipitation, mild temperatures and abundant insolation, give rise to a semi-arid Mediterranean climate which sometimes recalls the edges of the desert (Conesa and Alonso, 2006; Martín-Vide and Olcina, 2001). The exceptional nature of the rainfall in South-eastern Spain gives the landscape a distinctly barren, rugged and dusty appearance which contrasts sharply with the verdant vegetation of its irrigated spaces. On the other hand, the region is rich in biodiversity and endemic species and is known for the adaptation of its culture and technology to the scarcity of water and irregularity of precipitation over the course of centuries (Belmonte *et al*., 2017).

An analysis of the daily precipitation values at the region's observatories immediately reveals that the record is punctuated with days of very high rainfall compared to the modest annual average, with the recorded rainfall on some days accounting for more than 50% of the annual total. The occurrence or absence of such days can radically alter the character of a year from rainy to dry, or vice versa. Moreover, it is not uncommon for a markedly dry year to later be classified as rainy due to the occurrence of a day or two of torrential rainfall during the autumn. In summary, we find ourselves in a region with one of the highest degrees of pluviometric irregularity (Monjo and Martín-Vide, 2016) on the planet; this is a challenge for the statistical analysis of precipitation volumes, particularly in terms of daily and sub-daily rainfall.

This paper focuses on the synoptic causes of torrential rainfall in South-eastern Spain. In this regard, previous studies have presented the synoptic features of the torrential rainfalls in the region and their hydrological effects, primarily the resultant floods (Gallego Jiménez, 1997; Gil Olcina *et al*., 2004; Gilabert and Llasat, 2018). These studies emphasise the significance of cold air pockets at high altitudes, the 'gotas frías' or isolated high-altitude depressions (cut-off lows), the troughs in altitude, etc., that is to say, the importance of circulation in the middle and upper tropospheric levels, to the genesis of the South-eastern floods. Some studies compare them to the temperature of the surface waters of the Mediterranean (Millán *et al*., 1995, 2005; Pastor, 2012; Pastor *et al*., 2001, 2015). Others present spatial patterns (Peñarrocha *et al*., 2002). There are also studies that analyse one or several catastrophic events resulting in significant material losses in terms of agriculture, infrastructure and cities (Capel Molina, 1974; Pérez Cueva and Armengot, 1983, Gil Olcina, 1986; Pastor *et al*., 2001, Olcina *et al*., 2010; Espín *et al*, 2017., etc). Still others reconstruct historical episodes (Barriendos *et al*., 2019). The relationship between intense rainfall and soil erosion in a region with a high intensity of erosive and desertification processes is a subject of particular focus (Romero Díaz *et al*., 1992, 1998; Peña-Angulo *et al*., 2019). Some indicate the possible trends under climate change (Millán, 2014).

Despite the extensive literature on the phenomenon of torrential rainfall and the resulting flooding and washouts in the study area, there has been no systematic study of its atmospheric genesis over a long and recent period for the provinces of Alicante and Murcia combined; this is the *leitmotif* of this paper, which is structured as follows: Section 2 presents the baseline data and study area, Section 3, the methodology, Section 4, the results, Section 5, a discussion of the results, and Section 6, the conclusions.

2. Data and study area

There are three types of baseline data: pluviometric, synoptic and teleconnective.

a) The pluviometric data are comprised of the dates on which the precipitation recorded at any meteorological station in the Júcar and Segura catchment areas in the provinces of Alicante and Murcia during the period from 1941 to 2017 was equal to or greater than 200 mm/day.

b) The synoptic data comprise the reanalysis at the surface and at 500 hPa from NOAA (and CFSR as of 2014) at noon on those dates.

c) The teleconnective data are the daily values of the Western Mediterranean Oscillation index (WeMOi) (Martín-Vide and López-Bustins, 2006) for the aforementioned dates.

The pluviometric data come from stations operated by the AEMET (Spanish Meteorological Agency), formerly INM (National Institute of Meteorology) and SMN (National Meteorological Service), and from the Júcar (CHJ) and Segura (CHS) catchment areas. We identified a total of 68 dates with at least one recorded rainfall of 200 mm or more; this constitutes a statistically significant sample for determining the synoptic situations that generate this type of precipitation. These were the observational data used by Miró *et al*. (2017) for the reconstruction of daily volumes of torrential rainfall events. Due to the changing number of weather stations over the course of the study period, the homogeneity of the series cannot be guaranteed; however, homogeneity is not required, as trend analysis is not the subject of this paper. Even without the inclusion of all the occurrences, the 68 dates constitute a sufficiently broad set for determining the synoptic situations which trigger torrential rainfalls in the region, as well as their characteristics.

As expected, there are some consecutive dates among the 68 events where the torrential episode lasted more than one day, although we cannot rule out the well-known effect of the incorrect assignment of a record to a given date in some cases.

The synoptic information was obtained from the German portal *Wetterzentrale* (www.wetterzentrale.de) which contains several reanalysis files. We used the NOAA (USA) file that covers the entire study period except for the last four years, from 2014 to 2017, which are covered by the reanalysis from the same institution CFSR (*Climate Forecast System Reanalysis*) and which is available on the same portal. The combined surface and 500 hPa maps have proven optimal for applying a manual classification of synoptic situations to the 68 dates analysed.

The study area was limited to the provinces of Alicante and Murcia although geographically, the South-eastern region covers the whole of Almeria and a part of Granada that borders with the latter, as well as a section of Albacete that borders on Murcia (Fig. 1). Strictly speaking, the relatively wet northern tip of Alicante, with its average annual volumes exceeding 600 mm, and occasionally 800 mm, could be excluded. The provinces of Alicante and Murcia were selected due to the availability of precipitation data (Miró *et al*., 2017). At any rate, most of the selected events could have affected the provinces bordering the two comprising the study area. There are many more dates in Alicante than in Murcia, partly due to the weight of northern Alicante which, combined with southern Valencia, exhibits the maximum daily rainfall and the highest hourly and sub-hourly intensities in Spain (Pérez Cueva, 1994). Downpours of more than 100 mm but less than 200 mm in a day are relatively abundant at Murcian weather stations but are not among the selected events, as the threshold was established at 200 mm; in contrast, daily records exceeding 200 mm are relatively frequent in northern Alicante under the same synoptic situation, with an average of about two cases per year (Riesco and Alcover, 2003).

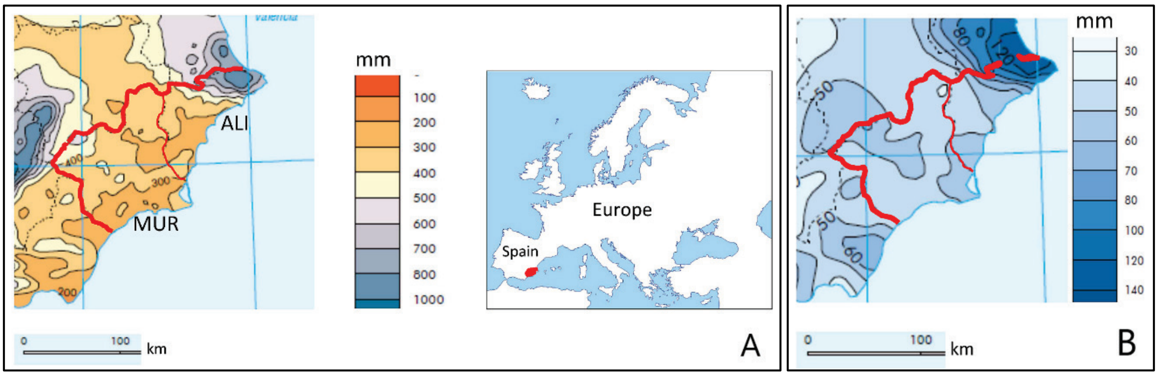

Figure 1. a) Study area (Alicante and Murcia provinces) with the annual rainfall average, and its localization in Europe; b) Annual maximum precipitation average. Source: Obra derivada de MapANE 2015-2017 CC-BY 4.0 ign.es.

3. Methodology

The methodological steps were as follows:

1) Identification of dates in the observational database with a precipitation of 200 mm or more recorded in at least one weather station in the provinces of Alicante and Murcia during the period from 1941 to 2017. There were 68 dates in total, which constitute a large statistical sample. Monthly and seasonal distributions of the identified dates were obtained.

2) Determination of the weather type of the dates identified using the manual synoptic classification of Martín-Vide (1984), from the noon reanalysis of NOAA (and CFSR from 2014 to 2017) found on the Wetterzentrale portal mentioned above. Only two events were classified as types that differ slightly from the 16 in Martín-Vide's classification (1984). In addition, the term DANA has been used in this classification instead of 'gota fria'.

3) Annotation of other relevant synoptic characteristics of the classified dates on a continental scale, as well as the atmospheric pressure in the study area.

4) Calculation of the frequency of the weather types of the classified dates, as well as the average air pressure and WeMOi of each type.

5) Selection of a surface weather and 500 hPa topography map as a model of each of the most frequent weather types.

4. Results

The first five columns of Annex present the selected dates with the meteorological stations which recorded 200 mm of precipitation or more during the study period; this information was obtained from the Miró *et al*. (2017) database. This is followed by the weather type determined using Martín Vide's 1984 synoptic classification, the surface atmospheric pressure, synoptic characteristics on a continental scale and the WeMOi value. Note that there may be several weather stations with records of 200 mm or more on the same date, but they will only be included in the analysis as a single event, with the '&' symbol in the columns for weather type, atmospheric pressure, synoptic characteristics and WeMOi for the same date, so as to avoid repetition.

The principal results for the 68 dates with torrential rainfalls are summarised in Table 1. The most relevant result is the high frequency of the Advection from the East with DANA type which was present in more than half of the events (52.9%), (Fig. 2). Lagging far behind the aforementioned weather type, but at frequencies which are not insignificant, are the Trough type (17.6%) (Fig. 3) and the Dynamic or Cold-core Cyclone (16.2%) type (Fig. 4). These three weather types combined account for 86.8% of the total (59 dates out of 68).

Table 1: Absolute and percentage frequencies of the synoptic situations on the dates with a precipitation of 200 mm/day or more at any observatory in Alicante or Murcia provinces, and averages of the atmospheric pressure and the corresponding WeMOi value (1941–2017). Source: Own elaboration.

Synoptic situation or weather type	Abs.Freq.	%	Mean Atm.Press. (hPa)	Mean WeMOi
Advection from the E with DANA	36	52.9	1016.4	-1.67
Trough	12	17.6	1015.1	-0.96
Dynamic or Cold-core Low	11	16.2	1008.7	-1.75
Advection from the E	5	7.4	1019.6	-1.48
Weak surface pressure gradient	2	2.9	1019.0	-1.18
Advection from the NE with DANA	1	1.5	1014.0	-0.66
DANA to the W	1	1.5	1014.0	-0.57

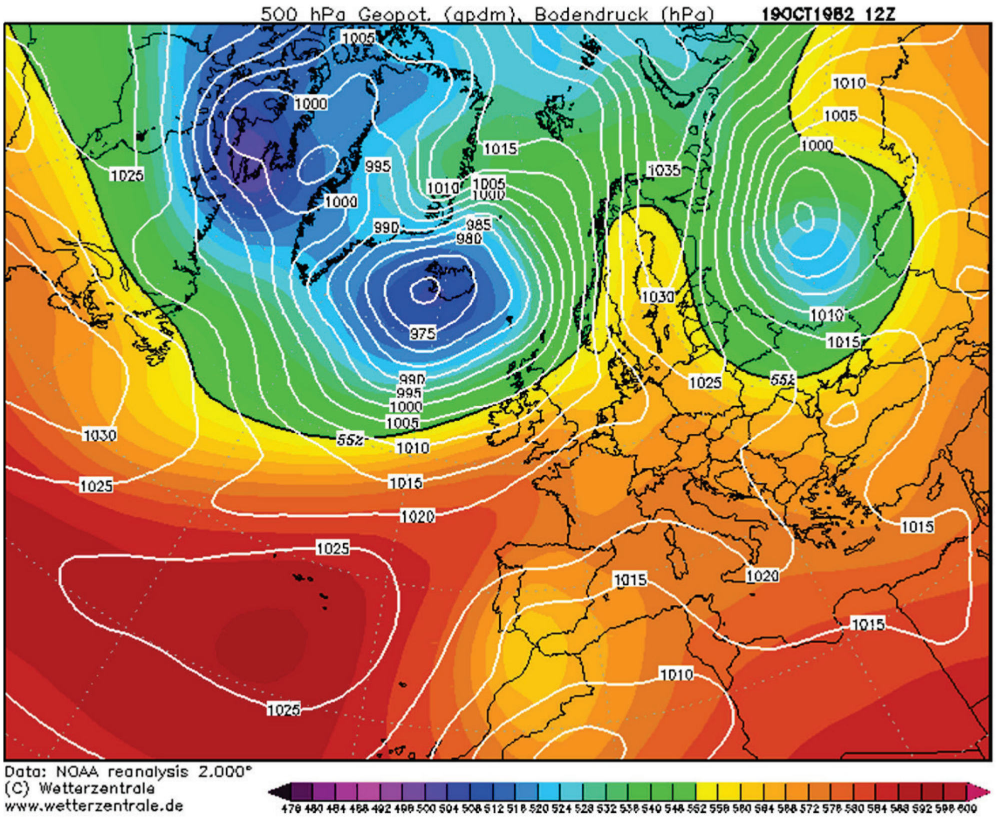

Figure 2. Advection from the East with DANA on 19 October 1982, at 12:00 UTC. Source: www.wetterzentrale.de.

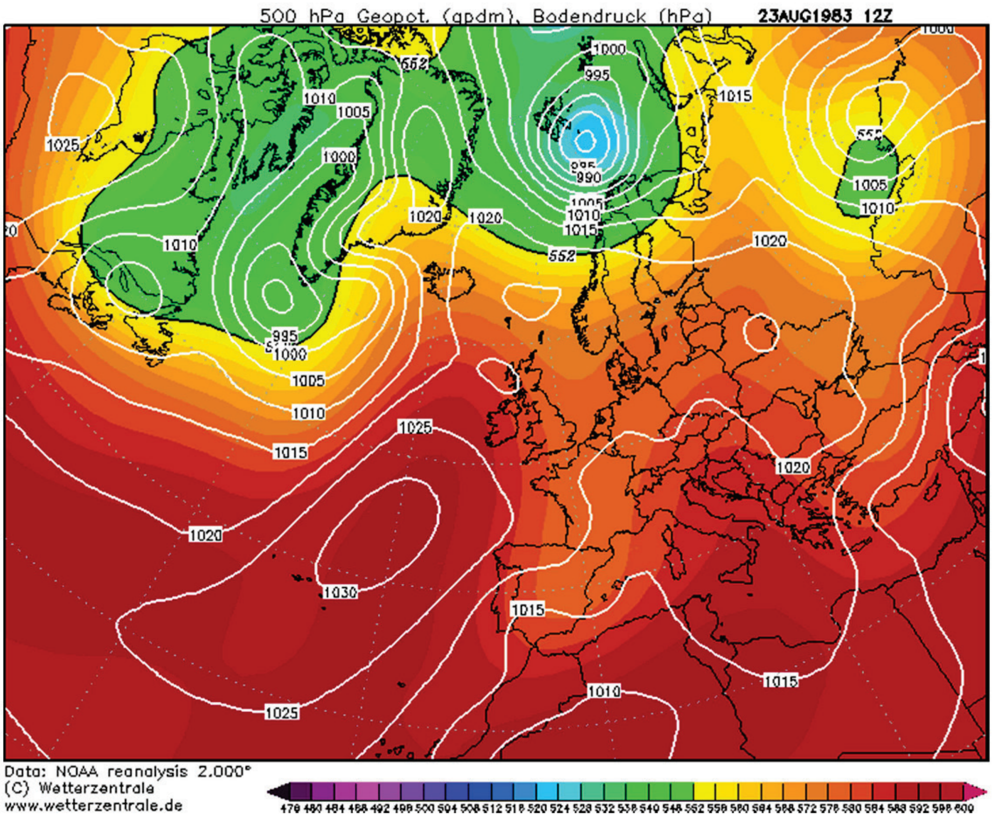

Figure 3. Trough on 23 August 1983, at 12:00 UTC. Source: www.wetterzentrale.de.

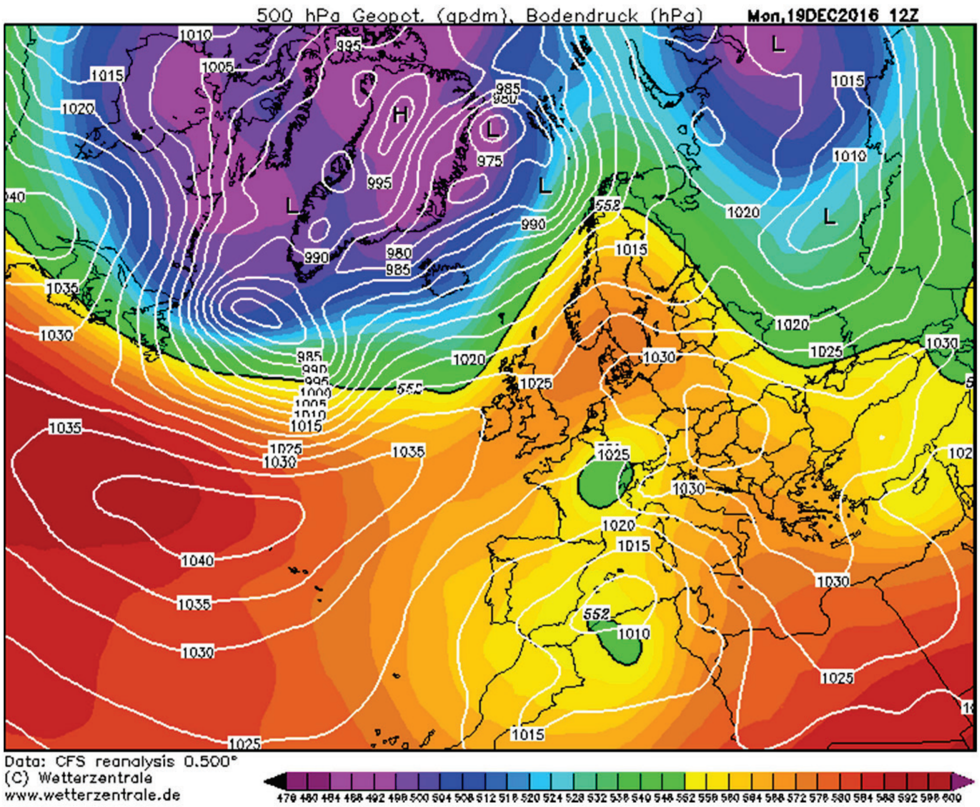

Figure 4. Dynamic or Cold-core Low on 19 December 2016, at 12:00 UTC. Source: www.wetterzentrale.de.

Flows with an eastern component (E and NE) on the surface occur in more than 60% of the events (61.8%)

The average atmospheric pressure for the 68 dates is 1015.2 hPa, higher than the normal at sea level (1013.2 hPa). The lowest average atmospheric pressure corresponds to the Dynamic or Cold-core Cyclone type (1008.7 hPa), and the highest corresponds to the Advection from the East without an upper-level Low type (1019.6 hPa), which ranks fourth in terms of frequency. The highest value was 1028 hPa on 14 November 1953, and the lowest was 1002 hPa on 7 May 2002.

For events with Advection from the East with DANA, the high frequency of anticyclones in central and northern Europe (83.3%), often with anticyclonic bridges between several nuclei or to the Azores High, is notable at a continental scale.

The WeMOi was negative on all the dates of the 68 events in the study; in 21 events, it was equal to or less than -2.0, an extremely negative value (López-Bustins, 2007). The average value is -1.5. The lowest was -3.03 on 10 October 2008.

The seasonal and monthly distribution of the dates demonstrates the well-known fact that autumn is the critical season, which accounted for nearly 70% of the events (69.1%), with the highest frequency in October (32.4%), followed by September (22.1%) and November (14.7%), while only two events were recorded in summer.

5. Discussion

The impact that the atmospheric mechanisms of the middle and upper levels of the troposphere, i.e. the troughs and the isolated high-altitude depressions or 'gotas frías' currently referred to by the acronym DANA, have in the genesis of intense or torrential rainfalls in Mediterranean Spain is well-known; however, the frequency revealed by the study is very striking. Specifically, the 'Advection from the East with DANA' weather type was present in more than half of the events in the study area (Martín-Vide, 1984).

The acronym DANA refers to an isolated high-altitude depression and has come to replace, with some nuance, the popular expression 'gota fría', or cut-off low (Palmén, 1949). A DANA results from the strangulation of a polar jet stream trough at latitudes similar to those of southern Europe, which gives rise to a cyclonic vortex in the middle and upper troposphere with the corresponding injection of cold air (Palmén, 1949; Martín-Vide, 1984; Quereda, 1989; Martín-Vide, 1989; Llasat, 1991; Gil Olcina and Olcina, 1999; Martín León, 2003; Nieto *et al*., 2005; Llasat et al., 2007; Munoz *et al*., 2019; Alshouhani, 2020).

After analysing six events that occurred between 2000 and 2012 in the Region of Murcia, Castejón Porcel and Romero Díaz (2014) also concluded that the existence of an isolated high-altitude depression is the critical situation for the occurrence of torrential rainfall. Due to their marine origin, the surface flows from the east provide the humidity necessary for large daily rainfall records, as well as the cold high-altitude depression, the necessary vertical thermal contrast and the unstable stratification which enables the triggering effect. The threshold of 200 mm which, even when distributed over many hours in a day, requires a high intensity of precipitation, probably increases the predominance of the DANAs with surface flows from the east in the genesis of the torrential rainfall in South-eastern Spain, which would perhaps not be so noteworthy at lower rainfall thresholds. In the Catalan provinces having a coastline and a lower threshold of 100 mm/day, several types other than the three most frequent types in the South-east were identified (Martín-Vide *et al*., 2008).

This does not contradict the known fact that not every isolated high-altitude depression produces copious or intense downpours (Llasat, 1991), as no contingency analysis has been carried out. However, when these downpours do occur, the existence of one of the three most frequent synoptic situations, Advection from the East with DANA, Trough, or Dynamic or Cold-Core Low, often linked in time, can be expected with a high degree of probability (86.8%) especially the first type. The synoptic causes of torrential rainfall on the Mediterranean side of the Iberian Peninsula differ significantly from those which produce light rainfall (Romero *et al*., 1999).

The specific location of the DANA is a decisive factor in the location of the precipitation peaks, which occur on the 'leading edge' of the depression, usually in the eastern or north-eastern sector of its periphery (Medina, 1976; Gallego Jiménez, 1997). The great diversity of the DANA locations also produces a varied spatial distribution of maximum rainfall in the region. The demanding threshold of 200 mm/day favours northern Alicante, where the orographic conditions and the orientation of the coastline promote very high records (Pérez Cueva, 1994).

The Advection from the East with DANA type forms a characteristic pattern on a continental scale with high pressures in central and northern Europe, often with an anticyclonic bridge to the Azores High. The anticyclone over the continent is characteristic of a blocking anticyclone, i.e. it is persistent (Barriopedro *et al*., 2006). The occurrence of blocking anticyclones over the British Isles, where rain is absent for one or two weeks, is particularly well known, while intense showers and downpours occur in southern Europe, particularly in the south and east of the Iberian Peninsula.

The next most frequent weather type after Advection from the East with DANA is the Trough which occurs at 500 hPa, often during the torrential rainfall events of the South-east is the former type prior to the detachment from the jet stream that characterises the isolated high-altitude depression, or DANA. The variety in the arrangements of trough axes, from parallel to highly oblique with respect to the meridians, and their situation to the west, above or to the east of the study area, explains the location of the highest records which generally coincide with the ascending or eastern branch of the trough (Medina, 1976; Martín-Vide, 1984; Gallego Jiménez, 1997).

The third weather type, Dynamic or Cold-Core Low, is often the result of the surface reflection of a DANA after a certain amount of time (Martín León, 2003). There are no noticeably low surface pressure values in the study area. The minimum record, 1002 hPa, is far above the usual surface pressure of the frontal or mid-latitude depressions of the polar front.

To elaborate on the topic of atmospheric pressure, it is usually higher than normal during torrential rainfall events in the South-east, except when a cold-core low is centred over the region. In contrast to what generally happens in the climates of Atlantic Europe, for example, the lack of a negative correlation between atmospheric pressure and precipitation in the east of the Iberian Peninsula is well known (Martín-Vide et al., 1999); this underscores the significance of the high-altitude mechanisms. Other studies of the Valencian Community, such as Armengot (2002), also found higher than normal pressures, including some which were substantially high, during the torrential events.

As for the effect that the WeMO pattern has on torrential rainfall in the South-eastern region, which was defined specifically to explain the variability that the NAO did not achieve for the eastern Iberian Peninsula (Martín-Vide, 2002; Martín-Vide and López-Bustins, 2006; López-Bustins, 2007), the results obtained are fully consistent with the nature of the aforementioned Mediterranean pattern. Its negative phase, or more precisely, the negative values of the WeMOi, corresponds to flows with an eastern component, which are humid in the eastern Iberian fringe, when a depression towards the south-west of the peninsula meets with high pressures in Central Europe and northern Italy. In view of the result demonstrating that the 68 events correspond to negative WeMOi dates, and in the 31% of the cases to extremely negative ones, we can conclude that the risk of torrential rainfall (≥200 mm/day) in the study area is practically zero, if the WeMOi is positive. The mean value of -1.5 of the WeMOi for all the study cases is consistent with the fact that the range of WeMOi values that recorded the maximum frequency of torrential episodes in Martín-Vide and López-Bustins (2006) was that of (-2, -1].

The surface flows of the eastern component, which are always humid, were present in more than 60% of the events, which is in line with the high water vapour contingent required for torrential episodes. In any case, there is still a significant 40% of events in which the contribution of humidity from

Mediterranean waters is not evident at a synoptic level; this indicates that mesoscale marine flows (Gómez *et al*., 2011) and the high local hygrometric content must be considered as possible contributions to these events.

The seasonal and monthly distribution of the dates demonstrates that autumn, during which approximately 70% of the events occurred, is the critical season with October as the most prominent month; this is known from the historical compilation and reconstruction of floods as well (Gil Guirado *et al*., 2019; Barriendos *et al*., 2019). The autumnal concentration of the events analysed corresponds to the most negative values of the daily WeMOi at the aforementioned station throughout the year; this was already recognised by Meseguer-Ruiz *et al*. (2018).

6. Conclusions

Advection from the East at the Surface with a DANA, or isolated high-altitude depression, is by far the most predominant weather type on days of torrential rainfall, assuming a threshold of ≥200 mm/day, in South-eastern Spain. It was present on more than 50% of the dates with precipitation records exceeding this threshold at any observatory in Alicante or Murcia. This weather type, in combination with the High-Altitude Trough type, sometimes prior to the formation of a DANA, and the Dynamic or Cold-core Low type, which sometimes follow a DANA temporally, when they are reflected at the surface, account for nearly 90% of the events. It is therefore quantifiably clear that the conditions of instability in the middle troposphere are decisive for the genesis of torrential rainfall in the South-eastern region. On the other hand, the surface flows of the eastern component, which are always humid, are present in more than 60% of events, which is in line with the high water vapour contingent required for torrential episodes.

On a continental scale, the Advection from the East with DANA type usually coincides with a blocking anticyclone in central and northern Europe, often forming an anticyclonic bridge to the Azores High. This is a typical pattern of the negative phase of the WeMO. On the 68 dates analysed, the WeMOi was negative, which is consistent with its pluviometric effects on the East Iberian and with the predominantly autumnal occurrence of the torrential rainfall events.

Acknowledgements

We wish to acknowledge the support received from the Spanish project CLICES CGL2017-83866-C3-2-R (AEI/FEDER, UE) and Climatology Group 2017 SGR 1362. We appreciate the interest in our research shown by the Water Research Institute of the University of Barcelona and the Royal Academy of Science and Arts of Barcelona. We also wish to acknowledge www.wetterzentrale.de for the reanalysis maps and to Javier Miró for the rainfall data base.

References

Alshouhani, H. 2020. A Comparative Study Between Short Life- Cut off Low and Long Life-Cut off Low Accompanied by Heavy Precipitation Storms Over Iraq: Case Study. *Al-Mustansiriyah Journal of Science* 31, 2. https://doi.org/10.23851/mjs.v31i2.755

Armengot, R. 2002. *Las lluvias intensas en la Comunidad Valenciana*. Ministerio de Medio Ambiente, Madrid.

Ayala-Carcedo, F., Olcina, J. (Coords.) 2002. *Riesgos naturales*. Editorial Ariel, Barcelona.

Barriendos, M., Gil-Guirado, S., Pino, D., Tuset, J., Pérez-Morales, A., Alberola, A., Costa, J., Balasch, J.C., Castelltort, X., Mazón, J., Ruiz-Bellet, J.L. 2019. Climatic and social factors behind the Spanish Mediterranean flood event chronologies from documentary sources (14th-20th centuries). *Global and Planetary Change* 182, 102997. https://doi.org/10.1016/j.gloplacha.2019.102997

Barriopedro, D., García-Herrera, R., Lupo, A.R., Hernández, E. 2006. A Climatology of Northern Hemisphere Blocking. *Journal of Climate* 19(6), 1042-1063. https://doi.org/10.1175/JCLI3678.1

Belmonte Serrato, F., Ballesteros Pelegrín, G.A., Sánchez Balibrea, M., Ibarra Marinas, D. (coord.) 2017: *Cuestiones sobre Paisaje, patrimonio natural y Medio Ambiente en el Sureste Ibérico*, Ediciones de la Universidad de Murcia, Murcia.

Capel Molina, J.J. 1974. Génesis de las inundaciones de octubre de 1973 en el sureste de la Península Ibérica. *Cuadernos Geográficos de la Universidad de Granada* 4, 149-166.

Castejón Porcel, G., Romero Díaz, A. 2014. Inundaciones en la Región de Murcia en los inicios del siglo XXI. *Biblio 3W,* XIX, 1102.

Conesa, C., Alonso, F. 2006. El clima de la Región de Murcia. En: C. Conesa (Ed.) *El medio físico de la Región de Murcia*. Universidad de Murcia, pp. 95-128, Murcia.

Cortesi, J N., Gonzalez-Hidalgo, C., Brunetti, M., Martin-Vide, J. 2012. Daily precipitation concentration across Europe 1971-2010. *Nat. Hazards Earth Syst. Sci*. 12, 2799-2810. https://doi.org/10.5194/nhess-12-2799-2012

Espín Sánchez, D., García Lorenzo, R., Ruiz Álvarez, V., Conesa García, C. 2017. Las lluvias torrenciales e inundaciones de los días 17 y 18 de diciembre de 2016 en la Región de Murcia con particular incidencia en el área vertiente del Mar Menor. *Ingeniería del Agua* 21(4), 213-229. https://doi.org/10.4995/ia.2017.7773

Gallego Jiménez, F. 1997. *Situaciones de flujo mediterráneo y precipitaciones asociadas: aplicación a la predicción cuantitativa en la cuenca del Segura*. Universidad de Murcia, Murcia.

Gil-Guirado, S., Pérez-Morales, A, López-Martínez, F. 2019. SMC-Flood database: a high-resolution press database on flood cases for the Spanish Mediterranean coast (1960-2015). *Nat. Hazards Earth Syst. Sci*. 19, 1955-1971. https://doi.org/10.5194/nhess-19-1955-2019

Gil Olcina, A. (Dir.) 1986. *Inundaciones en la ciudad y término de Alicante*. Universidad de Alicante, Alicante.

Gil Olcina, A., Olcina, J. 1999. *Climatología básica*. Ariel, Barcelona.

Gil Olcina, A., Olcina, J., Rico Amorós, A. 2004. *Aguaceros, aguaduchos e inundaciones en áreas urbanas alicantinas*. Publicaciones de la Universidad de Alicante, Alicante.

Gilabert, J., Llasat, M.C. 2018. Circulation weather types associated with extreme flood events in Northwestern Mediterranean. *International Journal of Climatology* 38, 1864-1876. https://doi.org/10.1002/joc.5301

Gómez, I., Pastor, F., Estrela, M. J. 2011. Sensitivity of a mesoscale model to different convective parameterization schemes in a heavy rain event. *Nat.Hazards Earth Syst. Sci.* 11, 343-357. https://doi.org/10.5194/nhess-11-343-2011

Llasat, M.C. 1991. *Gota fría*. Marcombo, 165 pp., Barcelona.

Llasat, M.C., Martín, F., Barrera, A. 2007. From the concept of "Kaltlufttropfen" (cold air pool) to the cut-off low. The case of September 1971 in Spain as an example of their role in heavy rainfalls. *Meteorol. Atmos. Phys.* 96, 43-60. https://doi.org/10.1007/s00703-006-0220-9

López-Bustins, J.A. 2007. *L'Oscil·lació de la Mediterrània Occidental i la Precipitació als Països Catalans*. Universitat de Barcelona, Barcelona. http://hdl.handle.net/10803/1953

Martín León, F. 2003. Las gotas frías/DANAs. Ideas y conceptos básicos. Ministerio de Medio Ambiente, Madrid. *Nota técnica STAP nº 38.* http://www.aemet.es/documentos/es/conocermas/estudios/dana_ext.pdf .

Martín-Vide, J. 1984. *Interpretación de los mapas del tiempo*. Ketres, Barcelona.

Martín-Vide, J. 1989. Precipitaciones torrenciales en España. *Norba. Revista de Geografía*, 6-7, 63-70.

Martín-Vide, J. 2002. Ensayo sobre la Oscilación del Mediterráneo Occidental y su influencia en la pluviometría del este de España. En: J.A. Guijarro, M. Grimalt, M. Laita, S. Alonso (Eds.), *El Agua y el Clima/L'Aigua i el Clima*. Publicaciones de la Asociación Española de Climatología, pp. 35-42, Palma.

Martín-Vide, J. 2004. Spatial distribution of daily precipitation concentration index in Peninsular Spain. *International Journal of Climatology* 24, 959-971. https://doi.org/10.1002/joc.1030

Martín-Vide, J. 2011. Estructura temporal fina y patrones espaciales de la precipitación en la España peninsular. *Memorias de la Real Academia de Ciencias y Artes de Barcelona* 1030, LXV, 3, 119-162.

Martín-Vide, J., López-Bustins, J.A. 2006. The Western Mediterranean Oscillation and rainfall in the Iberian Peninsula. *International Journal of Climatology* 26, 1455-1475. https://doi.org/10.1002/joc.1388.

Martín-Vide, J., Olcina, J. 2001. *Climas y tiempos de España*. Alianza Editorial, Madrid.

Martín-Vide, J., Barriendos, M., Peña, J.C., Raso, J.M., Llasat, Mª C., Rodríguez, R. 1999. Potencialidad del índice NAO en la previsión de episodios de alta pluviosidad en España. *Gerencia de riesgos* XVII (67), 19-31. Fundación Mapfre Estudios, Madrid.

Martín-Vide, J., Sánchez-Lorenzo, A., López-Bustins, J.A., Cordobilla, M.J., García-Manuel, A., Raso, J.M. 2008. Torrential Rainfall in Northeast of the Iberian Peninsula: Synoptic patterns and WeMO influence. *Advances in Science and Research* 2, 99-105. https://doi.org/10.5194/asr-2-99-2008

Medina, M. 1976. *Meteorología básica sinóptica*. Paraninfo, 320 pp., Madrid.

Meseguer-Ruiz, O., López-Bustins, J.A., Arbiol, L., Martín-Vide, J., Miró, J., Estrela, M.J. 2018. Episodios de precipitación torrencial en el este y sureste ibéricos y su relación con la variabilidad intra-anual de la Oscilación del Mediterráneo Occidental (WeMO) entre 1950 y 2016. En: J.P. Montávez-Gómez, J.J. Gómez- Navarro, J.M. López-Romero, L. Palacios-Peña, M. Turco, S. Jerez- Rodríguez, R. Lorente, P. Jiménez-Guerrero (Eds.), *El Clima: Aire, Agua, Tierra y Fuego*. Asociación Española de Climatología, pp. 53-63.

Millán, M. M. 2014. Extreme hydrometeorological events and climate change predictions in Europe. *Journal of Hydrology* 118, Part B, 206-224. https://doi.org/10.1016/j.jhydrol.2013.12.041

Millán, M. M., Estrela, M. J., Caselles, V. 1995. Torrential precipitations on the Spanish east coast: The role of the Mediterranean sea surface temperature. *Atmospheric Research* 36, 1-16. https://doi.org/10.1016/0169-8095(94)00048-I

Millán, M. M., Estrela, M. J., Miró, J. J. 2005. Rainfall Components: Variability and Spatial Distribution in a Mediterranean Area (Valencia Region). *Journal of Climate* 18, 2682-2705. https://doi.org/10.1175/JCLI3426.1

Miró, J.J., Caselles, V., Estrela, M. J. 2017. Multiple imputation of rainfall missing data in the Iberian Mediterranean context. *Atmospheric Research* 197, 313-330. http://doi.org/10.1016/j.atmosres.2017.07.016

Monjo, R., Martín-Vide, J. 2016. Daily precipitation concentration around the world according to several indices. *International Journal of Climatology* 36(11), 3828-3838. https://doi.org/10.1002/joc.4596

Munoz, C., Schultz, D., Vaughan, G. 2019. A Midlatitude Climatology and Interannual Variability of 200- and 500-hPa Cut-Off Lows. *Journal of Climate* 33(6), 2201-2222. https://doi.org/10.1175/JCLI-D-19-0497.1

Nieto, R., Gimeno, L., de la Torre Ramos, L., Ribera, P., Gallego, D., García-Herrera, R., García, J., Nunez Corchero, M., Redaño, A., Lorente, J. 2005. Climatology features of Cut-off Lows Systems in the Northern Hemisphere. *Journal of Climate* 18(16), 3085-3103. https://doi.org/10.1175/JCLI3386.1

Olcina, J., Hernández Hernández, M., Rico Amorós, A. M., Martínez Ibarra, E. 2010. Increased risk of flooding on the coast of Alicante (Region of Valencia, Spain). *Nat. Hazards Earth Syst. Sci*. 10, 2229-2234. https://doi.org/10.5194/nhess-10-2229-2010

Palmén, E. 1949. Origin and structure of high-level cyclones south of the maximum westerlies. *Tellus* 1 (1), 1-10.

Pastor, F. 2012. *Ciclogénesis intensas en la cuenca occidental del Mediterráneo y temperatura superficial del mar: Modelización y evaluación de las áreas de recarga*. Doctoral thesis. Universidad de Barcelona. http://hdl.handle.net/2445/35282

Pastor, F., Estrela, M.J., Peñarrocha, D., Millán, M.M. 2001. Torrential Rains on the Spanish Mediterranean Coast: Modeling the Effects of the Sea Surface Temperature. *Journal of Applied Meteorology* 40, 1180-1195. https://doi.org/10.1175/1520-0450(2001)040<1180:TROTSM>2.0.CO;2

Pastor, F., Valiente, J. A., Estrela, M. J. 2015. Sea surface temperature and torrential rains in the Valencia region: modelling the role of recharge areas. *Natural Hazards and Earth System Sciences* 15: 1677-1693. https://doi.org/10.5194/nhess-15-1677-2015

Peña-Angulo, D., Nadal-Romero, E., González-Hidalgo, J., Albaladejo, J., Andreu, V., Bagarello, V., Batalla, R.J., Bernal, S., Bienes, R., Campo, J., Campo-Bescós, M., Canatario, A. Cantón, Y., Casalí, J., Castillo, V., Cerdà, A., Cheggourr, A., Cid, P., Cortesi, N., Zorn, M. 2019. Spatial variability of the relationships of runoff and sediment yield with weather types throughout the Mediterranean basin. *Journal of Hydrology* 571, 390-405. https://doi.org/10.1016/j.jhydrol.2019.01.059

Peñarrocha, D., Estrela, M. J., Millán, M.M. 2002. Classification of daily rainfall patterns in a Mediterranean area with extreme intensity levels: The Valencia region. *International Journal of Climatology* 22, 677-695. https://doi.org/10.1002/joc.747

Pérez Cueva, A. (Ed.) 1994. *Atlas Climàtic de la Comunitat Valenciana*. Generalitat Valenciana, Conselleria d'Obres Publiques, Urbanisme i Transports, Valencia.

Pérez Cueva, A., Armengot, R. 1983. El temporal de octubre de 1982 en el marco de las lluvias torrenciales en la cuenca del bajo Júcar. *Cuadernos de Geografía*, 32-33, 61-86.

Quereda, J. 1989. *La ciclogénesis y las gotas frías del Mediterráneo Occidental*. Diputación de Castelló, 135 pp, Castelló.

Riesco, J., Alcover, V. 2003. *Predicción de precipitaciones intensas de origen marítimo mediterráneo en la Comunidad Valenciana y la Región de Murcia*. Ministerio de Medio Ambiente, 124 pp., Madrid.

Romero Díaz, A., López Bermúdez, F., Cabezas, F. 1992. Erosion and fluvial sedimentation in the River Segura Basin. Spain. *Catena* 19, 379-392. https://doi.org/10.1016/0341-8162(92)90010-9

Romero Díaz, A., López Bermúdez, F., Belmonte Serrato, F., Barberá, G.G. 1998. Erosión y escorrentía en el campo experimental de "El Ardal" (Murcia). Nueve años de experiencias. *Papeles de Geografía* 27, 129-144. https://revistas.um.es/geografia/article/view/45561

Romero, R., Sumner, G., Ramis, C., Genovés, A. 1999. A classification of the atmospheric circulation patterns producing significant daily rainfall in the Spanish Mediterranean area. *International Journal of Climatology* 19, 765-785. https://doi.org/10.1002/(SICI)1097-0088(19990615)19:7<765::AID JOC388>3.0.CO;2-T

Serrano-Notivoli, R., Martín-Vide, J., Saz, M.A., Longares, L.A., Beguería, S., Sarricolea, P., Meseguer-Ruiz, O., De Luis, M. 2018. Spatio-temporal variability of daily precipitation concentration in Spain based on a high-resolution gridded data set. *International Journal of Climatology* 38, e518-e530. https://doi.org/10.1002/joc.5387

Annex

Study events - Dates on which precipitation of 200 mm/day or more occurred at any observatory in Alicante or Murcia, synoptic situation, atmospheric pressure (hPa), other synoptic characteristics and WeMOi value (1941–2017). Source: Miró et al. *(2017) (columns 1 to 5) and author's research (columns 6 to 9).*

Meteorol. station	Lat.	Lon.	Date	mm	Synop. Situat.	hPa	Other synoptic characteristics	WeMOi
S. MIGUEL DE LAS SALINAS, CHS	38	-0.8	05/10/1941	264.6	Trough	1018	Very weak trough, Scandinavian A	-0.9
PUERTO LUMBRERAS, CHS	37.6	-1.8	21/10/1948	240	Advection from the E with DANA	1020	Azores A extended towards Cantabrian Sea	-1.51
PEGO CONVENTO	38.8	-0.1	14/11/1953	260	Advection from the E with DANA	1028	Very weak DANA, Central Europe A	-0.72
PEGO CONVENTO	38.8	-0.1	23/11/1955	233	Advection from the E	1023	Rhombus pattern in Atlantic Ocean	-0.92
CALLOSA D'EN SARRIA TOSSAL DE SALOMA	38.7	-0.1	10/10/1956	206	Weak surface pressure gradient	1017	NASH (North Atlantic Subtropical High)	-2.05
DENIA	38.8	0.12	01/10/1957	318,8	Advection from the E with DANA	1009	British Isles A	-1
DENIA	38.8	0.12	02/10/1957	343,2	Advection from the E with DANA	1009	A to the W of British Isles	-1.27
XABIA	38.8	0.17	02/10/1957	878	&	&	&	&
CAP DE SANT ANTONI	38.8	0.2	03/10/1957	409,7	Advection from the E with DANA	1014	A to the W of British Isles	-0.6
EL VERGER RACONS	38.9	0.03	15/10/1957	298	Advection from the E	1013	Anticyclonic bridge Azores-Europe	-1.18
XABIA	38.8	0.17	15/10/1957	300	&	&	&	&
DENIA	38.8	0.12	16/10/1957	239,4	Weak surface pressure gradient	1021	Azores A	-0.3
COCENTAINA, CONVENT	38.8	-0.4	26/10/1958	205	Advection from the E with DANA	1019	A over the Netherlands	-1.01
PANTANO DE BENIARRES	38.8	-0.4	27/10/1958	200	Advection from the E with DANA	1013	North Sea-Central Europe A	-1.71
XALO	38.7	0	07/06/1960	240,7	Advection from the E	1020	Azores A	-0.14
DENIA	38.8	0.12	30/10/1961	250	DANA to the W	1014	No baric gradient	-0.57
EL VERGER RACONS	38.9	0.03	30/10/1961	200	&	&	&	&

Meteorol. station	Lat.	Lon.	Date	mm	Synop. Situat.	hPa	Other synoptic characteristics	WeMOi
XABIA	38.8	0.17	30/10/1961	225	&	&	&	&
CAP DE SANT ANTONI	38.8	0.2	31/10/1961	224	Advection from the E with DANA	1018	------------	-0.79
PEGO CONVENTO	38.8	-0.1	02/11/1961	220	Advection from the E with DANA	1020	Azores A with bridge with Central Europe A	-1.35
PEGO CONVENTO	38.8	-0.1	07/09/1967	295	Trough	1017	Weak E flow on surface	-0.02
EL VERGER RACONS	38.9	0.03	08/09/1967	305	Trough	1017	Weak E flow on surface	-0.37
PEGO CONVENTO	38.8	-0.1	28/04/1969	232	Dynamic or Cold-core Low	1005	Low zonal index	-1.57
XALO	38.7	0	28/04/1969	223	&	&	&	&
VALL DE LAGUARD FONTILLES	38.8	-0.1	29/04/1969	253	Dynamic or Cold-core Low	1003	Low zonal index	-0.44
BENISSA AYUNTAMIENTO	38.7	0.05	06/10/1971	244	Advection from the E with DANA	1022	Central Europe A	-2.73
BENISSA CONVENTO	38.7	0.05	06/10/1971	249	&	&	&	&
BOLULLA	38.7	-0.1	06/10/1971	247	&	&	&	&
CALLOSA D'EN SARRIA TOSSAL DE SALOMÃ	38.7	-0.1	06/10/1971	253,7	&	&	&	&
EL VERGER RACONS	38.9	0.03	06/10/1971	218	&	&	&	&
TARBENA CH JUCAR POBLE DE DALT	38.7	-0.1	06/10/1971	210,7	&	&	&	&
VALL DE LAGUARD FONTILLES	38.8	-0.1	06/10/1971	237	&	&	&	&
XALO	38.7	0	06/10/1971	226,6	&	&	&	&
EL VERGER RACONS	38.9	0.03	30/11/1972	213	Trough	1007	Azores A	-0.36
PEGO CONVENTO	38.8	-0.1	22/03/1973	216	Advection from the E with DANA	1015	--------------	-2.56
TARBENA CH JUCAR POBLE DE DALT	38.7	-0.1	22/03/1973	205	&	&	&	&
ALICANTE/EL ALTET	38.3	-0.6	19/10/1982	235	Advection from the E with DANA	1014	Azores A	-1.13
SAN VICENTE DEL RASPEIG-ST	38.4	-0.5	19/10/1982	220	&	&	&	&
ALICANTE	38.4	-0.5	20/10/1982	233,1	Advection from the E with DANA	1011	NASH	-2.05

Meteorol. station	Lat.	Lon.	Date	mm	Synop. Situat.	hPa	Other synoptic characteristics	WeMOi
ALCALALI	38.8	-0	23/08/1983	217	Trough	1016	Weak E flow, Azores A extended to British Isles	-0.48
XALO	38.7	0	23/08/1983	220,8	&	&	&	&
LAGUNA DE LA MATA	38	-0.7	21/02/1985	220	Trough	1022	Advection from E on surface	-1.84
LAGUNA DE TORREVIEJA	38	-0.7	21/02/1985	220	&	&	&	&
EMBASSAMENT DE GUADALEST	38.7	-0.2	28/10/1985	210	Advection from the E with DANA	1015	British Isles A	-1.59
TARBENA CH JUCAR POBLE DE DALT	38.7	-0.1	28/10/1985	236,3	&	&	&	&
TORMOS	38.8	-0.1	28/10/1985	209	&	&	&	&
PEDREGUER	38.8	0.03	15/11/1985	373	Advection from the E	1019	Trough to the W Iberian Peninsula, Scandinavian A with bridge with Azores A	-2.12
PEGO CONVENTO	38.8	-0.1	15/11/1985	249	&	&	&	&
GATA DE GORGOS	38.8	0.09	16/11/1985	200	Advection from the E with DANA	1019	Scandinavian A with bridge towards Azores A	-1.76
TORMOS	38.8	-0.1	16/11/1985	259	&	&	&	&
PANTANO DE BENIARRES	38.8	-0.4	28/09/1986	208,6	Advection from the E with DANA	1024	Russian-Scandinavian A	-1.1
AGRES, FRUTOS EVA	38.8	-0.5	29/09/1986	233	Advection from the E with DANA	1024	British Isles A	-1.56
ALCALALI	38.8	-0	29/09/1986	220	&	&	&	&
ALCOI	38.7	-0.5	29/09/1986	251	&	&	&	&
ALCOI JUAN XXIII	38.7	-0.5	29/09/1986	350,1	&	&	&	&
ALMUDAINA	38.8	-0.4	29/09/1986	204	&	&	&	&
BANYERES DE MARIOLA	38.7	-0.7	29/09/1986	230	&	&	&	&
DENIA CENTRO CIUDAD	38.8	0.1	29/09/1986	217	&	&	&	&
PEDREGUER	38.8	0.03	29/09/1986	231	&	&	&	&
TARBENA CH JUCAR POBLE DE DALT	38.7	-0.1	29/09/1986	241,1	&	&	&	&
TORMOS	38.8	-0.1	29/09/1986	259	&	&	&	&
XALO	38.7	0	29/09/1986	223	&	&	&	&
AGRES, FRUTOS EVA	38.8	-0.5	30/09/1986	268	Advection from the E with DANA	1015	North Sea A	-2.04

Meteorol. station	Lat.	Lon.	Date	mm	Synop. Situat.	hPa	Other synoptic characteristics	WeMOi
CALLOSA D'EN SARRIA	38.6	-0.1	30/09/1986	200	&	&	&	&
CALLOSA D'EN SARRIA EL ALGAR	38.7	-0.1	30/09/1986	216,7	&	&	&	&
GORGA	38.7	-0.4	30/09/1986	232	&	&	&	&
TARBENA CH JUCAR POBLE DE DALT	38.7	-0.1	30/09/1986	218,2	&	&	&	&
COCENTAINA, BOMBERS	38.7	-0.5	03/11/1987	260	Advection from the E with DANA	1011	Bristish Isles A, rhombus pattern	-2.97
DENIA CENTRO CIUDAD	38.8	0.1	03/11/1987	377	&	&	&	&
DENIA, BOMBERS	38.8	0.1	03/11/1987	374,2	&	&	&	&
EL VERGER RACONS	38.9	0.03	03/11/1987	299	&	&	&	&
JAVEA-VIVEROS CHORRO	38.8	0.17	03/11/1987	217,9	&	&	&	&
PEGO CONVENTO	38.8	-0.1	03/11/1987	371,5	&	&	&	&
ORIHUELA 'LOS DESAMPARADOS'	38.1	-1	04/11/1987	316	Advection from the E with DANA	1015	Bristish Isles A	-2.84
PILAR DE LA HORADADA, LO MONTE	37.9	-0.8	04/11/1987	205	&	&	&	&
S. MIGUEL DE LAS SALINAS, CHS	38	-0.8	04/11/1987	265	&	&	&	&
SAN MIGUEL DE LAS SALINAS	38	-0.8	04/11/1987	265	&	&	&	&
SAN PEDRO DEL PINATAR, AYTO	37.8	-0.8	04/11/1987	210	&	&	&	&
ALCALALI	38.8	-0	30/09/1988	218	Trough	1015	Flows from NE on Surface, British Isles A	-1.29
BENISSA CONVENTO	38.7	0.05	30/09/1988	200	&	&	&	&
DENIA CENTRO CIUDAD	38.8	0.1	30/09/1988	200	&	&	&	&
GATA DE GORGOS	38.8	0.09	30/09/1988	206	&	&	&	&
TORMOS	38.8	-0.1	30/09/1988	258,5	&	&	&	&
XALO	38.7	0	30/09/1988	215	&	&	&	&
TORMOS	38.8	-0.1	18/03/1989	223	Advection from the E with DANA	1012	Azores A	-1
PILAR DE LA HORADADA, LO MONTE	37.9	-0.8	03/09/1989	210	Trough	1015	Azores A extended towards the N	-0.38
ABARAN (SIERRA DEL ORO)	38.2	-1.4	04/09/1989	205	Advection from the E	1015	Azores A extended towards British Isles	-0.69

Meteorol. station	Lat.	Lon.	Date	mm	Synop. Situat.	hPa	Other synoptic characteristics	WeMOi
					with DANA			
AGRES, FRUTOS EVA	38.8	-0.5	04/09/1989	200	&	&	&	&
ALMORADI, LAS MORERAS	38	-0.8	04/09/1989	212	&	&	&	&
LAGUNA DE LA MATA	38	-0.7	04/09/1989	250	&	&	&	&
LAGUNA DE TORREVIEJA	38	-0.7	04/09/1989	240	&	&	&	&
RICOTE (LA CALERA)	38.2	-1.4	04/09/1989	219	&	&	&	&
S.MIGUEL DE LAS SALINAS, CHS	38	-0.8	04/09/1989	228	&	&	&	&
SAN MIGUEL DE LAS SALINAS	38	-0.8	04/09/1989	228	&	&	&	&
TARBENA CH JUCAR POBLE DE DALT	38.7	-0.1	04/09/1989	255,6	&	&	&	&
EL VERGER RACONS	38.9	0.03	05/09/1989	242,3	Advection from the E with DANA	1015	Azores-British Isles A	-1.53
GATA DE GORGOS	38.8	0.09	05/09/1989	201	&	&	&	&
PEDREGUER	38.8	0.03	05/09/1989	206	&	&	&	&
GORGA	38.7	-0.4	07/09/1989	210	Advection from the E with DANA	1011	North Atlantic A	-2.1
CALLOSA D'EN SARRIA EL ALGAR	38.7	-0.1	03/05/1992	201	Advection from the NE with DANA	1014	Azores-British Isles A	-0.66
TARBENA CH JUCAR POBLE DE DALT	38.7	-0.1	03/05/1992	200	&	&	&	&
TORMOS	38.8	-0.1	03/05/1992	206	&	&	&	&
VALL DE LA GALLINERA-PATRO	38.8	-0.3	03/05/1992	244	&	&	&	&
TORMOS	38.8	-0.1	08/10/1992	218	Advection from the E with DANA	1014	British Isles A	-1.67
AGRES, FRUTOS EVA	38.8	-0.5	01/02/1993	203	Advection from the E with DANA	1023	Central Europe A	-2.78
ALMUDAINA	38.8	-0.4	01/02/1993	240,5	&	&	&	&
PEDREGUER	38.8	0.03	15/04/1994	266	Advection from the E with DANA	1012	Algeria low; A to the W of British Isles	-1.52
TORMOS	38.8	-0.1	10/09/1996	220	Advection from the E	1013	A to the W of British Isles	-1.88

Meteorol. station	Lat.	Lon.	Date	mm	Synop. Situat.	hPa	Other synoptic characteristics	WeMOi
					with DANA			
DENIA CENTRO CIUDAD	38.8	0.1	11/09/1996	420	Dynamic or Cold-core Low	1007	A to the W of British Isles	-1.71
CALLOSA D'EN SARRIA EL ALGAR	38.7	-0.1	08/04/1997	230	Advection from the E with DANA	1020	Central Europe-Scandinavia-Artic elongate A	-2.68
PEDREGUER	38.8	0.03	08/04/1997	239	&	&	&	&
ALICANTE	38.4	-0.5	30/09/1997	270,2	Advection from the E with DANA	1020	France-North Sea A	-1.07
SAN VICENTE DEL RASPEIG-ST	38.4	-0.5	30/09/1997	209,5	&	&	&	&
ALCALALI	38.8	-0	04/12/1997	230	Dynamic or Cold-core Low	1006	---------------	-1.68
JALON SOLANA	38.8	-0	04/12/1997	221	&	&	&	&
TARBENA C H JUCAR POBLE DE DALT	38.7	-0.1	04/12/1997	250,2	&	&	&	&
VALL DE LAGUARD FONTILLES	38.8	-0.1	04/12/1997	400	&	&	&	&
DENIA, BOMBERS	38.8	0.1	11/11/1999	330	Advection from the E with DANA	1016	British Isles A	-2.41
EL VERGER RACONS	38.9	0.03	11/11/1999	300	&	&	&	&
JAVEA AYUNTAMIENTO	38.8	0.17	11/11/1999	220	&	&	&	&
JAVEA-VIVEROS CHORRO	38.8	0.17	11/11/1999	240,8	&	&	&	&
PEDREGUER	38.8	0.03	11/11/1999	252	&	&	&	&
PEGO CONVENTO	38.8	-0.1	11/11/1999	237,7	&	&	&	&
DENIA CENTRO CIUDAD	38.8	0.1	23/10/2000	220	Advection from the E with DANA	1018	Azores A with bridge with Central Europe A	-2.41
EL VERGER RACONS	38.9	0.03	02/04/2002	230	Trough	1007	Algeria low, NASH	-1.29
PEGO CONVENTO	38.8	-0.1	06/05/2002	251	Dynamic or Cold-core Low	1012	Azores A with bridge with Scandinavian A, flow from the E on surface	-2.1
VALL DE LAGUARD FONTILLES	38.8	-0.1	07/05/2002	300	Dynamic or Cold-core Low	1002	A to the W of British Isles with bridge with Scandinavian A, flow from the E on surface	-2.47

Meteorol. station	Lat.	Lon.	Date	mm	Synop. Situat.	hPa	Other synoptic characteristics	WeMOi
AGRES, FRUTOS EVA	38.8	-0.5	15/04/2003	200	Trough	1010	Russian-Scandinavian A, Algeria low	-2.51
VALL DE LA GALLINERA-PATRO	38.8	-0.3	15/04/2003	210	&	&	&	&
VALL DE LAGUARD FONTILLES	38.8	-0.1	15/04/2003	222,5	&	&	&	&
DENIA CENTRO CIUDAD	38.8	0.1	11/10/2007	210	Advection from the E with DANA	1017	A over European mid-latitudes	-1.59
JALON SOLANA	38.8	-0	11/10/2007	231,9	&	&	&	&
VALL DE LAGUARD FONTILLES	38.8	-0.1	11/10/2007	371,2	&	&	&	&
ALTEA, IVIA	38.6	-0.1	12/10/2007	204,8	Advection from the E with DANA	1017	British Isles A, rhombus pattern	-0.98
BOLULLA	38.7	-0.1	12/10/2007	222	&	&	&	&
DENIA-GATA, IVIA	38.8	0.08	12/10/2007	228,2	&	&	&	&
GATA DE GORGOS	38.8	0.09	12/10/2007	258,9	&	&	&	&
ONDARA, IVIA	38.8	0.01	12/10/2007	218	&	&	&	&
PANTANO DE BENIARRES	38.8	-0.4	12/10/2007	230	&	&	&	&
PEDREGUER	38.8	0.03	12/10/2007	293	&	&	&	&
PLANES, IVIA	38.8	-0.4	12/10/2007	246,2	&	&	&	&
TARBENA C H JUCAR POBLE DE DALT	38.7	-0.1	12/10/2007	227	&	&	&	&
VALL DE LA GALLINERA-PATRO	38.8	-0.3	12/10/2007	333	&	&	&	&
VALL DE LA GALLINERA-PATRO	38.8	-0.3	08/10/2008	205	Trough	1015	Azores A	-0.26
PANTANO DE BENIARRES	38.8	-0.4	10/10/2008	234,6	Advection from the E	1023	Dynamic cold-core low over Morocco, Central Europe A	-3.03
ALMORADI C H SEGURA	38.1	-0.8	28/09/2009	236	Advection from the E with DANA	1018	British Isles A, rhombus pattern	-1.2
PANTANO DE BENIARRES	38.8	-0.4	28/09/2009	202,2	&	&	&	&
TARBENA C H JUCAR POBLE DE DALT	38.7	-0.1	25/01/2010	236	Trough	1022	Flows from the E on surface, Argelia low, high zonal index	-1.8
HUERCAL OVERA	37.4	-1.9	28/09/2012	243,8	Dynamic or Cold-core Low	1008	Azores A with bridge with Russian A	-1.71

Meteorol. station	Lat.	Lon.	Date	mm	Synop. Situat.	hPa	Other synoptic characteristics	WeMOi
PUERTO LUMBRERAS	37.6	-1.8	28/09/2012	204,2	&	&	&	&
PANTANO DE BENIARRES	38.8	-0.4	11/11/2012	220	Dynamic or Cold-core Low	1009	Azores A	-0.57
VALL DE LAGUARD FONTILLES	38.8	-0.1	11/11/2012	230	&	&	&	&
ALMUDAINA	38.8	-0.4	18/12/2016	255	Advection from the E with DANA	1024	NASH with bridge with British Isles-France-Central Europe A	-2.31
PANTANO DE BENIARRES	38.8	-0.4	18/12/2016	200,2	&	&	&	&
TORRE PACHECO, TORRE BLANCA	37.8	-0.9	18/12/2016	221,3	&	&	&	&
TORREPACHECO (TORRE BLANCA)	37.8	-0.9	18/12/2016	202	&	&	&	&
PANTANO DE BENIARRES	38.8	-0.4	19/12/2016	201,5	Dynamic or Cold-core Low	1011	NASH with bridge with Central Europe A	-2.5
PLANES, IVIA	38.8	-0.4	19/12/2016	316,1	&	&	&	&
VALL DE LAGUARD FONTILLES	38.8	-0.1	19/12/2016	213	&	&	&	&
MULA (EMB. DE LA CIERVA)	38.1	-1.5	19/01/2017	330	Dynamic or Cold-core Low	1012	Central Europe A	-2.44
BOLULLA	38.7	-0.1	21/01/2017	217	Dynamic or Cold-core Low	1011	Azores A	-2.04
CALLOSA D'EN SARRIA TOSSAL DE SALOMÃ	38.7	-0.1	21/01/2017	210,8	&	&	&	&
TARBENA CH JUCAR POBLE DE DALT	38.7	-0.1	21/01/2017	338	&	&	&	&