CATALOGATION OF CYCLONES IN THE WESTERN MEDITERRANEAN

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1. Introduction

The Mediterranean is the most cyclogenetic zone of the world. Most of the cyclones are meso-scale and weak (Genovés et al., 1989; INM, 1992, 1993, 1994 and 1995), but some of them are strong and cover a wide area (Radinovic, 1978; Alpert et al., 1990). From the location frequencies of the observed mediterranean cyclones from 1992 to 1995, it seems to exist a close relation between many of them and the orography. In these cases a pressure distribution with strong gradient over the ranges is observed. So, these cyclones can be related to observed local winds (Bessemoulin et al., 1993). In the same way, in most of the heavy-rain events detected over the Western Mediterranean, a cyclone is observed near the heavy-rain area, «determining», sometimes, the locations of it (Jansá et al., 1996). Then, we are interested on knowing if there are any classification of the mediterranean cyclones, their possible origin, frequency, location and relation to the severe weather.

From 1992 the ocurrence of a cyclone in the Western Mediterranean is stored at the Meteorological Center of the Balearic Islands. This database is extracted from hand analysis of pressure charts, so from a subjective way. Otherwise, another database of cyclones in the Western Mediterranean, extracted from a LAM-INM analysis, therefore objective, has been obtained. That was performed from geopotential height at 1000 hPa for the same period (1992-1995).

In this study we did a cyclone catalogation with a cluster analysis for the subjective and objective databases. The frequency and location of each typology for both databases and a comparison between them was obtained.

2. Cluster analysis

The subjective cyclone database was formed with all the cyclones detected in the Western Mediterranean by hand analysis of the pressure charts at 00 and 12 UTC. We used a four year database, from december 1991 until november 1995. Each cyclone is characterized by the date of occurrence, latitude and longitude coordenates of the center, the central and surrounding (at distances of 200 and 400 km) pressure. The selection of cyclones is subjective, including the meso-scale ones, and so it is possible to collect some cyclones which size is less than the shorter grid size used (200 km). For this study we ignored the cyclones with geostrophic vorticity less than 0.8 10^{-4} s^{-1}.

The characteristics of the spatial and seasonal distribution for all the four years can be seen in the Pemmoc (spanish acronym of Western Mediterranean Meteorological Studies Program) Bulletin (INM, 1992, 1993, 1994, 1995 and 1996).

The objective database was formed with the cyclones detected in the Western Mediterranean by the LAM-INM numerical model (0.910 latitude and longitude) at 1000 hPa (Picornell, 1994). We selected the same area, the same period of time and the same lower limit of geostrophic vorticity at 200 km (0.8 10^{-4} s^{-1}).

The election of the variables used in a cluster analysis determines the obtained typologies. We pretend to classify the mediterranean cyclones by their intensity and shape of the pressure distribution. The intensity was characterized with the geostrophic vorticity (calculated with two different grid sizes, 200 and 400 km), $Vort_2$ and $Vort_4$. The pressure distribution was characterized by the symmetry and the eccentricity, both calculated from the differences of pressure at 200 km. The symmetry represents the standard deviation of the pressure differences around the center, and so, the lower the value the more circular the shape. The eccentricity means the difference between the pressure gradient along the NS and EW axis, so the stretching of the pressure shape along one of those axis. Positive values mean a bigger pressure gradient in the NS direction than in the EW direction, and then a stretching in the EW axis, negative values in the NW axis and nearly zero values no stretching in any of both axis. The equations of the four variables are:

$$Vort_2(i) = \frac{\sum_{j=1}^{4} g(i,j)}{4*1.22} [10^{-4} s^{-1}]$$

$$Vort_4(i) = \frac{\sum_{j=1}^{4} g(i,j+4)}{4*4*1.22} [10^{-4} s^{-1}]$$

$$Simmetry(i) = \frac{s(g(i,j))}{\overline{g(i,j)}}$$

$$Eccen(i) = \frac{g_{NS}(i) - g_{EW}(i)}{\overline{g(i,j)}}$$

with $g(i,j)=p(i,j)-p(i,0)$, $s(g(i,j))$ the standard deviation of the pressure differences at 200 km, $g_{EW}(i)= g(i,1)+g(i,3)$, $g_{NS}(i)= g(i,2)+g(i,4)$ and

$$\overline{g(i,j)}$$

the mean of the pressure differences at 200 km (for i=1,..,6437 or 3785 and j=1,..4 for 200 km and j=5,..,8 for 400 km).

The algorithm used in this study was the convergent k-means cluster method, which is a variant of MacQueen's K-means algorithm (Andenberg, 1973; Gong and Richman, 1995). This method minimizes the total within group sum of squares (*E*) for the partition of the database in *k* clusters. *E* decreases as *k* increases, so we chose *k* when the reduction of $E(k)/E(1)$ is not significant. For the subjective database it is when $k=7$. The seed points were formed as the centroids of a partition of each database in 7 grups with the same number of values.

2.1. Subjective database

In the Table 1 we present the mean value of the variables for the whole database and for each one of the obtained centroides. Next, the characteristics of each of the seven obtained typologies are described. For the whole database and for each typology the spatial distribution (Figure 1) and the mean pressure distribution (Figure 2) are shown.

Type 1: these cyclones are weak with both grid sizes, asymmetric and eccentric in the E-W direction. Type 1 is the less frequent, with the 5.9 % of the total. Its seasonal distribution shows a maximun in winter (31.5 %) and a minimum in summer (17.2 %). Most of these cyclones are placed south of Pyrenees. As well as type 7, this typology could be weak orographic cyclones.

Type 2: cyclones with weak vorticity with both grid sizes, quasi-symmetric and eccentric in E-W direction. This type represents the 18.4 % of the total. It is quite spread in all the seasons, with a maximum in autumn (27.8 %) and a minimum in spring (21.7 %). The cyclones of this typologie are located, preferably, at the south of the Pyrenees, Alboran Sea and Algerian Sea. They could be mainly consisting of weak orographic cyclones.

Type 3: weak vorticity in both grid sizes, asymmetric and eccentric in the N-S direction. Type 3 represents the 11.1 % of the total. It has a maximum in autumn (27.9 %) and a minimum in winter (18.3 %). The low centers are located south of Pyrenees, mainland and at the eastern coast of Spain and in the Gulf of Cadiz, and they could be related to the orographic cyclones, weak thermal lows and fronts which crosses the area.

Type 4: cyclones with moderate vorticity in 200 km and weak in 400 km grid size, asymmetric and eccentric in the E-W direction. This type represents the 13.4 % of the total, with a maximum in spring and summer (27.9 %) and a minimum in autumn (18.9 %). Preferably, their cyclones are placed south of Pyrenees. As well as types 1 and 2, they could be orographic cyclones, but more intense than the others.

Type 5: cyclones weak in both grid sizes, symmetrics and non-eccentric. This type is the most frequent type (24.9 %), with a maximum in summer (29.4 %) and a minimum in winter (19.2 %). Their centers are widespread in all the zones.

Type 6: strong cyclones in both grid sizes, quasi-symmetric and non-eccentric. This type is, with the type 1, the less frequent (6.7 %). It presents a maximum in spring (31.2 %) and a minimum in autumn (14.5 %). The low centers are located, preferably, in the Genoa Gulf and South of Pyrenees. They could be intense orographic lows and well developed cyclones.

Type 7: cyclones with moderate vorticity in both grid sizes, symmetric and non-eccentric. This type is formed by the 19.4 % of the total. It presents a maximum in summer (39.1 %) and a minimum (16.0 %) in winter. They are placed, preferably, in the Genoa Gulf and in mainland of Spain. For this reason, their

	Database	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
$Vort_2^*$	2.02	1.51	1.56	1.65	2.60	1.62	3.61	2.38
$Vort_4^*$	0.72	0.43	0.55	0.60	0.79	0.56	1.39	0.95
Simm.	0.51	1.10	0.54	0.73	0.68	0.30	0.52	0.32
Ecce.	0.14	0.64	0.56	-0.57	0.43	-0.02	0.10	0.00

Table 1: Mean values of the variables for the whole manual database and for each of the 7 types. Subjective database. (* Units 10^{-4} s^{-1}).

	Database	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
$Vort_2^*$	1.33	1.07	1.11	1.10	1.74	1.11	2.81	1.76
$Vort_4^*$	0.59	0.44	0.48	0.49	0.82	0.47	1.36	0.82
Simm.	0.62	1.04	0.60	0.82	0.76	0.38	0.47	0.40
Ecce.	0.13	0.62	0.47	-0.37	0.24	-0.05	0.09	0.00

Table 2: Mean values of the variables for the whole database and for each of the 7 types. Objective database. (* Units 10^{-4} s^{-1}).

cyclones could be Genoa cyclones and moderate thermal lows.

2.2. Objective database

As in the subjective database, in Table 2 the mean value of the variables for the database and the centroides of the objective database are shown.

When comparing the results obtained for both databases, some aspects must be considered: first of all, there are less cyclones in the objective one than in the subjective one (a half approximately); second there are some differences in the distribution of the centres. In this way, the objective database does not obtain as many cyclones in the South of Pyrenees and in the Alboran Sea as the subjective one, while in the Genoa Gulf it presents the same, even more, number of cyclones than the subjective one. It can be due to the low resolution (0.910 latitude and longitude) of the objective database as regards the subjective one (Picornell, 1994).

The mean values of vorticity are more intense for the subjective database, mainly with the vorticity at 200 km (2.02 front 1.33 10^{-4} s^{-1}) and less at 400 km (0.72 front 0.59 10^{-4} s^{-1}). Concerning to the shape variables, the symmetry and the eccentricity, the mean values are quite similar. The same behavior can be observed when comparing each type of the manual database with its type of the objective one.

Another difference between both databases is the percentage of elements of each type. Therefore, the manual database has more cyclones of the types 4, 5, 6 and 7 and less of the types 1,2 and 3. Also there are some differences in the spatial and seasonal distribution. These are due to the different origin of the databases. However there is a good agreement between the pressure distribution of the centroides, although the subjective values are always bigger than the objective ones.

3. Conclusions

In this study, we present the results obtained from the catalogation of the cyclones of the Western Mediterranean from two different databases and in an independent way. From a general point of view, it can be established that both databases present the same seven typologies, in their mean values, their spatial and seasonal distributions and the mean pressure values are quite similar. For this reason, we can conclude that these seven groups represent real typologies of cyclones in the Western Mediterranean.

From these results it can be derived that the most of the mediterranean cyclones are of meso-scale, weak, asymmetric and eccentric in the EW direction (types 1, 2 and 4) o symmetric and circular (types 5 and 7). The types 1, 2 and 4 could be orographic, due mainly to the location, near of main ranges oriented in the EW direction. The type 3 could be represented by orographic cyclones (lee coastal trough of Spain mainland), weak thermal lows and some cyclones related to fronts. The type 5 is present in all the area and it could consist of weak and near circular cyclones. The most intense cyclones are type 6, which can cover the intense orographic cyclones (lee of Pyrenees) as well as the developed ones (Genoa cyclones). And finally, the type 7 could represent some of Genoa cyclones and thermal low centers.

Some of the differences between both databases can be explained from the different origin of them. In this way, due to the fact that the analysis of the LAM-INM numerical model smoothes the pressure structures, the manual analysis detects more cyclones than the objective one, especially South of Pyrenees and in the Alboran Sea. Then, the centers detected by the objective analysis are less intense that it could be expected.

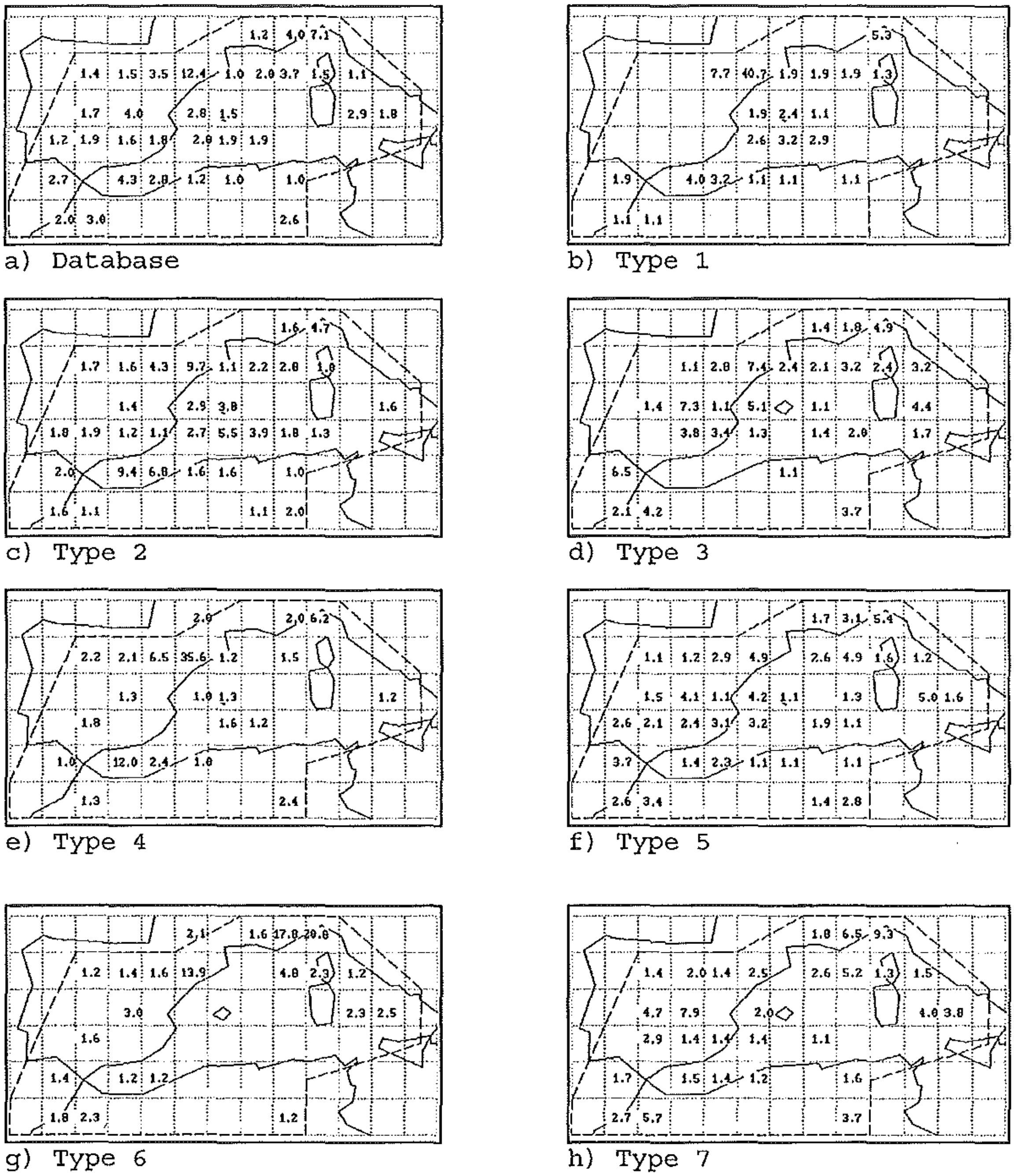

Fig 1: Location frequency (%, >= 1 %) for the whole database and for each type of the subjective database: a) Database, b) Type 1, c) Type 2, d) Type 3, e) Type 4, f) Type 5, g) Type 6 and h) Type 7.

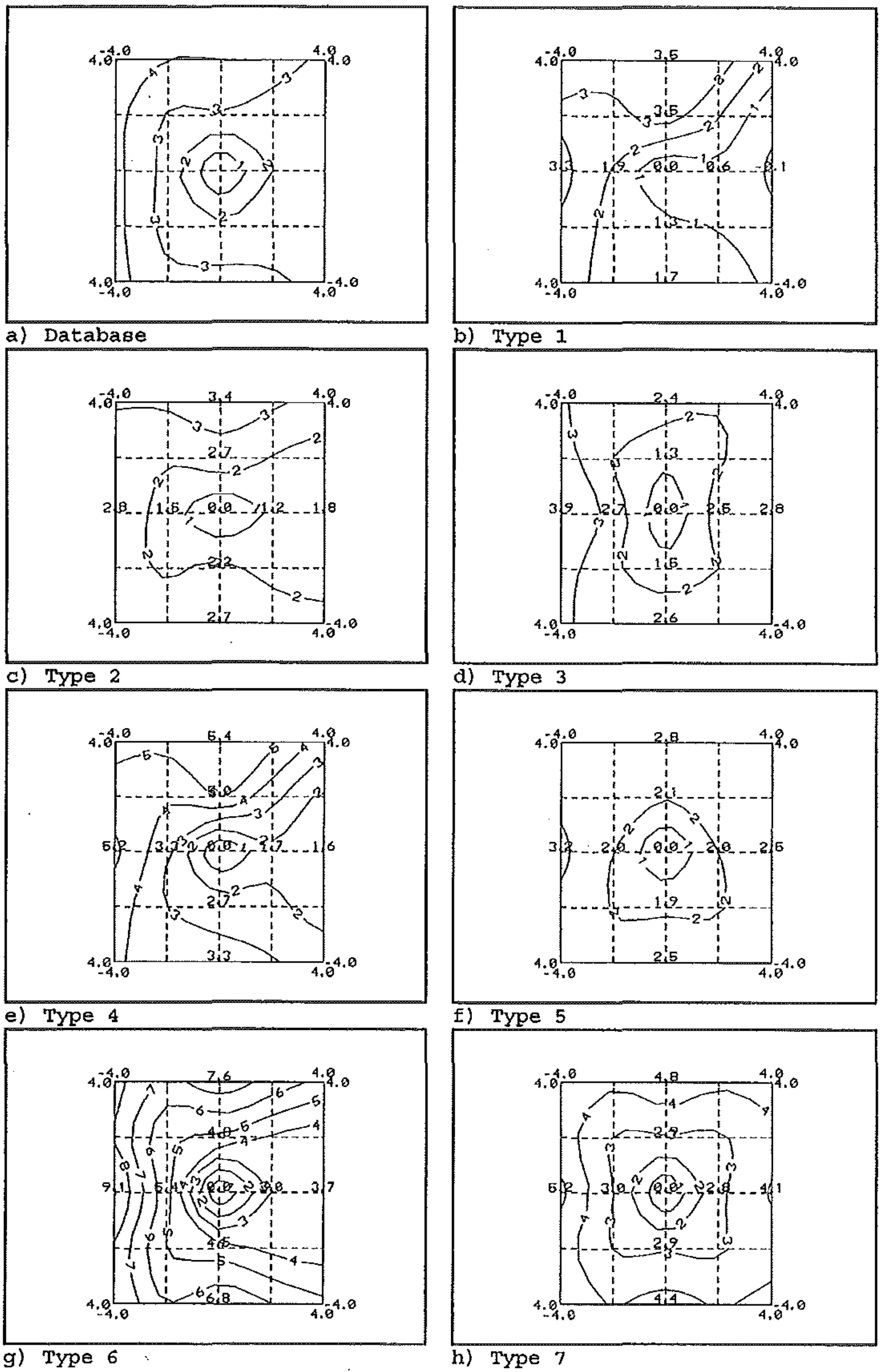

Fig 2 Mean pressure distribution (relative to the center, hPa) for the whole database and for each type of the subjective database: a) database, b) Type 1, c) Type 2, d) Type 3, e) Type 4, f) Type 5, g) Type 6 and h) Type 7.

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