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A synoptic and mesoscale diagnosis of a tornado outbreak in the Balearic Islands

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Abstract

A tornadic event occurred over the Balearic Islands (Western Mediterranean) during the evening of 11 September 1996 and the following night. A total of six tornadoes were observed, affecting populated areas, with an economical damage of more than 6 million Euro. The meteorological situation in which severe weather developed was characterised at low levels by a low covering all the Western Mediterranean with well-marked warm advection towards the Balearic Islands. At mid and upper levels, a low was located to the southwest of the Iberian peninsula, producing southwesterly winds over the region. Satellite imagery shows that the first tornado, observed over the Ibiza Island, was produced by a mature thunderstorm, which presented a well-defined V-shape on the IR images. Tornadoes occurring in Majorca and Minorca islands were produced by convective systems, which were in their initial development state. Most of these tornadogenetic convective systems developed over a low-level convergence line formed as a consequence of the existence of a low moving northeastwards along the south of the Balearics and a very small and deep cyclone formed offshore in front of the Valencia coast. Positive interaction between the low-level convergence line and an upper-level jet streak for producing the lift of low-level parcels has also been identified. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Tornadoes; Balearic Islands; Convective system

1. Introduction

The Balearic Islands, located east of mainland Spain in the Western Mediterranean (see Fig. 1), are affected two to three times every year by tornadic episodes (Gayà et al.,

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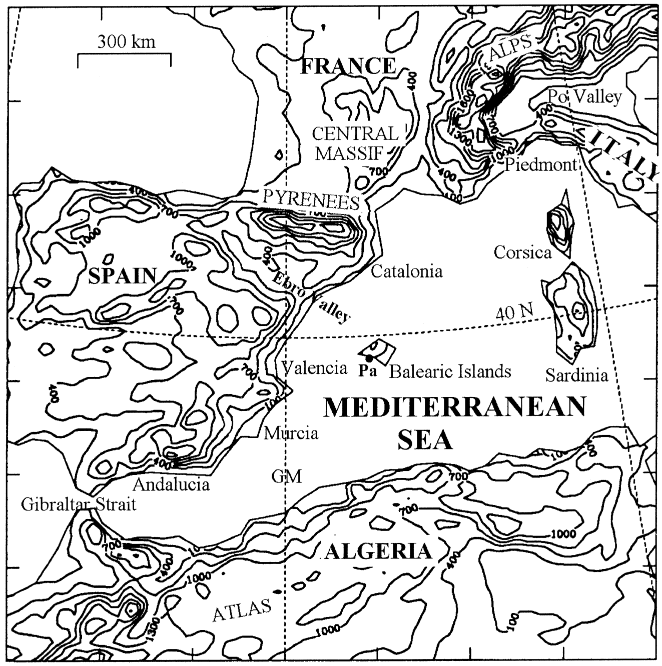

Fig. 1. The western Mediterranean showing the geographical location of the Balearic Islands. Regions referred to in the text are indicated. The radiosonde station of Palma de Mallorca is labelled with Pa.

2000). Most of the tornadoes are classified as F1 category in the Fujita scale (Fujita, 1981), but in some cases, have reached F3. To date, very few studies exist on the meteorological conditions in which tornadoes develop in Spain. As far as we know, Gayà et al. (1997) give a classification of the thermodynamic and synoptic frames in which tornadoes have been observed in the Balearic Islands and Martin et al. (1995) studied the synoptic conditions simultaneous to the development of a tornado on 24 May 1993 in central Spain. A detailed observational study as well as the synoptic and mesoscale meteorological conditions during the development of a tornado in Catalonia (northeastern Spain, see Fig. 1) on 31 August 1994 can be found in Ramis et al. (1997, 1999).

A tornadic event occurred on the 11 and 12 September 1996 in the Balearic Islands. In this event, over a 12-h period, six tornadoes developed, indicating that it was actually a tornado outbreak. In addition, during those days, heavy precipitation occurred in eastern Spain producing floods, and strong winds destroyed boats in some harbours of the Balearics. This event can be considered as a good example of severe weather in the Western Mediterranean.

This paper presents a study of the synoptic and mesoscale conditions during the aforementioned tornado outbreak in the Balearic Islands. The aim of the work is to provide information about the meteorological conditions in which severe weather can occur in Mediterranean Spain. We are also interested in the identification of favourable ingredients and mechanisms for tornadic development in the referred area. Such a study can also be useful for forecasters in the Western Mediterranean. The paper is organised as follows: Section 2 presents the event, the synoptic frame is explained in Section 3, the mesoscale environment is discussed in Section 4, and conclusions are given in Section 5.

2. The event

On the afternoon of 11 September 1996, convection developed over eastern Spain and the Western Mediterranean. Late in the evening a tornado formed over Ibiza Island (see Fig. 2). During the night and early morning of 12 September, five tornadoes more developed—three in the island of Majorca and two in Minorca. Fig. 2 shows the location, time, severity of damage, direction of movement and length of the path for the six tornadoes, as estimated from personal survey of one of the authors (Gayà). Industrial areas in Ibiza and tourist zones in Majorca were affected. In addition, many pines and almond trees were overturned or snapped. Although it is difficult to estimate the damage, this was certainly greater than 6 million Euro (information from insurance companies).

At the same time, heavy precipitation occurred in the Valencia region (see Fig. 1 for location). A precipitation exceeding 450 mm was recorded in coastal region where floods occurred. Fig. 3 shows the precipitation collected from 0700 UTC 11 September to 0700 UTC of the next day. The Balearic Islands were also affected by significant precipitation.

In addition, during the night of 11–12 September, a small cyclone developed offshore of the Valencia coast. This cyclone deepened quickly and moved towards the Balearic

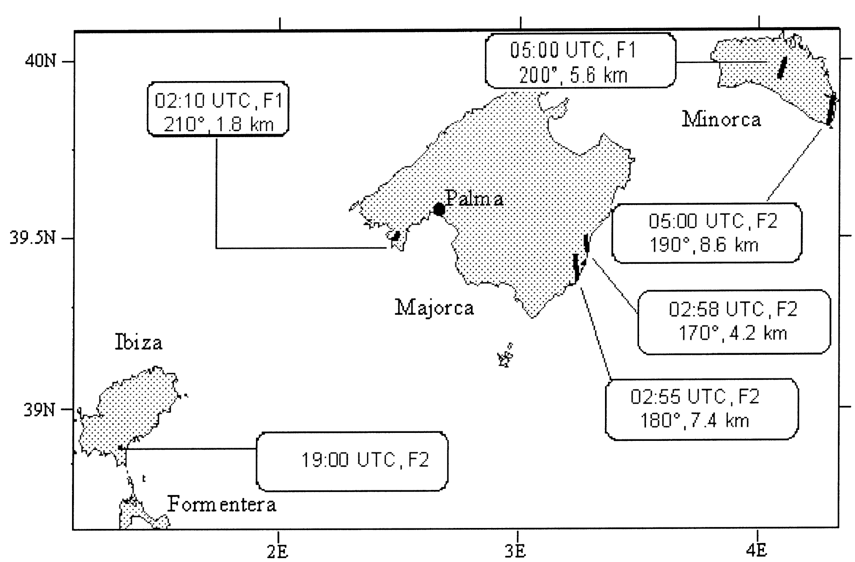

Fig. 2. Location, time, damage severity estimated using the Fujita scale, direction of movement and path length of the six tornadoes observed during the event.

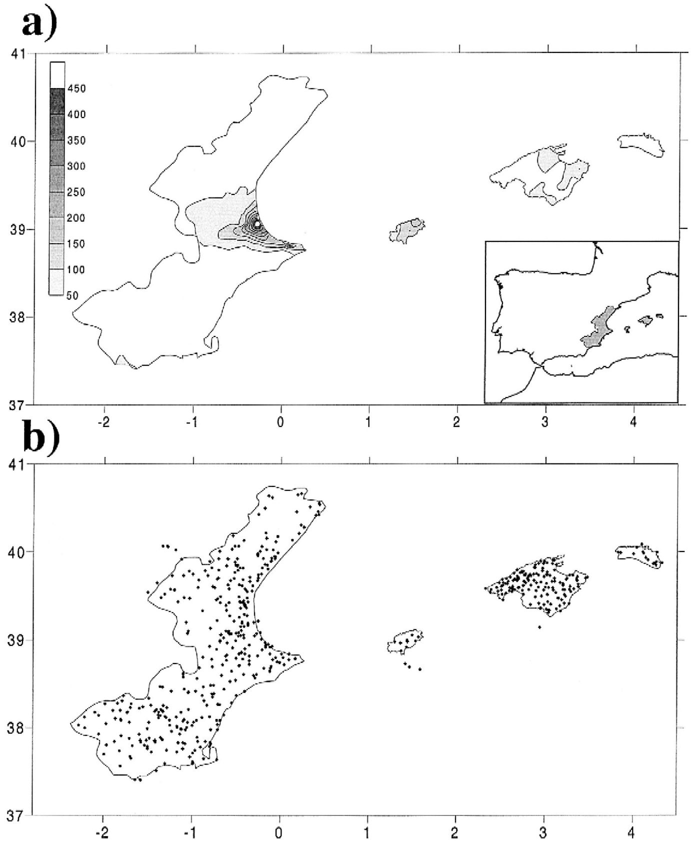

Fig. 3. (a) Analysis of the recorded precipitation (mm) from 0700 UTC 11 September 1996 to 0700 UTC of the next day in the Valencia region and Balearic Islands. (b) Location of the raingauges used to perform the previous analysis.

Islands on 12 September, producing strong winds and damage to many boats in the Palma harbour (see Fig. 2 for location). A detailed description of the cyclone evolution and effects can be found in Gili et al. (1997).

3. Synoptic meteorological settings

This section presents the synoptic frame in which convection developed over the Western Mediterranean and a diagnostic study of the large-scale ingredients which favour sustained convection. Triggering mechanisms will be considered in the next section. This way of defining the problem follows the ideas of Rockwood and Maddox (1988) and Doswell (1987): the synoptic scale provides the appropriate environment for convective development, but mesoscale processes determine when and where convection

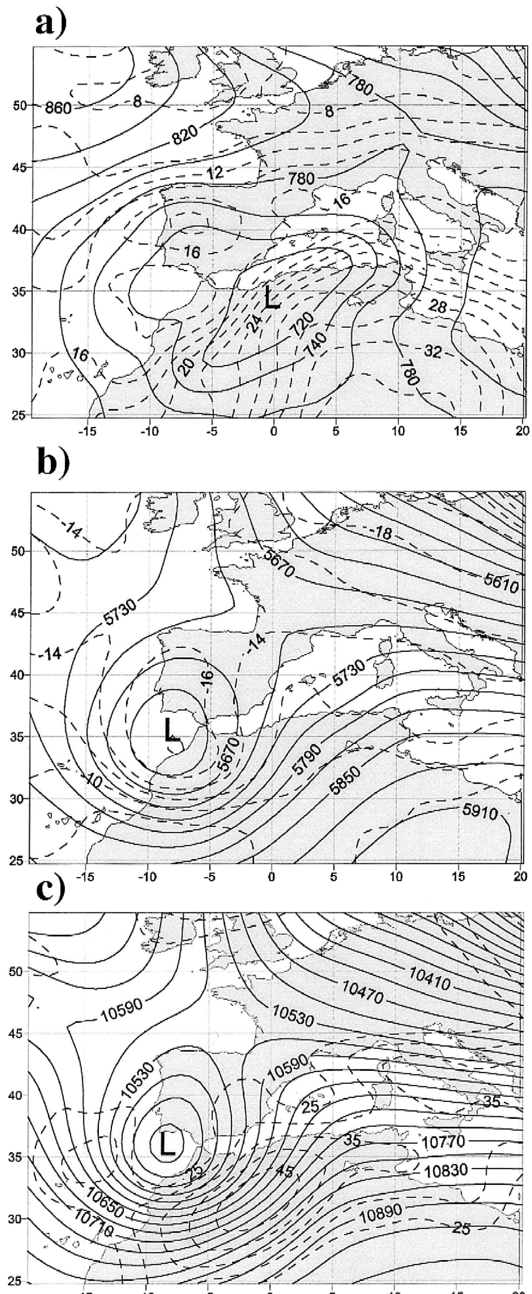

Fig. 4. Synoptic situation (ECMWF analysis) on 11 September 1996 at 1200 UTC at (a) 925, (b) 500 and (c) 250 hPa. In (a) and (b) isohypes (gpm, solid lines) and isotherms (°C, dashed lines), in (c) isohypes (gpm, solid lines) and isotachs (m s^{-1}, dashed lines).

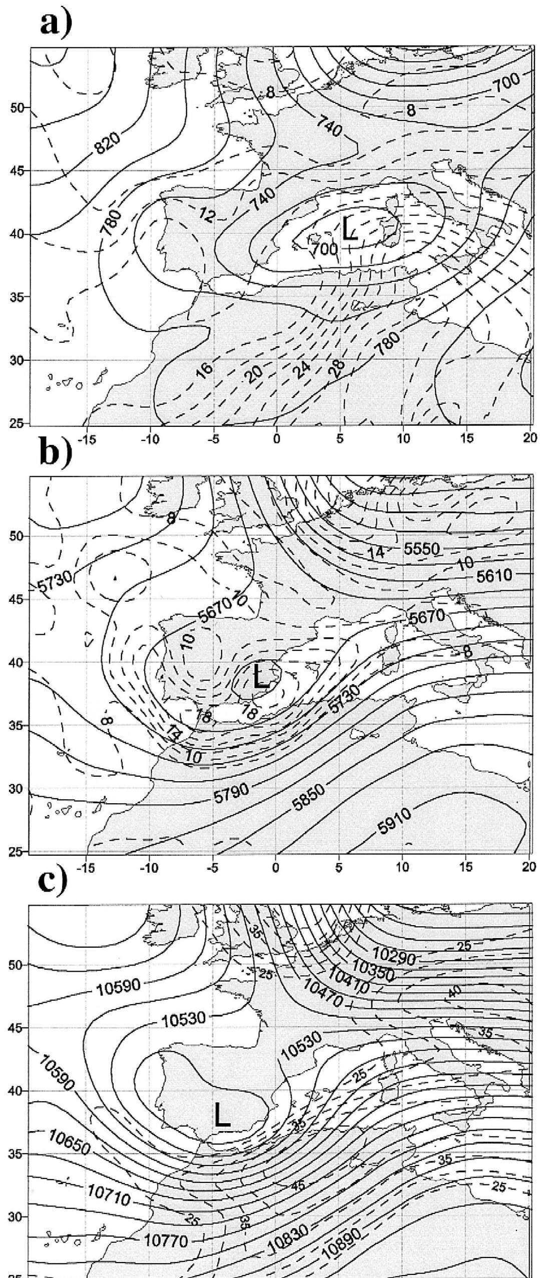

Fig. 5. Synoptic situation (ECMWF analysis) on 12 September 1996 at 0600 UTC. In (a) isohypes (gpm, solid lines) and isotherms (°C, dashed lines) at 925 hPa; in (b) isohypes (gpm, solid lines) and isolines of absolute vorticity (10^{-5} s^{-1}, dashed lines) at 500 hPa; and in (c) isohypes (gpm, solid lines) and isotachs (m s^{-1}, dashed lines) at 250 hPa.

develops by providing enough lift to allow parcels to reach their level of free convection.

ECMWF analyses on 11 September at 1200 UTC show that at low levels, a short baroclinic wave with a frontal system (warm–cold) was over the North African coast (Fig. 4a). The Western Mediterranean, the Iberian peninsula as well as North Africa were under the influence of the cyclonic circulation. Warm advection was evident over the Balearic Islands and the eastern Spanish coast. At mid-tropospheric levels (500 hPa, Fig. 4b), a low with cold core was located to the southwest of the Iberian peninsula. Over the Western Mediterranean, there was a negatively tilted ridge with relatively warm air. The major centre of vorticity associated with the low was sited over North Africa, close to the Atlantic coast. Thus, insignificant vorticity advection existed over the Western Mediterranean, in particular over the Spanish coast and Balearic Islands. At

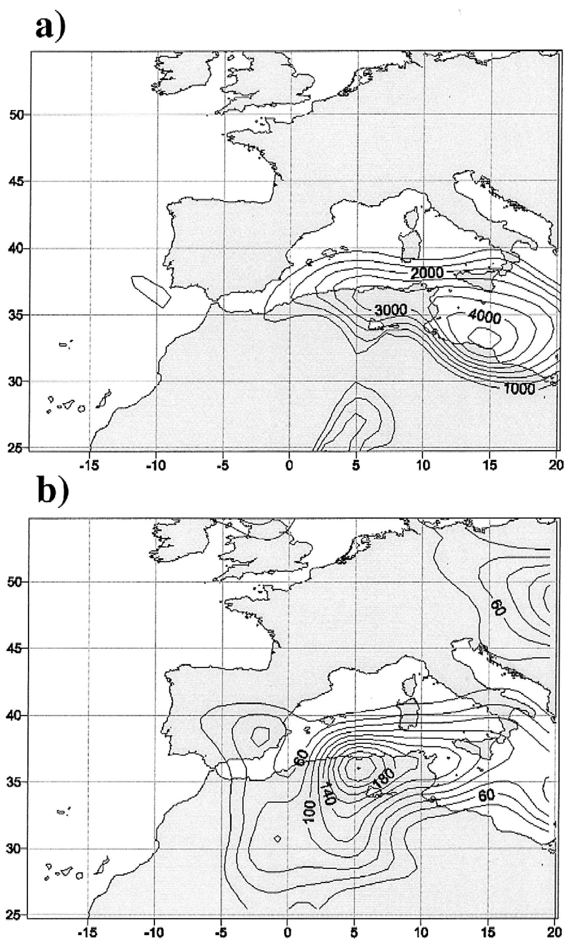

Fig. 6. Spatial distribution of (a) CAPE (J kg^{-1}) and (b) SRH (m^2 s^{-2}) on 11 September 1996 at 1200 UTC, deduced from ECMWF analyses.

upper tropospheric levels (250 hPa, Fig. 4c) the situation was very similar to 500 hPa. The major feature was the existence of a southwesterly jet streak with its exit region over the African Mediterranean coast.

The situation evolved very slowly in such a way that at low levels on 12 September at 0600 UTC (Fig. 5a), the low centre was located over the western Mediterranean to the east of the Balearic Islands. The frontal system can still be clearly identified, with warm advection continuing north of the Balearic Islands, but with minor intensity over the Mediterranean Spanish coast. At mid-tropospheric levels (500 hPa, Fig. 5b) the low had moved towards the Mediterranean and the major vorticity centre shifted northeastwards, over the African coast. Then, during the first hours of 12 September, the upward vertical forcing due to differential vorticity advection became moderate over the Western Mediterranean. At 250 hPa (Fig. 5c), the low also has displaced towards the Mediterranean. The jet streak has also moved to the east and its exit region was over the south of Italy.

A review of the synoptic situation demonstrates that the warm advection at low levels over the Western Mediterranean towards the Balearic Islands and eastern Spanish coast can present a mechanism for increasing the latent instability of the region since temperature advection at mid-levels was very weak. In addition, quasi-geostrophic theory demonstrates that warm advection itself is an upward forcing for vertical motion, which favours the convective development (Doswell, 1987). At mid-tropospheric levels during the later hours of the 11 September, there was no significant dynamical upward vertical forcing identifiable over the area of interest since notable vorticity and temperature advection were far to the south and southwest. However, downward forcing was also not evident over that area, so no opposition existed at that levels for compensating the low-level forcing and restraining upward motions. During the first hours of 12 September, the low-level warm advection was still notable and the mid-level positive

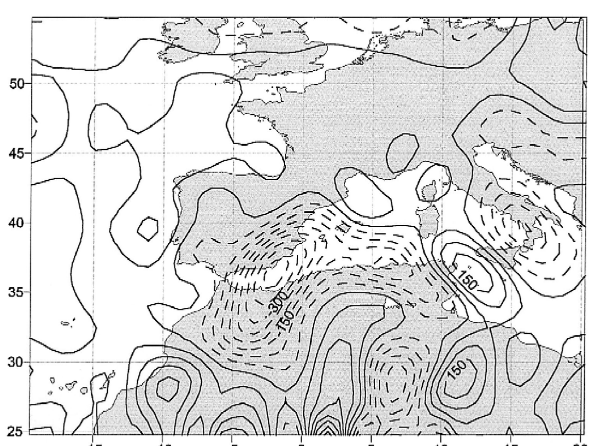

Fig. 7. Spatial distribution of integrated water vapour divergence (units of 10^{-3} g m^{-2} s^{-1}) in the layer 1000–850 hPa on 11 September 1996 at 1200 UTC, deduced from ECMWF analyses. Dashed lines depict negative values (convergence).

vorticity advection had increased over the Balearic Islands area. In order to confirm the previous qualitatively derived forcings, a Q-vector analysis as proposed by Hoskins and Pedder (1980) was used. It revealed that at low levels an upward vertical forcing existed which moved northeastwards from south Valencia at 1800 UTC 11 September to the northeast of the Balearic Islands at 0600 UTC 12 September. At mid-levels, the greatest upward vertical forcings were associated with the vorticity advection accompanying the low so being far to the southwest at the first hours of the episode but affecting significantly the Balearic Islands area in the later hours of the event.

More information about the influence of the large-scale environment on deep convection can be obtained looking at the spatial distribution of Convective Available Potential Energy (CAPE; Weisman and Klemp, 1986), helicity (H, Lilly, 1986) and storm-relative helicity (SRH, Davies-Jones et al., 1990). The CAPE defines the positive buoyant energy available to a parcel as it rises from its level of free convection upward

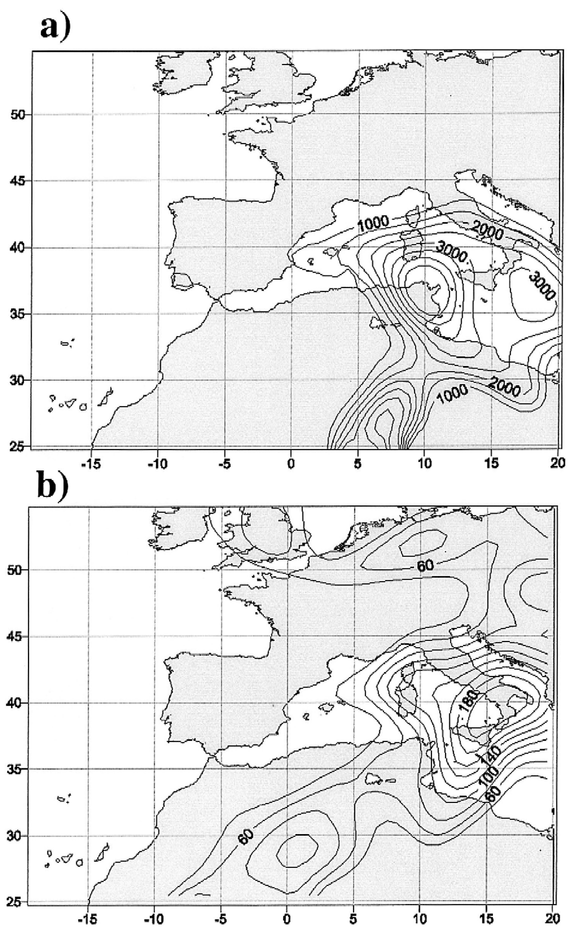

Fig. 8. As in Fig. 6 but on 12 September 1996 at 0600 UTC.

through the depth of a cloud. Helicity provides a measure of the horizontal stream-wise vorticity available for producing rotation in thunderstorm updrafts as the horizontal vortex tubes are tilted vertically in convective cells. Helicity is also a measure of the vertically integrated temperature advection in the considered layer (Tudurí and Ramis, 1997). SRH has the same interpretations as helicity but referred to a coordinate system moving with the thunderstorm. In this sense, Fig. 6 shows that, on 11 September at 1200 UTC, CAPE presented a spatial distribution in such a way that the highest values were far from the Balearic Islands. However, values up to 1000 J kg^{-1} were present over the Balearic Islands and southeastern Spanish coast. The SRH, calculated between 1000 and 700 hPa (roughly 3000 m) and estimating storm motion by using the rule 30R75 (Davies and Johns, 1993) presented also, at the same time, important values over the Western Mediterranean, reaching 60 m^2 s^{-2} over the Balearic Islands. Davies-Jones et al. (1990) have shown that environments with slightly higher values of SRH than the calculated from the ECMWF analysis over the Balearic Islands, are able to produce mid-level mesocyclones in thunderstorms.

Convergence of water vapour at low levels also provides information about the capability of large-scale environment to develop and sustain convection. Fig. 7 shows the water vapour convergence field for the layer 1000–850 hPa on 11 September at 1200 UTC. The convergence was significant over most of the Western Mediterranean with the highest values obtained over the southeastern Spanish coast.

Thus, synoptic diagnosis reveals that on 11 September at 1200 UTC, there were large-scale ingredients such as upward vertical motion, moderate CAPE and SRH values, and significant water vapour convergence, which could favour the development of convection over the area surrounding the Balearic Islands.

At 0600 UTC of 12 September 1996, the spatial distribution of CAPE (Fig. 8a) shows values between 1000 and 1500 J kg^{-1} over the Balearic Islands, with the highest values still far to the east of the area of interest. Moreover, the SRH decreased in the Western Mediterranean (Fig. 8b), with the main nucleus displaced towards Italy. Even so, the

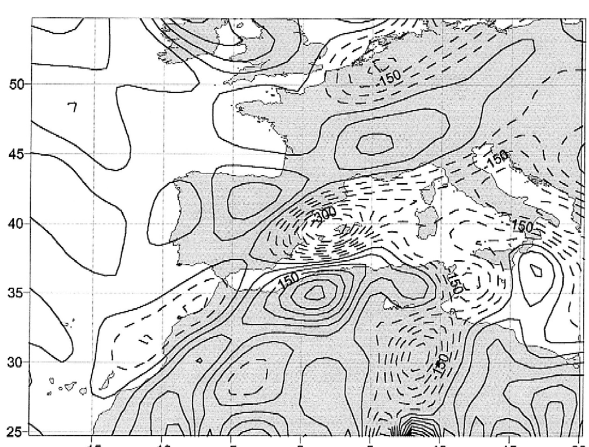

Fig. 9. As in Fig. 7 but on 12 September 1996 at 0600 UTC.

water vapour divergence field for that time (Fig. 9) shows an important convergence nucleus located over the Balearic Islands. Therefore, by the early hours of 12 September, the large-scale environment appears to have maintained its capability to sustain convection, but its potential to provide rotation to the updrafts in thunderstorms seems to be diminished

There is evidence that upper tropospheric and stratospheric dry intrusions towards medium and low tropospheric levels favours the generation of instability (Griffiths et al., 2000). The possibility of the existence of dry intrusions can be studied through the analysis of the Potential Vorticity (PV). In a sense, Fig. 10 shows the PV at 250 hPa on 11 September at 1800 UTC and 12 September at 0600 UTC calculated from the ECMWF data. Fig. 10a depicts values up to 7 PVU (Potential Vorticity Unit, 10^{-6} K m^2 s^{-1} kg^{-1}) to the southwest of the Iberian peninsula, associated with the aforementioned upper-level low. Fig. 10b shows a centre of 5 PVU sited over the south of Spain

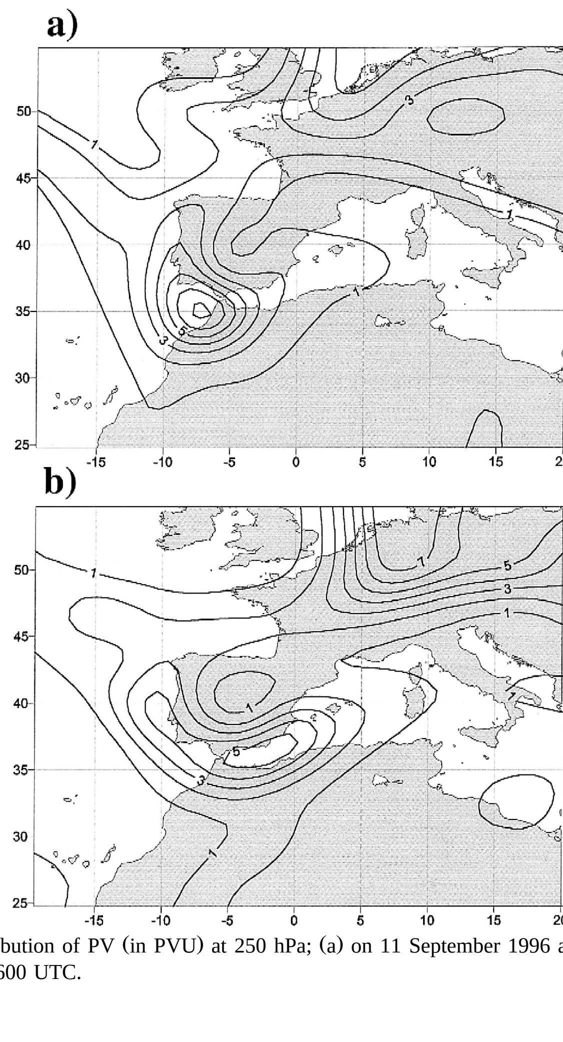

Fig. 10. Spatial distribution of PV (in PVU) at 250 hPa; (a) on 11 September 1996 at 1800 UTC, (b) on 12 September 1996 at 0600 UTC.

and values of up to 3–4 PVU are obtained over the Balearic Islands. In addition, values up to 1.0 PVU are found to the south of the Iberian peninsula at 400 hPa on 11 September at 1800 UTC. In the following hours, the PV at 400 hPa increased, achieving values greater than 1.3 PVU on 12 September at 1200 UTC over the Balearic Islands. The large values found in the area of interest indicate that dry upper tropospheric intrusions could have occurred. Furthermore, these PV positive anomalies could have had a significant role in the development of the small cyclone offshore of the Valencia coast which, as it is presented later, contributed decisively to the thunderstorms formation over Majorca and Minorca.

4. Mesoscale study

Mesoscale features determine, in an appropriate large-scale environment for convection, when and where convective cells develop by providing the lifting mechanism for low-level parcels to reach their level of free convection. To identify these features, it is necessary to use the available raw meteorological information in order to identify systems that operational objective analyses filter. In such mesoscale analyses, satellite information results are often decisive for identifying small systems that can explain development of convection. When the major area of interest is over the sea, there is usually a lag of data and new difficulties appear. It may be necessary to include conceptual models of the pressure distribution around a thunderstorm (Scofield and Purdom, 1986) or around a range mountain when a pressure dipole forms (Bessemoulin et al., 1993). It is well known that identifying mesoscale systems in convective studies is a difficult task.

Fig. 11a shows the Meteosat IR image on 11 September at 1430 UTC. A cloud band with a northwest–southeast direction is identified over the Spanish Mediterranean coast. This band had a displacement northeastward. In front of it an incipient convective cell can be identified. When the cloud band arrived at the convective cell, it had a fast development as can be observed in Fig. 11b. This convective system moved eastwards, to the right of the wind at mid-troposheric levels, arriving over Ibiza Island at 1830 UTC. Fig. 11c shows the convective system at that time. It is clearly identifiable the feature known as V-shape (McCann, 1981) in which overshooting tops and warm spot emerge. The V-shape is a reasonable evidence of the convection severity. The radar installed in the Valencia region does not provide clear information about whether or not the convective cell over Ibiza can be considered a supercell. In fact, Fig. 12 shows the Z-max radar product (obtained from a volumetric scan and considering for each point the maximum reflectivity in the column) and only a slight signature of a hook echo shape emerges. Moreover, a weak echo region (WER) is also suggested from the zonal projection (upper panel) of the convective cell. Although these are not strict evidences for the supercellular character of the system, they appear as good signatures of the convective strength. Unfortunately, no radar information is available for the central and east Balearic Islands area, and Doppler velocity fields are not available to investigate the existence of a mesocyclone.

An analysis of the radiosonde ascent in Palma (Pa in Fig. 1) provides information about the convective environment. Fig. 13 shows the sounding and the wind hodograph

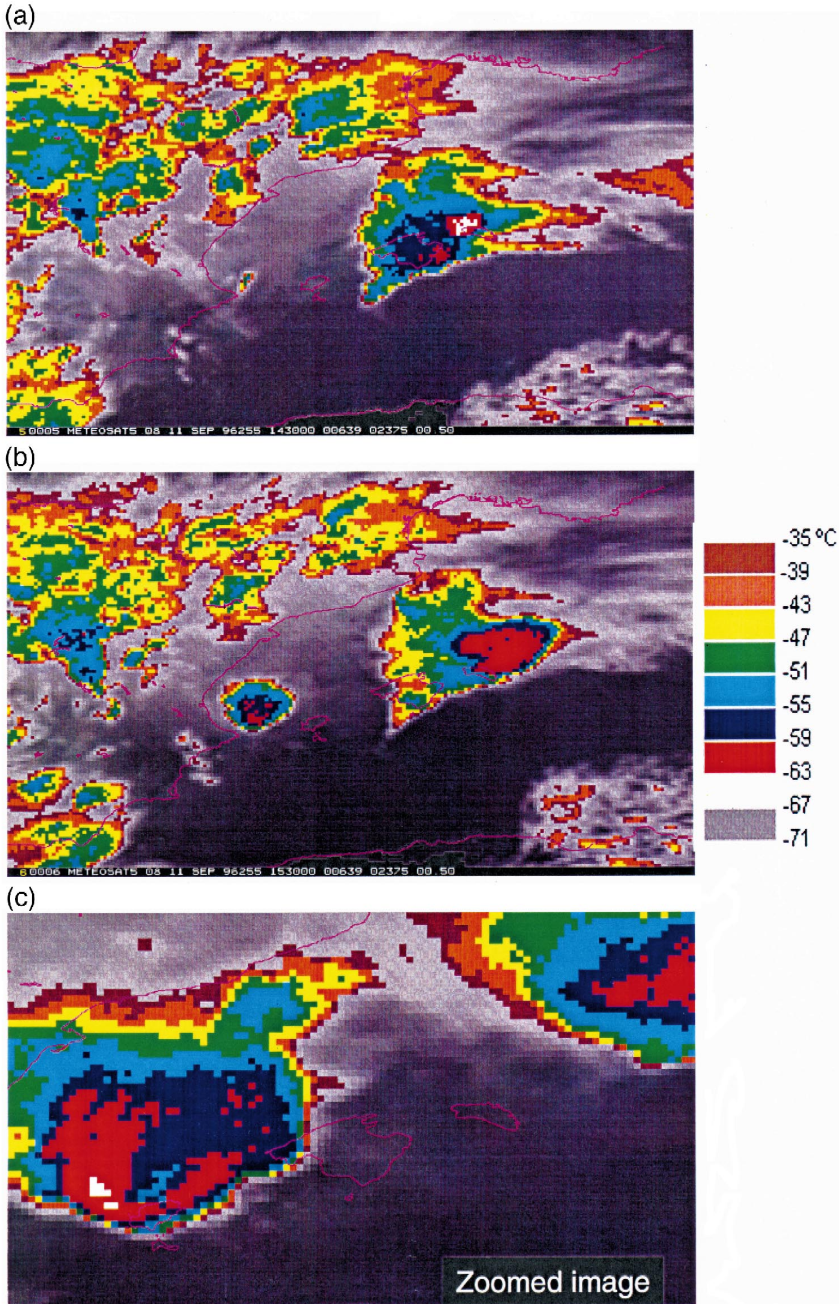

Fig. 11. Meteosat IR images on 11 September 1996; (a) at 1430 UTC, (b) at 1530 UTC and (c) at 1830 UTC (zoomed image). Colour scale indicates temperature.

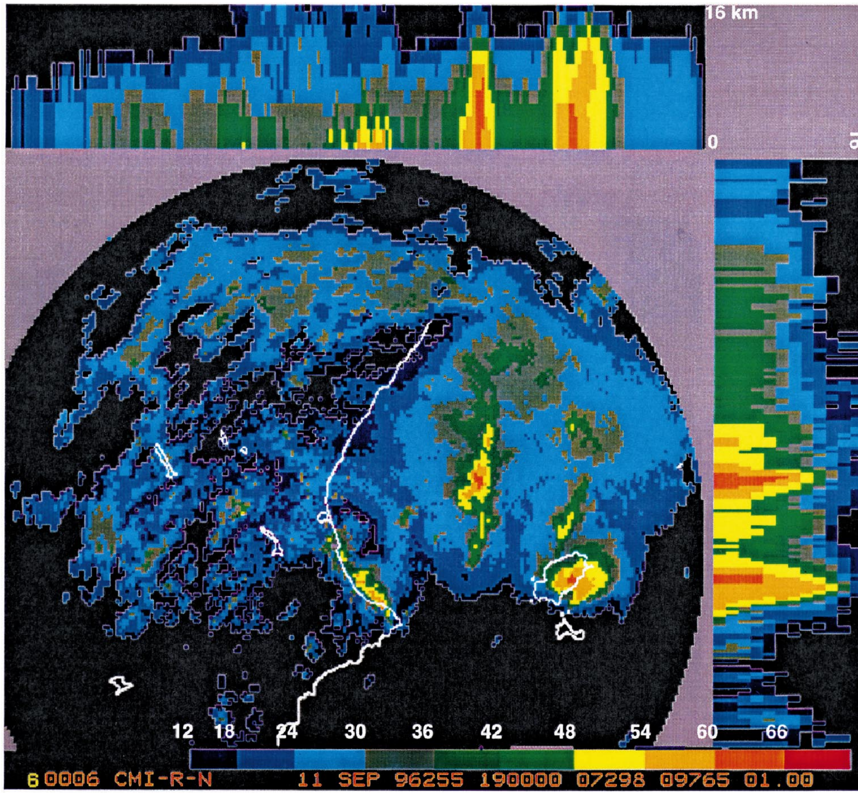

Fig. 12. Z-max images as derived from the radar in Valencia on 11 September 1996 at 1900 UTC. Color scale indicates reflectivity (dBZ).

from 11 September at 1200 UTC. The sounding attained only 200 hPa but some parameters can still be calculated. The CAPE is 2485 J kg^{-1}, a higher value than that obtained from the ECMWF gridded analyses. The K-index is 30, the Total Total's index 45 and the Lifted index -0.6 (see Tudurí and Ramis, 1997 for a review of the stability indices). The estimated SRH using the 30R75 rule (Davies and Johns, 1993) is 377 m^2 s^{-2}. In such an environment, the energy–helicity index (EHI; Davies, 1993) attains a value of 5.8. This large value suggests that the environment is able to support supercell developments. Vertical distributions of temperature and humidity (see Fig. 13a) are very similar to that found by McCaul (1991) for close proximity hurricane–tornado soundings. Since humidity is very high in all the troposphere (precipitable water is 36 mm) it looks favourable for producing heavy rain (Barnes and Newton, 1986). Analysis of surface data on 11 September at 1800 UTC (Fig. 14) demonstrates that the low over the Western Mediterranean was deeper than it was deduced from ECMWF analyses (Fig. 4) and that it was located to the south of the Balearic Islands. It also depicts that the warm and humid tongue extended more westwards than that indicated by the ECMWF analyses. Thus, the eastern flank of the low provides warm and humid air to the convection.

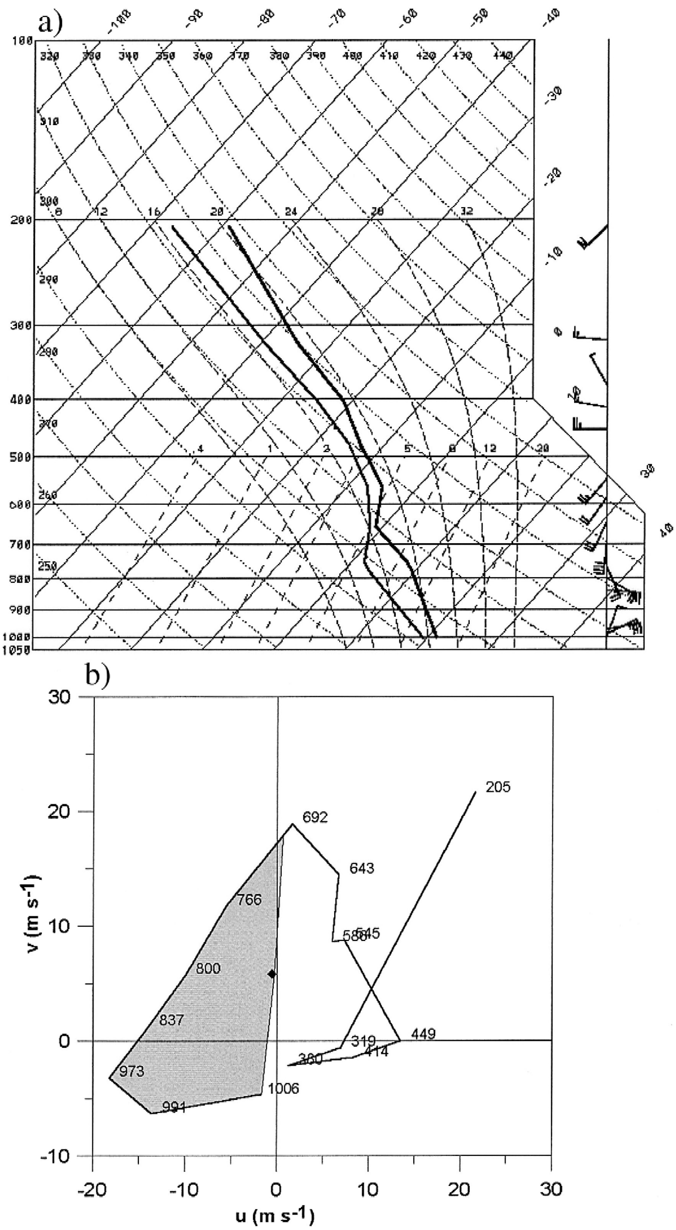

Fig. 13. (a) Skew-T plot of the sounding and (b) hodograph at Palma de Mallorca (Pa in Fig. 1) for 11 September at 1200 UTC. Black dot indicates the storm velocity calculated using the rule 30R75. The shaded zone represents SRH.

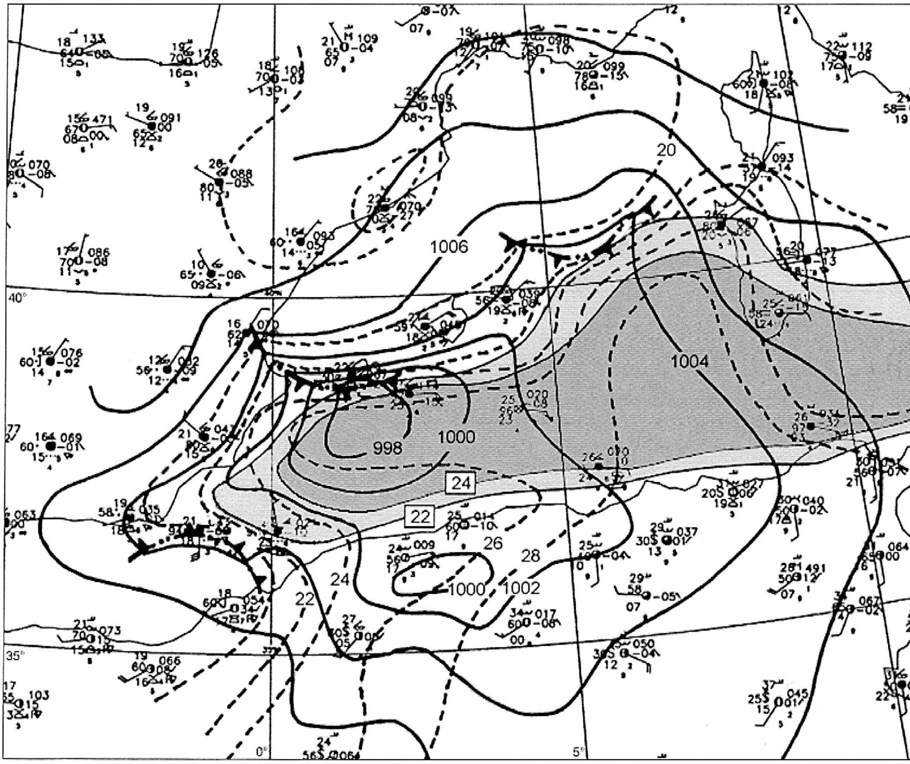

Fig. 14. Mesoscale hand analysis of surface pressure on 11 September 1996 at 1800 UTC. Isobars (hPa) in solid lines and isotherms (°C) in dashed lines. Light and dark shaded regions indicate dew point values greater than 22°C and 24°C, respectively.

During the night, a low-level cloud band oriented northwest–southeast approached Majorca. Over its western flank, a convective system developed and produced a tornado on the western side of the island. Fig. 15 shows the cloud band and the aforementioned convective system. It also shows incipient convection over the cloud band from which two tornadoes developed on the eastern flank of Majorca. Tornadogenesis, which occurs in incipient strong convection, has been previously observed by Brady and Szoke (1989). The new convective system over eastern Majorca grew very quickly and moved northeastwards.

The sounding in Palma on 12 September at 0000 UTC (Fig. 16) demonstrates that the environment was more favourable for convective development than 12 h before. However, this sounding must be carefully interpreted since it is contaminated by convection. In fact, the aforementioned tornadic storm moved from Ibiza to Majorca, where it arrived at about 2300 UTC. Consequently, only the SRH has been estimated using the rule 30R75, which attains 92 m^2 s^{-2}, large enough for the environment to support mesocyclones. The surface pressure analysis on 12 September at 0300 UTC (Fig. 17) shows that a small cyclone formed offshore of the Valencia coast. The low centre previously identified to the south of Ibiza (Fig. 14) moved to the northeast and

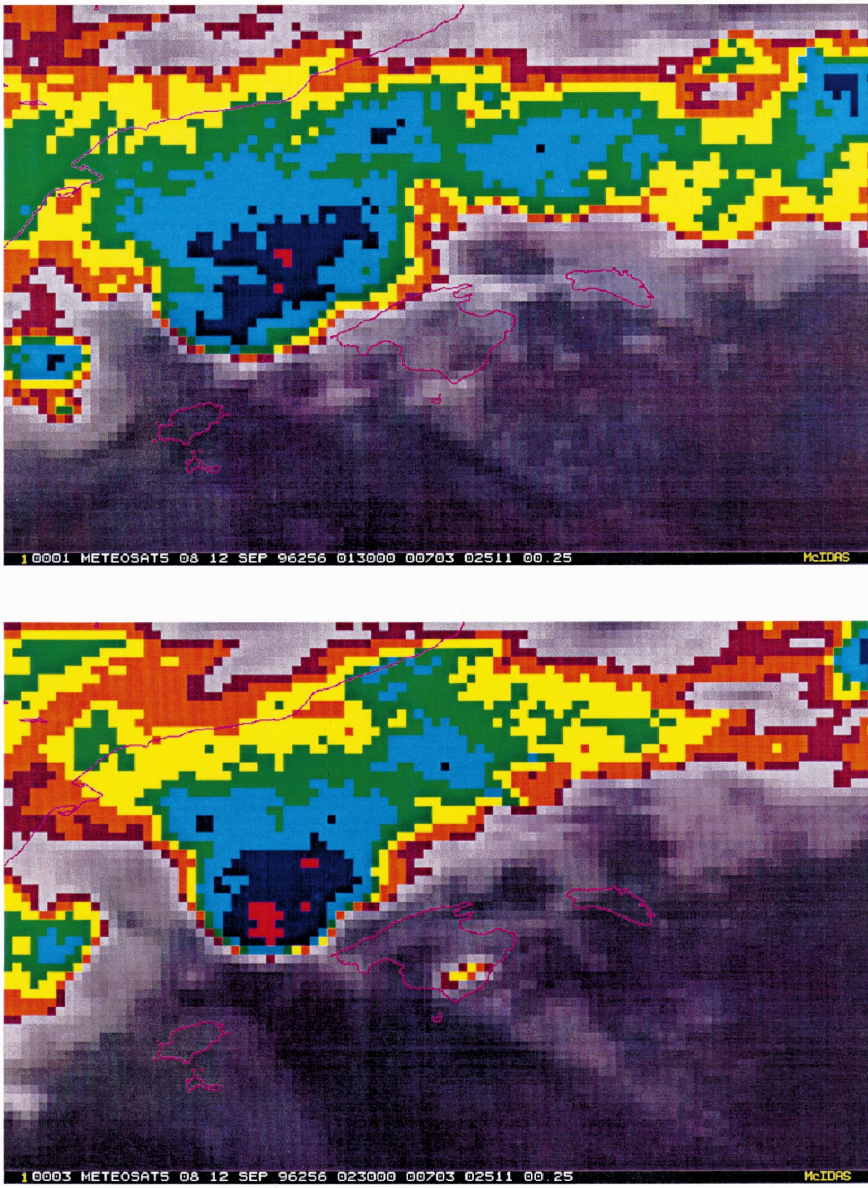

Fig. 15. Meteosat IR image on 12 September 1996 at 0130 and 0230 UTC. Colour scale as in Fig. 11.

was located very close to Majorca. Combination of both systems small cyclone and the main low, are responsible for the formation of a convergence line, which is observed at this time over Majorca. This converge line moved associated with the main low. The pass of the convergence line over Majorca can be identified by a backing of the wind from northeast to southwest, both measured at the automatic weather stations. Fig. 18

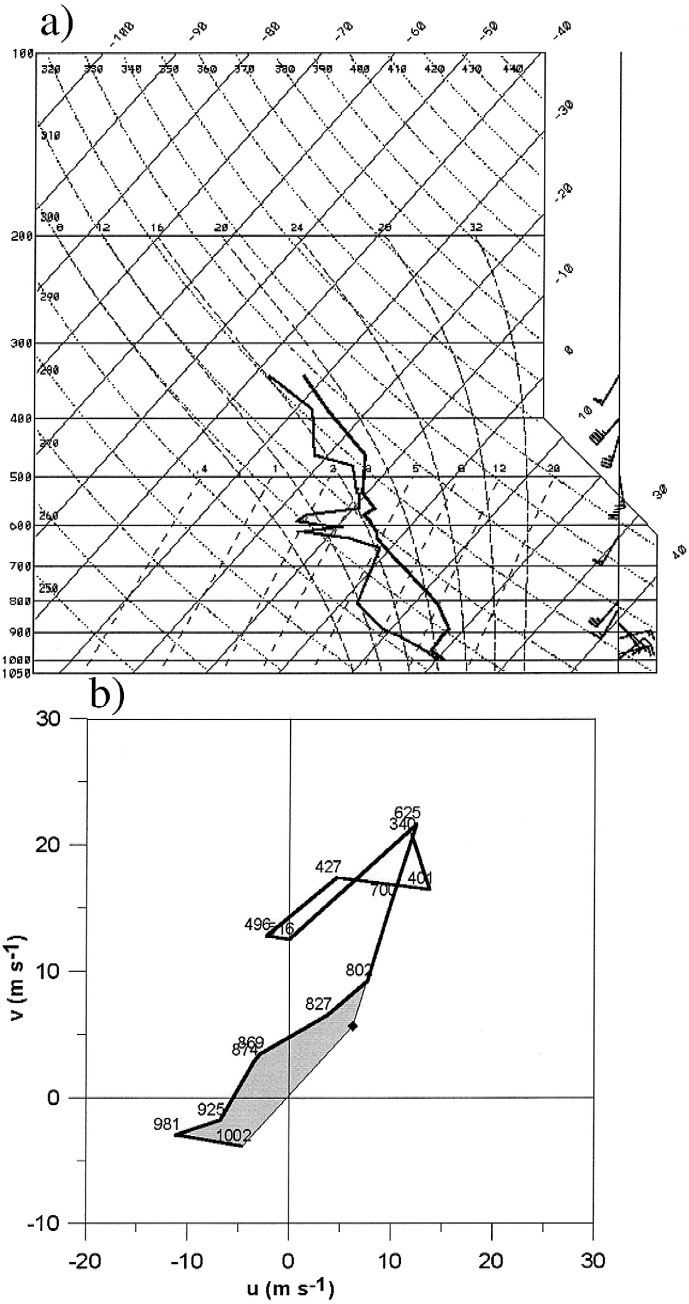

Fig. 16. As in Fig. 13 but on 12 September 1996 at 0000 UTC.

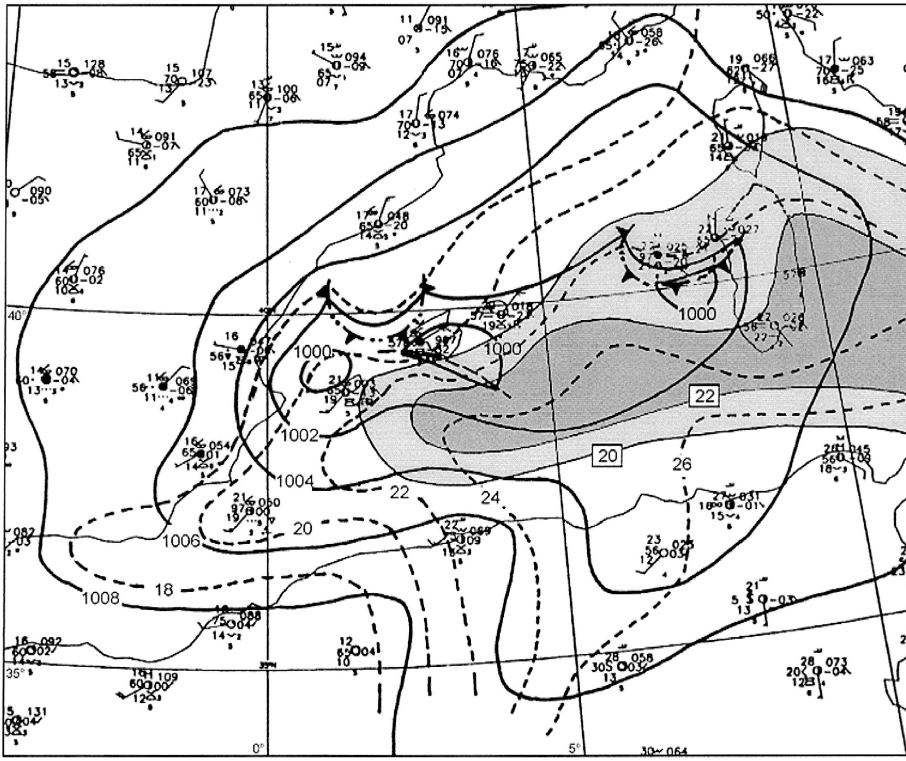

Fig. 17. Mesoscale hand analysis of surface pressure on 12 September 1996 at 0300 UTC. Isobars (hPa) in solid lines and isotherms (°C) in dashed lines. Light and dark shaded regions indicate dew point values greater than 20°C and 22°C respectively.

shows the winds observed at 0200 and 0300 UTC, and it reveals the change in the wind direction, from which the location of the convergence line can be estimated. To northeasterly winds over Majorca maintained its direction during several hours previous to the pass of the convergence line and afterwards, it kept with a southeasterly orientation several hours more.

Over the next few hours, the main low as well as the cloud band continued their displacement towards the northeast. The convective system, which formed over eastern Majorca, increased its size and a tornado developed when arrived over Minorca. At the same time, as Fig. 19 shows, a new convective system was in an incipient state over the cloud band in eastern Minorca. This new system developed another tornado at 0500 UTC.

Surface pressure analysis on 12 September at 0600 UTC (Fig. 20) also reflects how the small cyclone produced winds from the southwest over Ibiza and Majorca. The main low continued its displacement towards the northeast as well as the convergence line associated with it. The humid and warm air tongue continued its progress eastwards following the main low. The lifting mechanism for low-level parcels then can be attributed to that indicated convergence line, which progressed towards the northeast

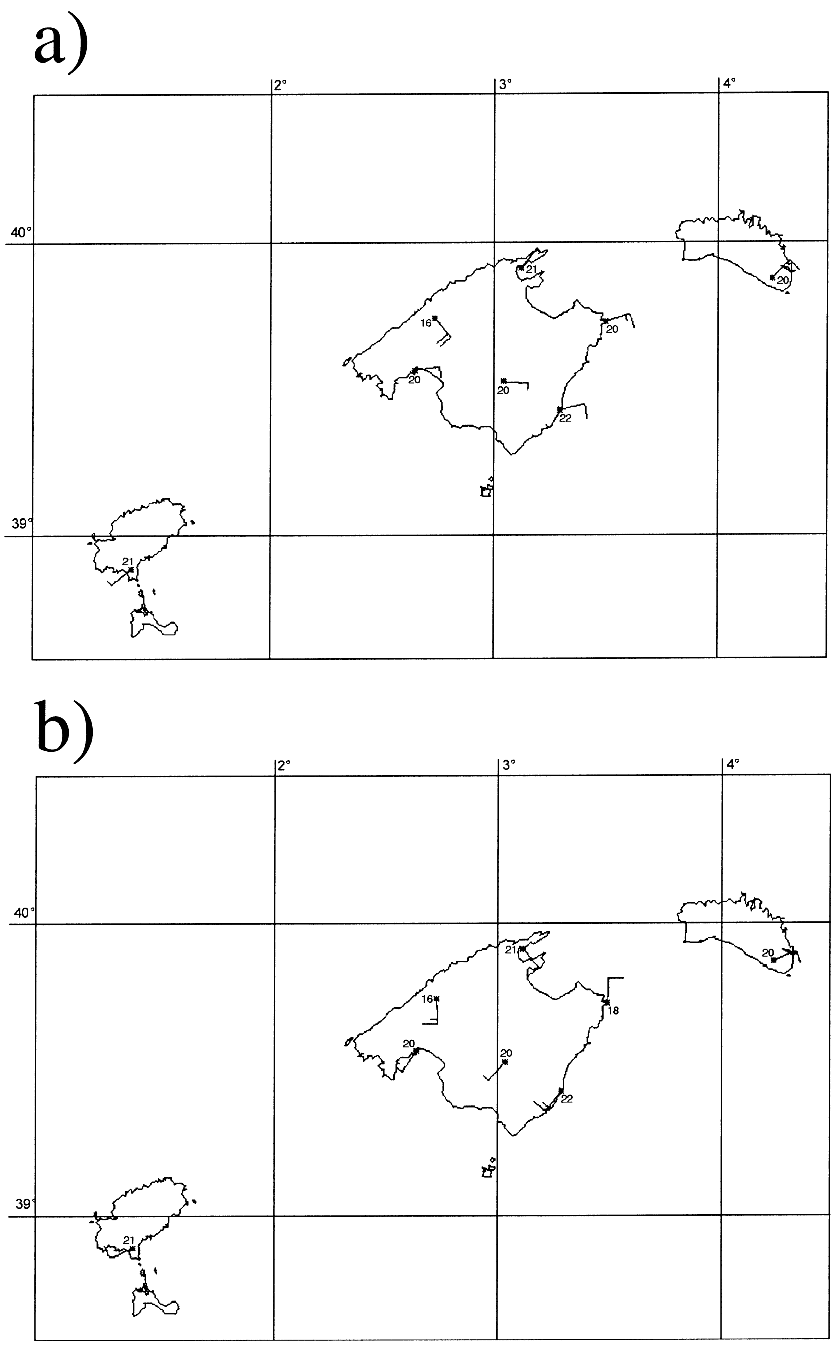

Fig. 18. Winds (kt) and temperatures (°C) as recorded by the automatic weather station in the Balearic Islands. (a) At 0200 UTC and (b) at 0300 UTC on 12 September 1996.

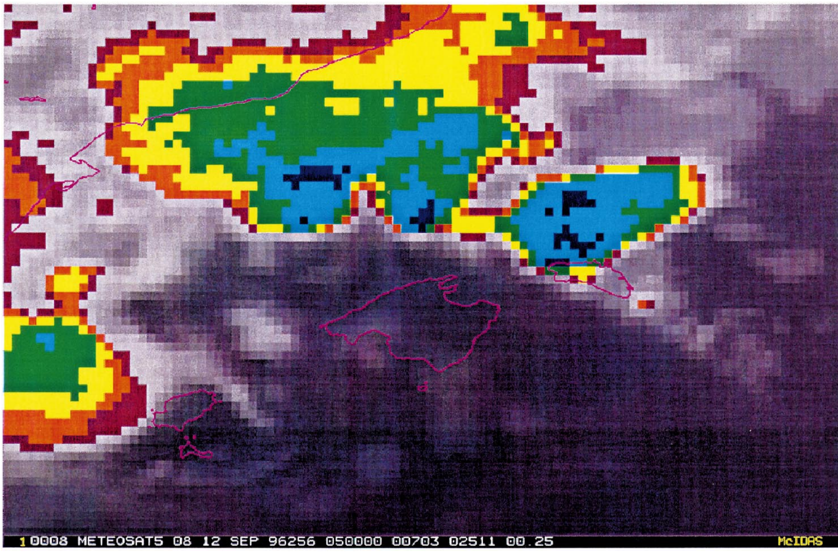

Fig. 19. As in Fig. 15 but on 12 September 1996 at 0500 UTC.

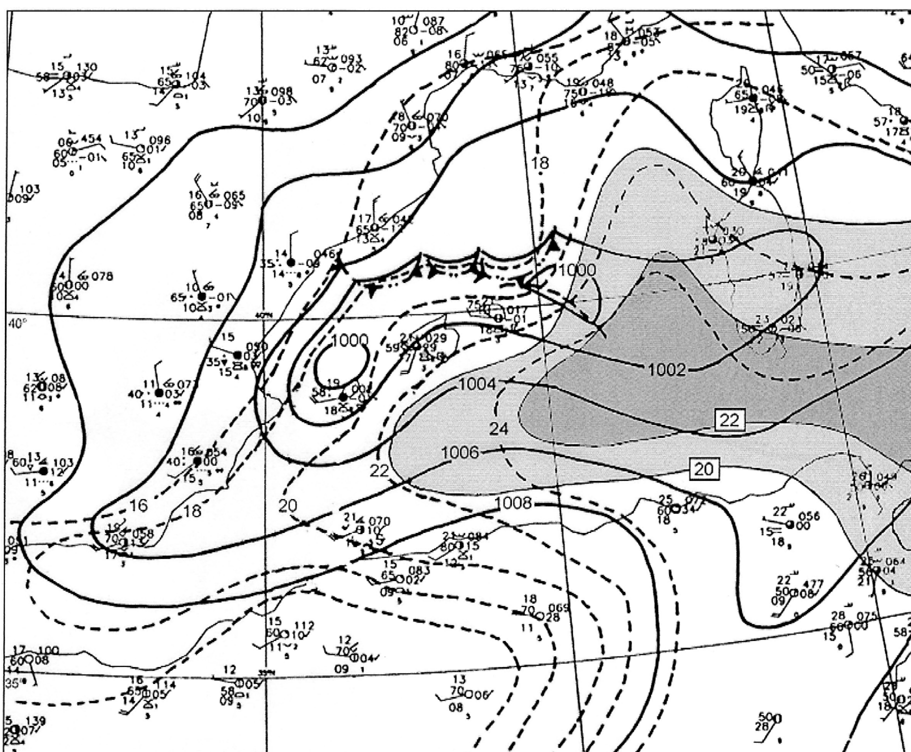

Fig. 20. As in Fig. 17 but on 12 September 1996 at 0600 UTC.

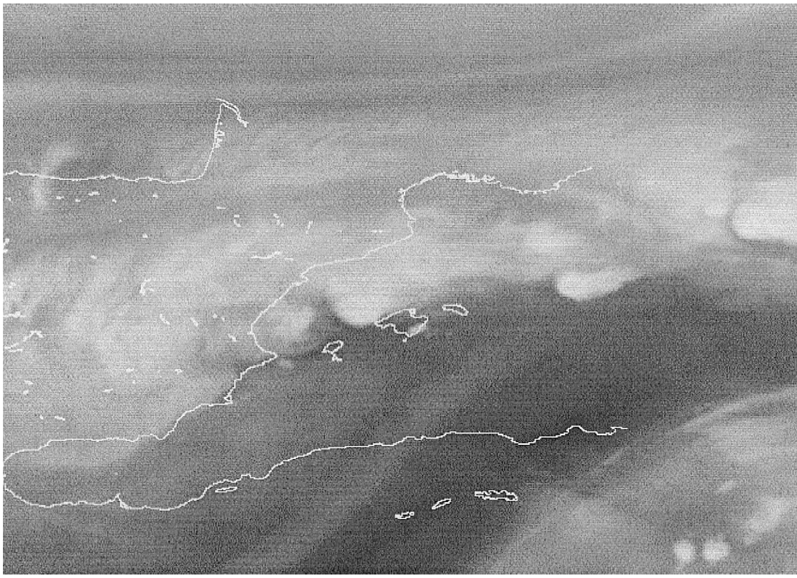

Fig. 21. Meteosat WV image on 12 September 1996 at 0230 UTC.

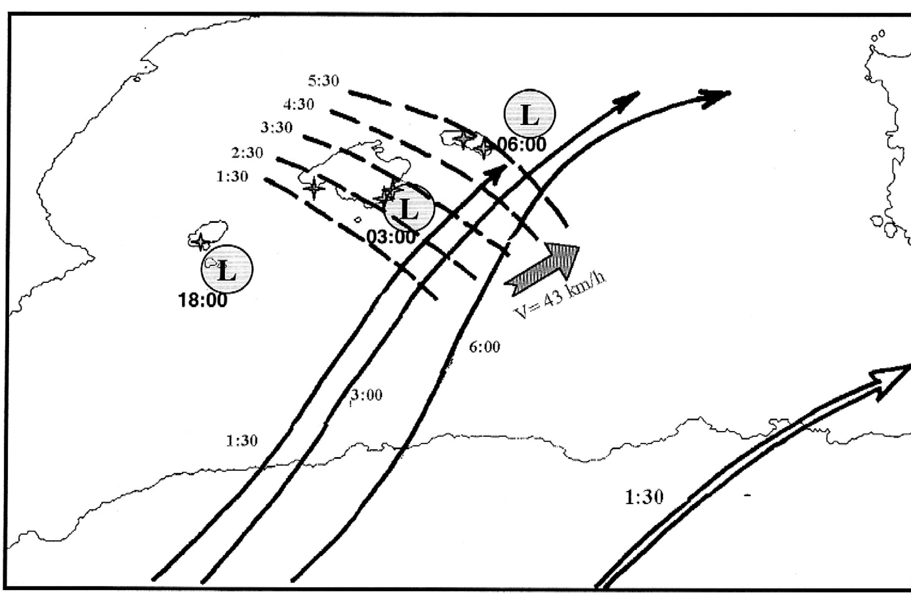

Fig. 22. Time evolution of the main low, convergence line and secondary jet streak over the area of interest. The location of the tornadoes developed in Majorca and Minorca are indicated by stars.

over the Western Mediterranean. However, the existence of a jet streak (identified at synoptic scale over the ECMWF analyses) requires the consideration of the possible influence of upper-level forcing. If the left exit region of a jet streak overlaps with low-level forcing mechanisms, a synergistic effect between low and upper levels exists and low-level parcels can easily overcome its level of free convection (Carlson, 1991). In this way, analysis of Meteosat WV images can provide information about the location of jet streaks (Scofield and Purdom, 1986). Fig. 21 shows the Meteosat WV image on 12 September at 0230 UTC. A clear jet streak (sharp moisture gradient) is evident close the right down corner of the image corresponding to that analysed in the ECMWF maps, but also signatures of a secondary jet streak appears from North Africa towards the Balearic Islands. As its left exit region overlaps the low-level convergence line, the combined action favours the development of convection. Fig. 22 shows the location of the main low, the convergence line (deduced from IR images) and the jet streaks (deduced from WV images) at different times. Taking into account the time and location of development of the tornadoes, the positive interaction of low- and upper-level forcing for upward motion was probably a decisive factor for providing enough lifting to low-level parcels.

It should be interesting to study the influence of upper-level PV anomalies on the development of the small cyclone and then, its indirect action to the development of the convective systems. This will not be considered in this paper since it requires finer data sets including numerical simulation experiments.

5. Conclusions

A tornado outbreak event in the Balearic Islands has been presented. The analysis of large-scale meteorological situation demonstrates that at low levels—all Western Mediterranean, the Iberian peninsula, and northern Africa were under the influence of a low. At mid and upper levels, a closed low was located to the southwest of the Iberian peninsula producing southwesterly flow over the Mediterranean Spanish coast. A negatively tilted ridge was present over the Western Mediterranean. No strong forcing for upward vertical motion can be identified from the analysis of mid-tropospheric levels but a well-marked warm advection towards the Balearic Islands and eastern Spain is identified at low levels. Large-scale evolution was very slow and maintained similar structures during the entire event.

Satellite pictures reveal that the first convective system, which produced a tornado in Ibiza, was long lived. It developed over a cloud band close to the Valencia coast and moved slowly eastwards. At the moment of the tornado development, the thunderstorm was mature as deduced from its clear V-shape signature on the IR Meteosat image. The parameters deduced from the Palma de Majorca radiosounding show an environment favourable to support supercells, as indicated by the EHI with a value of 5.8.

Tornadoes observed over Majorca were produced by convective systems developed from a convergence line produced by the interaction of a main low and an incipient small cyclone developed offshore the Valencia coast. The main low, and the associated convergence line, moved northeastwards with an estimated speed of about 43 km/h. At least two of the tornadoes occurred over Majorca—formed during the initial developing state of their parent convective systems. Furthermore, one of the tornadoes that formed over Minorca was also produced by a convective system in its initial state.

Meteosat WV imagery suggests that the existence of a secondary jet streak, which left exit region, overlaps the low-level convergence line. Their positive interaction to produce upward motion could have been decisive to provide lifting to low-level parcels and trigger convection.

This paper intends to contribute to the knowledge of the synoptic and mesoscale scenarios in which severe weather can develop in the Western Mediterranean. It can be used to support forecasters in the Western Mediterranean since it presents dynamical mechanisms that have acted to produce such a severe event.

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