MEDICANES: QUASI-TROPICAL MESOSCALE CYCLONES IN THE MEDITERRANEAN

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Abstract
Certain mesoscale cyclones (diameter up to 300 km) that form over the Mediterranean have been called medicanes. The cloud structures associated with these depressions, including a cloud-free eye, resemble a tropical cyclone in satellite images. They have been observed in the western and central Mediterranean but scarcely in the east. They develop embedded in mature larger scale cyclones that cause cold air intrusions over the Mediterranean. A cold core cut off low with remarkable potential vorticity characterizes the higher levels. Numerical simulations of various episodes have shown the importance of sensible and latent heat surface fluxes but not of the topography on the path and intensification of medicanes. The latent heat release in convective clouds that accompany these cyclones proves to be a decisive factor for its development, as well as the high levels cyclonic disturbance during its genesis phase.

Key words: medicane, Mediterranean, cyclone, mesoscale.

1. INTRODUCTION

Satellite images, especially from Meteosat, have evidenced the occasional formation of cloud systems over the Mediterranean largely resembling, except for its size, tropical cyclones. Indeed, these systems are nearly axi-symmetric and possess convective cloud bands wrapped around a cloud-free central eye (see Fig. 1).

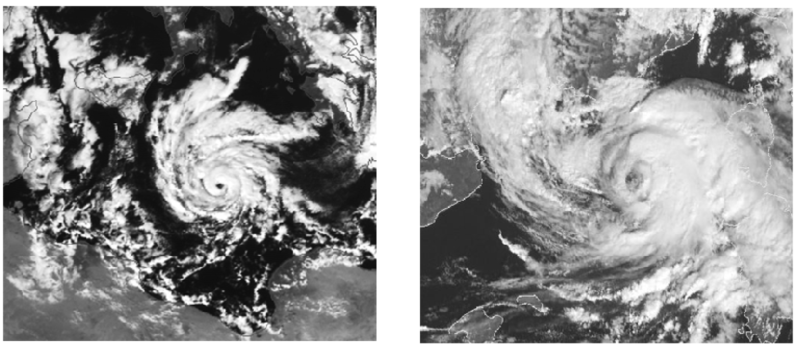

Fig. 1: VIS images from Meteosat. a) 16 January 1995 at 13:00 UTC; b) 8 November 2011 at 10:00 UTC (source EUMETSAT).

When the size of these cloud clusters is small, on the order of 300 km in diameter, (Jansà, 2003), the atmospheric disturbances causing them have been called *MEDICANES* (MEDIterranean+hurriCANES; Emanuel, 2005). The cloudy structure of *medicanes* is very similar to that of polar lows that develop at high latitudes, especially off the Atlantic coast of the Scandinavian peninsula; some authors even consider *medicanes* as polar lows forming at lower latitudes owing to the similarity of the physical mechanisms involved in their genesis and development (Bussinger and Reed, 1989).

Medicanes are nearly circular mesoscale cyclones that exhibit a great pressure gradient. This feature is well manifested by the shape of the barogram (Fig. 2) and the translational speed registered for some of the cases. The storms generally produce heavy rainfalls and the associated winds can reach great intensities, in some cases close to the speeds produced by tropical cyclones. In the event that these cyclones approach the continental coast or move over an island, hazardous meteorological phenomena might be produced, causing great material losses and even personal injury. As an example, the *medicane* that formed on 1 October 1986 near the Algerian coast evolved northwards and crossed the island of Mallorca during the night. The associated strong winds (higher than 50 kt) inflicted important damages to boats moored in the port of Palma de Mallorca where a nautical exhibition was taking place. Estimated damage surpassed 5 M€. More recently, another *medicane* formed on 8 November 2011 between Mallorca and Corsica (Fig. 1b). That one was named '*tropical storm 01M*' by NOAA. Its central pressure was estimated at 991 hPa and associated winds on the order of 45 kt could be inferred. It moved northwards and affected southern France and north Italy, where rainfalls in excess of 600 mm in 24 h and 11 fatalities were produced. Further information on this case can be found at
http://oiswww.eumetsat.org/WEBOPS/iotm/iotm/20111108_tropstorm/20111108_tropstorm.html.

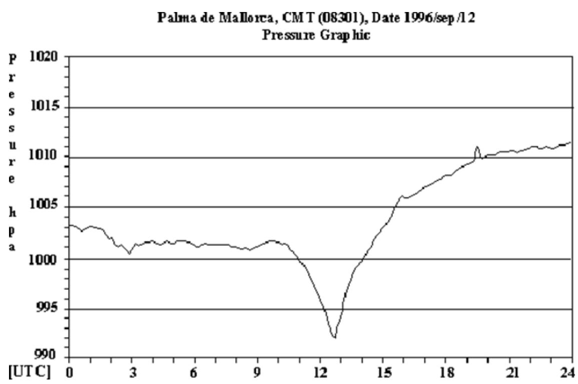

Fig. 2: Barogram at Palma de Mallorca on 16 September 1996 (source AEMET)

From the pioneering work of Pettersen in 1956, the Mediterranea sea is well known as one of the most cyclogenetic zones worldwide. The Gulf of Genova is particularly prone to the development of low-pressure systems when a primary cyclone evolves over Europe towards the east and the associated cold front enters over the Mediterranean and is distorted by the Alps and Pyrenees (Buzzi and Tibaldi, 1978). The so developed cyclones very often give place to northerly windstorms in the Gulf of Lyons extending southwards even as far as Tunisia. On some occasions strong cold air advections reach the Sahara and interact with the Saharan warm air, producing a baroclinic zone along which the pre-existing desert cyclone deepens. As this depression develops and moves northwards over the Mediterranean, it experiences an additional intensification and a reinforcement of the associated winds. Some examples of this kind of developments are the 19-22 December 1979 (Homar *et al.,* 2002) and 10-12 November 2001 (Ramis *et al.,* 2003) cyclones. Both storms were highly damaging and also produced numerous fatalities, especially in Algeria.

It is possible to detect Mediterranean depressions that cover the full spectrum of sizes, from synoptic scale cyclones to *medicanes* or even smaller disturbances. This chapter will deal only with the type of cyclones described above as *medicanes* and which preserve the indicated cloud structure for a relatively long period. A few studies have investigated the environments in which these cyclones develop (Rasmussen and Zick, 1987; Pytharoulis *et al*., 2000; Tous and Romero, 2011; Tous and Romero, 2013) while other works have analysed, by means of numerical simulations, the most influential factors on the development and trajectory of some *medicanes* (e.g. Homar *et al.,* 2003; Tous *et al.,* 2013). The most relevant aspects obtained from both approaches are presented in the following sections.

2. CLIMATOLOGY OF MEDICANES

Objective methods aimed at cyclone detection and characterization of the thermal structure, e.g. Picornell *et al.* (2001), can not be applied to *medicanes* using standard objective analyses and reanalyses (e.g. ERA40). The resolution of these products impedes the characterization of these cyclones. As alternative, Tous and Romero (2011) followed the visual inspection of Meteosat IR images, once assembled at 30 min intervals in the form of movies. They considered the period from February 1982 to December 2005 and looked for cloud structures fulfilling the conditions: maximum diameter of 300 km, radial symmetry, presence of a cloud-free eye, evidence of convective clouds and lifespan longer than 6 h.

Inspection of satellite movies along with consideration of some bibliographical references of studied cases resulted in the identification of 12 cases strictly satisfying the above criteria. Fig. 3 shows the spatial localization of these cyclones. It can be observed that *medicanes* have occurred in both the western and central Mediterranean. Half of them, 6 cases, have been observed in winter (DJF), 3 cases in autumn (SON), 3 cases in spring (MAM) and none during summer. The events list should be completed with the recent cases of 22 March 2007, 18 October 2007 and 8 November 2011, all of them over the western Mediterranean.

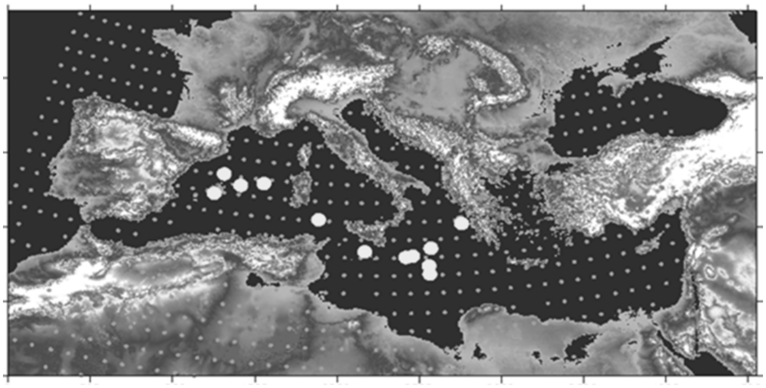

Fig. 3: Geographical distribution of detected medicanes (from Tous and Romero, 2011)

3. METEOROLOGICAL ENVIRONMENTS

From the studies undertaken by Pytharoulis *et al.* (2000) and Homar *et al.* (2003), among others, it is deduced that *medicanes* develop in the core of cyclonic environments, characterized by a depression and a well marked cold front at surface and a prominent trough of cut-off cyclone at higher levels. These disturbances aloft have a cold character and possess high values of Potential Vorticity (PV) (Fig. 4). This synoptic situation favours the intrusion of cold air over the Mediterranean. It was also observed that the *medicane* develops during the mature or final phase of the baroclinic cyclone.

It seems clear that the formation and subsequent development of the *medicane* requires some kind of seed as well as small scale mechanisms responsible for its deepening. The development of such a mesoscale cyclone by means of baroclinic instability alone would require very large wind shear and weak static stability, at least at low levels. Thus, it is more logical to attribute this development to small-scale mechanisms such as the latent heat release in the convective systems occurring around the nucleus of the cyclone and to an intense evaporation from the sea that would permit the maintenance of the convection during a prolonged period of time. Though at larger scale, these are the mechanisms that concur during the development of tropical cyclones.

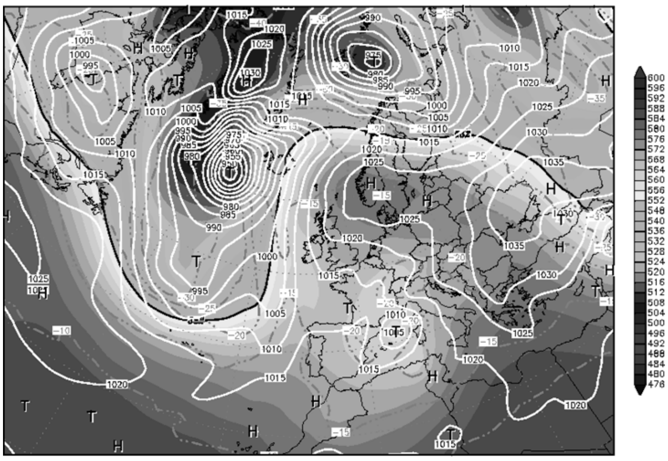

Fig. 4: GFS analysis from 8 November 2011 at 00:00 UTC. White contours are isobars at surface (hPa), shading represents the isohypses at 500 hPa (damgp) according to the grey scale and dashed lines are isotherms (ºC) at 500 hPa.

Using the ERA40 reanalyses, Tous and Romero (2013) calculated, for the Mediterranean environments observed on the days of *medicane* development, values of several parameters that have shown its utility in characterizing the environments leading to tropical cyclones. Justification of this approach lies on the structural resemblance, although at different spatial scale, of *medicanes* and tropical cyclones. Calculated parameters were: AVOR85 (absolute vorticity at 850 hPa; high values of vorticity favour development), RH600 (relative humidity at 600 hPa; high values of humidity at mid-tropospheric levels reduce the likelihood of strong downdrafts in the convective clouds), SST (sea surface temperature; high values compared to the overlying air favours evaporation), and VSHEAR8525 (wind shear between 850 and 250 hPa; low shear values across the troposphere favour the development). Another factor, related with the sensible and latent heat fluxes, is the local tendency of equivalent potential temperature at surface level (DIAB1000). Taking into account the temporal and spatial discretization of the used data, this can be written as:

$$DIAB1000 = \frac{\theta_e(t+dt) - \theta_e(t-dt)}{2dt} - Adv\theta_e(t)$$

where $Adv\theta_e(t)$ (equivalent potential temperature advection) is calculated at the given time *t* by means of spatial finite differences and *dt* is the time interval between analyses.

The ‘air-sea interaction’ theory developed by Emanuel (1986) for tropical cyclones demonstrates that these disturbances can be idealized as a thermodynamic Carnot cycle, where the heat input occurs largely in the form of latent heat of evaporation acquired from the sea surface by the inward airflow. The application of this model in equilibrium conditions allows to estimate the maximum wind speed of the storm that the environment can support (Bister and Emanuel, 1998; 2002):

$$MAXWS \approx \sqrt{\frac{C_k}{C_D}\frac{T_S - T_0}{T_0}(k_0^* - k)}$$

where T_S is SST, T_0 is the temperature at the top of convective clouds, k is the specific enthalpy of the air near the surface, k_0^* is the specific enthalpy of the air in contact with the sea, assumed to be saturated at sea surface temperature, and C_D and C_k are the dimensionless transfer coefficients of momentum and enthalpy.

Emanuel (2003) proposed an empirical genesis index for tropical cyclones (GENPDF) that combines the indicated parameters in the following expression:

$$GENPDF = \left|10^5 AVOR85\right|^{\frac{3}{2}} \left(\frac{RH600}{50}\right)^3 \left(\frac{MAXWS}{70}\right)^3 (1 + 0.1VSHEAR8525)^{-2}$$

Tous and Romero (2013) calculated the mean value of that index over a square of 600x600 km^2 centred at the point where each of the *medicanes* of the database was detected, focusing on the cyclone maturity time. For this calculation, the closest available time of the analysis (00, 06, 12 or 18 UTC) was used. As an additional index, the maximum value found inside the considered geographical squared region, GENPDFmax, was also considered. In its original formulation, the GENPDF index was adjusted as the number of tropical cyclones observed per decade in a square of 2.5º x 2.5º. Owing to the few cases of observed *medicanes* and, therefore, to the lack of a wider climatology, the GENPDF parameter lacks true dimensions in this study and is merely used in qualitative terms, as a possible indicator of the environments leading to *medicanes*.

Table 1 shows the calculated values of the above parameters for the cases of *medicane* and for the bulk of intense cyclones extracted from the MEDEX database (Campins *et al.*, 2006)

	MEDEX 5%	MEDEX 95%	MEDIC min	MEDIC max
AVOR850 (10^{-5} s^{-1})	10.2	18.8	9.6	17.7
DIAB1000 (ºC/12h)	-5.9	6.4	0.2	7.7
RH600 (%)	30.8	89.9	49.2	80.9
SST (ºC)	7.9	19.0	15.0	23.2
VSHEAR8525 (m s^{-1})	7.3	42.3	4.7	29.0
MAXWS (m s^{-1})	0.3	49.1	31.6	49.5
GENPDF	0.0	16.8	0.9	36.6
GENPDFmax	0.0	61.5	3.8	329.5

Table 1. Values of the parameters for MEDEX intense cyclones (precentiles 5% Y 95%) and for medicanes (minimum and maximum) (from Tous and Romero, 2013)

Observe from the table that sensible and latent surface heat fluxes are always directed upwards in the case of *medicanes*, that sea surface temperature was never below 15 ºC, and that MAXWS acquires always high values in the case of *medicanes* and also that GENPDF and GENPDFmax are much higher for *medicanes* than for intense cyclones. By tracking in time the GENPDFmax index during the life cycle of *medicanes*, it is observed that this parameter exhibits a rapid increase during the formation phase of the cyclone, reaching the maximum values near the mature state. Finally, it was shown that some environments presenting high values of GENPDF did not lead to the formation of *medicanes*, and thus such ingredient must be considered a necessary but not sufficient condition for the genesis of these cyclones, suggesting the relevance of other smaller scale factors for the genesis of the phenomenon. See for more details Tous and Romero (2013).

4. INFLUENCE OF SURFACE FLOWS ON THE PATH AND INTENSITY

Current mesoscale numerical models make use of advanced parameterizations of physical phenomena allowing the study of the influence of physical factors that are considered important in the development of small-scale circulations. Numerical simulations will then determine whether medicanes follow a common pattern regarding energy flows from the sea. Specifically, we can quantitatively assess the effects of these flows on the path and intensification of the medicanes, besides discerning whether they are a necessary condition for their genesis and further development.
By using the 12 medicanes identified and highlighted in Fig. 3, Tous et al. (2013) show a study of these characteristics. Initially, they performed control simulations to ascertain the model capacity to simulate with good approximation the observed medicanes. Only if the model is able to reproduce satisfactorily the physical processes involved in the system, the derived experiments and conclusions will be representative of the real system. Subsequent simulations were conducted with sensible and latent heat fluxes removed. The comparison of the results allows to retrieve quantitative information about the influence of these factors.
The model used by Tous et al. (2013) was the NCAR/Penn State University MM5V3 (Duhia, 1993). The integration domain consists of 196 x 196 points with a gridsize of 7.5 km in the zonal and meridional directions, and was centered over the point of maximum development of the medicane being studied in each case. In the vertical, 31 σ levels were considered with higher resolution in the low troposphere. Each simulation ran for 48 hours beginning 24 hours prior to the time of maximum development of the cyclone. The Kain-Fritsch (1990) scheme was used for the convective parameterization, the Reisner scheme for the microphysics and the MRF for the boundary layer processes. The initial and boundary conditions (time-varying) were taken from the ECMWF analysis.

Only one out of the 12 control simulations did not develop a medicane or any similar structure. In two of them, despite generating a small cyclone, it was very short-lived, much shorter than actually observed. The remaining 9 cases simulated a small cyclone with warm core and a life cycle similar to the observed. The model thus shows ability to simulate this type of disturbances. Figure 5 shows the results of two simulations. The small cyclones (they meet the aforementioned definition of a medicane on satellite images) are clearly depicted, with a strong pressure gradient, a great symmetry and a warm core at 700 hPa.

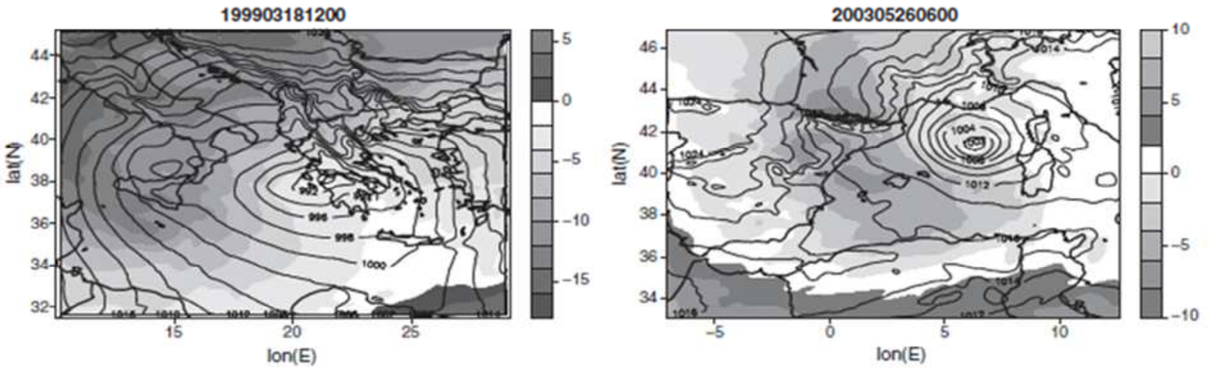

Fig. 5: Control simulation of 2 *medicanes* (the date and time (UTC) is indicated on top of each panel). The isobars (hPa) are indicated with continuous lines. Temperature (ºC) at 700 hPa is shown with shaded greys according to the scale (from Tous et al., 2013).

Considering only the 9 cases well reproduced by the model, both in its spatial structure and life cycle, Tous et al. (2013) analyzed, by comparing control simulations with those in which sensible and latent heat fluxes are removed, the influence of these fluxes on the cyclone's path, travel speed and life-time. Results indicate that three groups of medicanes can be considered depending on the impact of such changes: in the first group, comprising three events, a significant deviation from the path between the two simulations is found; the second group, which includes four events, also shows some deviation between the trajectories but much lower than the previous group; and finally the third group, comprising the remaining two cases, shows remarkable overlapping between the paths in the control and modified simulations. Figure 6 shows the trajectories for a case in each group, as well as the spatial distribution of sensible and latent heat fluxes.

Using the same 9 cases, Tous et al. (2013) analyze the influence of the fluxes on the intensification of the medicanes by comparing the evolution of the pressure at the center of the cyclone in the control and modified simulations. In general, the influence of these flows is noticeable; in all cases the control simulation shows lower values of sea level pressure at the center of the cyclone than the simulation with no surface fluxes, that is, these fluxes favor the intensification of medicanes. They have also identified three groups with different behaviors. The first group, which is analogous to the previous first group in the trajectory analysis, shows a strong influence of surface fluxes, with differences in depth at the end of the simulation that reach the 20 hPa. In the second group, which coincides with the second group of trajectories, the pressure difference increases with time but does not reach values as high as in the first group. Finally, the third group shows a behavior in which the influence of the fluxes does not appear to be crucial for the evolution of medicane.

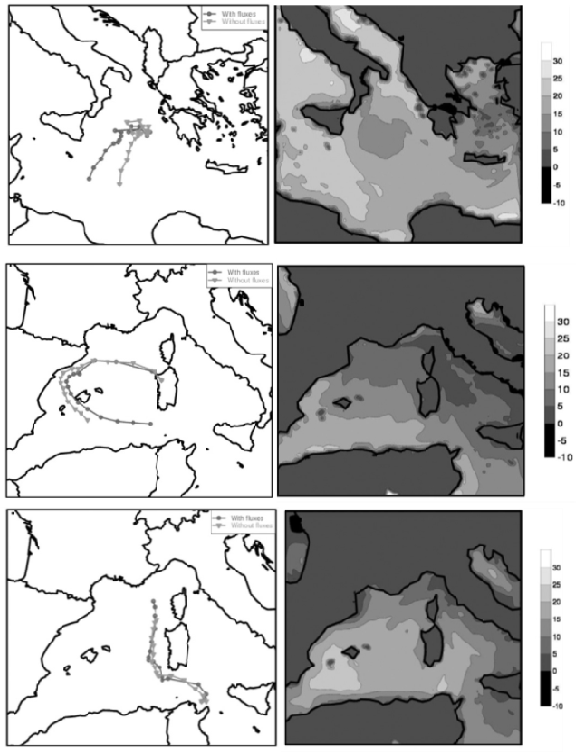

Fig. 6: Simulated trajectories and spatial distribution of sensible and latent heat fluxes (10^3 J/kg according to the scale of grey shadings) of an event of the first group (upper row), second group (central row) and third group (lower row) (from Tous et al., 2013)

The explanation for the different behavior of the medicanes in each group can be found in terms of the values and spatial distribution of the surface fluxes and the spatial distribution of precipitable water (PW, not shown), which always takes higher values in the control simulations than in the experiments without fluxes, especially in the first group. In this group, the cyclone moves (steered by the upper levels dynamics) towards areas with high values of surface fluxes, especially of latent heat flux. The associated strong winds favor the evaporation, and the large amount of precipitable water contained in the atmosphere above the area of the incipient cyclone cause the developed convection to release large amounts of heat, which causes a strong intensification of the medicane. For the second group, surface fluxes are smaller than for the first group and quite uniform along the path of the incipient medicane. The evaporation and precipitable water are also smaller in this group. That is indeed the main cause for the convection to be less intense, as the warming by latent heat release is lower and therefore the cyclone does not develop as deeply. Finally, the last group is characterized by showing high values of heat fluxes in areas away from the trajectory of the cyclone; the values of the fluxes in the medicane area are lower than the two preceding groups and fairly uniform.
These results reveal the strong influence surface fluxes have on the path and intensification of medicanes. However, other factors may also be relevant and make the dynamics of these small cyclones different from that of tropical cyclones. For example, high-level disturbances, always present in such weather conditions. The following section presents a study of their influence.

5. INFLUENCE OF DYNAMICAL FACTORS ON THE DEVELOPMENT AND INTENSIFICATION

An important case of a medicane affecting the Balearic Islands, where strong winds were registered, occurred on 12 September 1996. The barogram of the day from Palma de Mallorca is plotted in Figure 2. During the previous day, intermittent severe weather occurred over the western Mediterranean: very heavy rainfall over the coast of Valencia and six tornadoes on the Balearic Islands. For a description of this event see Homar et al. (2001).

The influence of the mid and upper tropospheric levels disturbance on the medicane development was studied by Homar et al. (2003) by means of numerical simulations. Initially, the structure of the disturbance in terms of PV was identified. The influence of the isolated vorticity structure is analyzed by obtaining the balanced geopotential, wind and temperature fields associated with the original PV structure and those balance fields associated with a weakened PV structure. To do so, a PV inversion technique, developed by Davis and Emanuel (1991), is used. The resulting fields are used as initial conditions of the respective numerical simulations. Additionally, also by means of numerical simulations, the influence on the development of the medicane of the regional orography, evaporation from the sea, surface sensible heat flux, latent heat release in convective clouds, as well as the interaction between some of these factors was investigated using a methodology developed by Stein and Alpert (1993).

The meteorological setting in which the medicane formed is shown in Fig. 7.

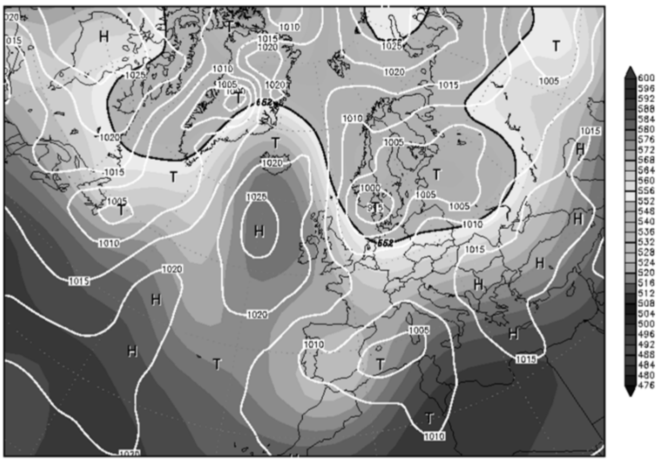

Fig. 7: NCEP reanalisis of 12 September 1996 at 00:00 UTC. The contours show isobars (hPa) at surface. The grey shading depicts isohypses at 500 hPa (damgp) following the scale.

At synoptic scale it matches the situation described above: a cyclone over the western Mediterranean with no remarkable barometric gradient and a depression at mid and upper tropospheric levels, which is isolated from the zonal circulation of higher latitudes.

The numerical model used by Homar et al. (2003) was the non-hydrostatic version MM5V2 (Dudhia 1993) developed by NCAR/Penn State University. The initial and boundary conditions were obtained from the NCEP analysis, available at 00:00 and 12:00 UTC. The simulations start on September 11 at 12:00 UTC and extend for 36 hours. They used a configuration with two-way nested domains. The lower resolution domain had a gridsize of 60 km with a total of 82 x 82 grid points covering much of Europe, North Africa and parts of the Atlantic Ocean. The higher resolution domain was 109 x 109 grid points with 20 km gridsize, covering the western Mediterranean, the Iberian Peninsula and much of France. In the vertical, 32 σ levels were used, with higher resolution near the ground. We used the convective parameterization of Kain and Fritsch (1990) in both domains. The microphysical processes were parameterized using the Tao and Simpson (1993) scheme and for the boundary layer a modified version of Hong and Pan (1996) was activated. The sea surface temperature, from the NCEP analysis, remained constant during the 36 hours of simulation.

The control experiment reproduces with sufficient approximation the evolution of the medicane but the simulated trajectory is shifted about 100 km southward of the medicane path inferred from satellite imagery (Fig. 8). Also the pressure at the cyclone center fails to be as low as the one registered by the Palma de Mallorca barogram (Fig. 2).

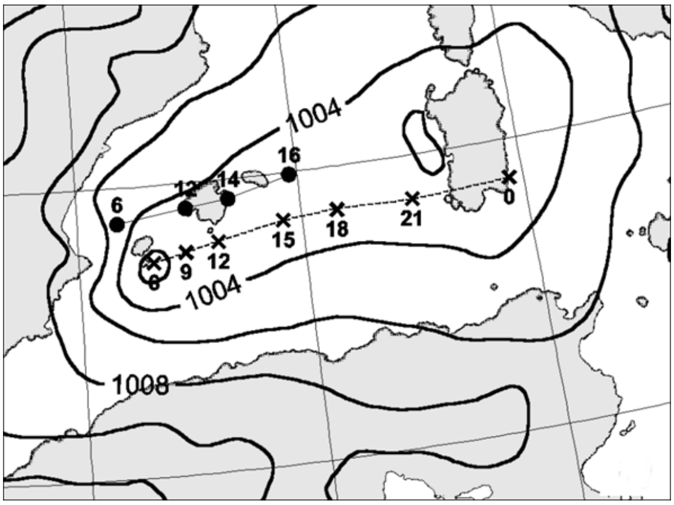

Fig. 8: Isobars (hPa) at sea level on 12 September 1996 at 06:00 UTC for the control experiment. Crosses indicate the position of the simulated medicane at the indicated time. Dots depict the position of the medicane as inferred from satellite images (from Homar *et al.*, 2003)

Figure 9 shows the results of various simulations on 12 September 1996 at 12:00 UTC. Notice how the control experiment (Fig. 9a) reproduces the small-scale cyclone (150-200 km diameter) with a strong barometric gradient. It also shows an important convective precipitation area to the west of the cyclone.

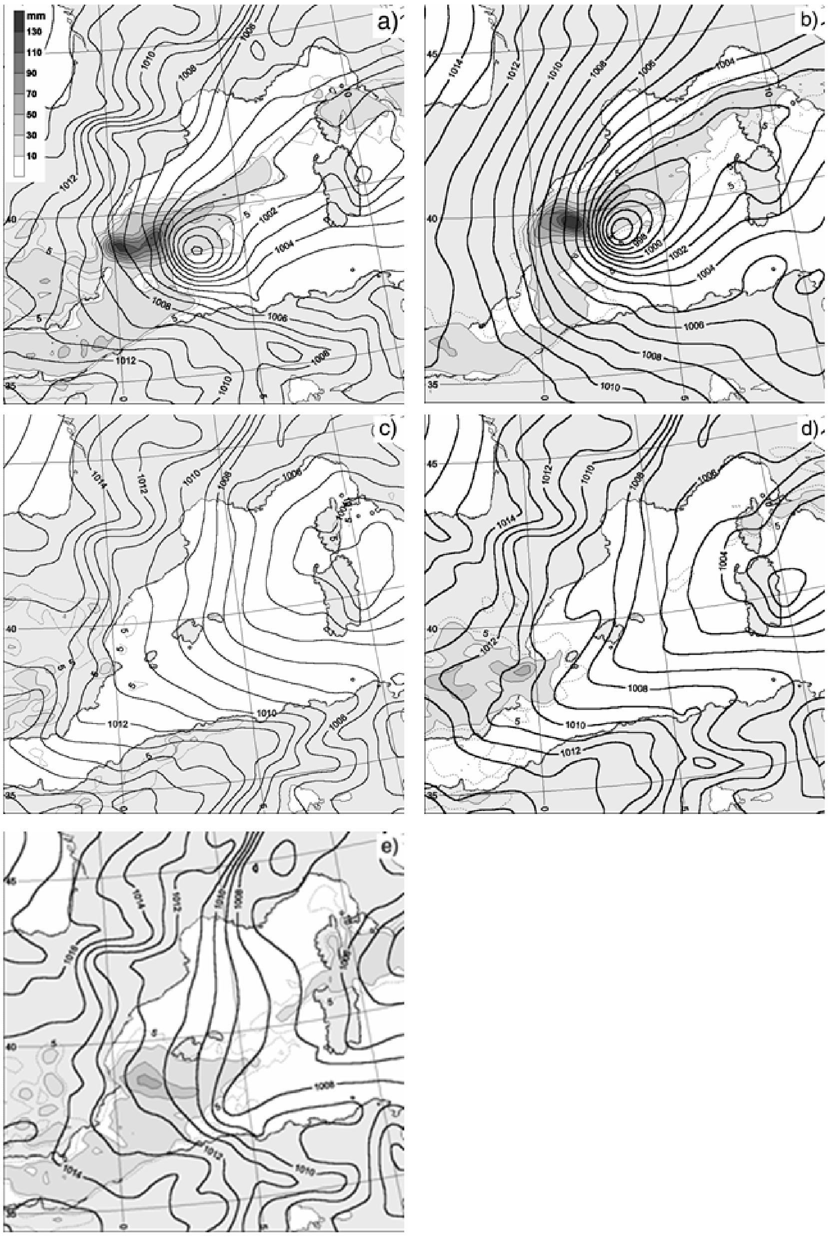

Fig. 9: Sea level pressure (hPa, solid line) and accumulated precipitation (mm, dashed line and shaded areas) valid on 12 September 1996 at 12:00 UTC for: a) control experiment, b) no orography experiment, c) no latent heat release experiment, d) no evaporation experiment and e) experiment with weakened upper-level forcing (from Homar *et al.,* 2003)

The experiment with flattened orography (Fig. 9b) shows the formation of the cyclone approximately at the same position as in the control experiment and a similar precipitation field. Notably, the terrain, so important and fundamental to the development of some cyclones in the Mediterranean, plays a negligible role in this case, and even more, the no-orography simulation developed a deeper cyclone than the control experiment. The critical importance of the latent heat release, mainly in the convective clouds surrounding the center of the cyclone, is clearly revealed in the experiment in which this heat source is removed. Figure 9c shows that in this case the model does not develop the small cyclone although the primary cyclone still forms and the latent heat release is of much smaller (if any) importance. The lack of water vapor feeding the convection is also a decisive factor in the development of the medicane. Figure 9d shows how the cyclone is not formed if no evaporation from the sea is allowed in the numerical experiment, besides the reduction in precipitation compared to the full experiment with active evaporation. We observe the formation of a trough to the south of the Balearic Islands, but once the water vapor initially present in the simulation is fully used, the latent heat release cannot continue and thus the deepening of the low also stops. Although it has been shown that water-related processes (evaporation and latent heat release from condensation) are essential in the formation and development of the medicane, the high levels dynamic forcing is also relevant (being a distinctive feature with respect to tropical cyclones). As previously mentioned, all cases show a cold low at high levels (500, 300 hPa), which is associated with an important positive PV anomaly. Weakening the potential vorticity anomaly and inverting this field to get the geopotential, wind and temperature, by means of the aforementioned method, results in a weaker upper-level trough and a reduced steering dynamical forcing to the lower levels. Figure 9e shows the result of the simulation initialized using the geopotential, wind and temperature fields derived from the inversion of the weakened PV field. The result shows how the medicane does not develop in this case, producing only a trough to the southeast of the Balearic Islands. In short, the high levels forcing is an important factor in the development of these small sized cyclones, as also shown by Nordeng and Røsting (2011) for a case of a remarkable polar low.

The role of the sensible heat flux between atmosphere and ocean in the development of the cyclone, while notable, is not as important as the evaporation from the sea. In the experiment in which this heat flux is removed (not shown), the position of the cyclone is approximately the same as in the control experiment but the pressure at the center is higher.

Once the importance of the evaporation and the upper levels forcing on the development of the medicane was proven, the factors separation technique of Stein and Alpert (1993) was used to analyze the isolated effects of these two factors and their synergism throughout the lifetime of the cyclone. The effect of the evaporation (E_{LGF}), PV anomaly (E_{PV}) and their interaction (E_{INT}) were obtained from the following expressions

$$E_{LGF} = F_{10} - F_{00}$$
$$E_{PV} = F_{01} - F_{00}$$
$$E_{INT} = F_{11} - (F_{10} + F_{01}) + F_{00}$$

where F_{11} represents the control experiment, F_{00} indicates an experiment with the evaporation and upper-level forcing (partially) suppressed, F_{01} an experiment without evaporation and F_{10} the experiment with weakened upper-level dynamical forcing.

Figure 10 shows the quantitative importance of these factors on the pressure at the center of the cyclone during the simulated period. The effect of the evaporation is kept virtually constant throughout the life of the cyclone while the effect of the upper levels forcing is very important during the genesis stages of the cyclone but decreases with time. The interaction between the two factors follows the opposite evolution of the dynamical forcing. Initially this effect is almost negligible but then it grows quickly and for more than half the cyclone’s lifetime, it turns to be the most determinant factor among the three. If we analyze the spatial distribution of the importance of these factors as well as their synergism at certain stages of the life cycle of the medicane, the evolution previously discussed becomes evident. Thus, the spatial distribution at 12:00 UTC on 12 September shows that the effect of the synergism between the two factors is located and centered on the cyclone and, therefore, it emerges as the main responsible for its deepening or maintenance.

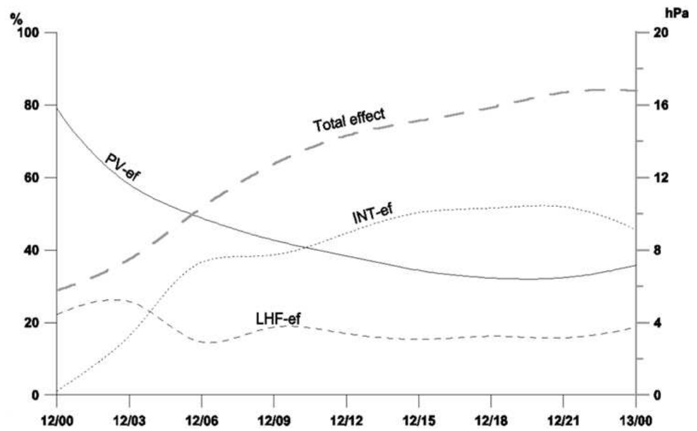

Fig. 10: Efects of the evaporation, Potential Vorticity and their synergism on the sea-level pressure at the center of the cyclone on 12 September 1996 (from Homar *et al.*, 2003)

6. FINAL THOUGHTS

The mesoscale cyclones called *medicanes* that develop in the Mediterranean, although rare, represent an adverse meteorological phenomenon due to their associated winds and rains but also for the damage they cause. The environments that favour their genesis have been identified and we defined a set of necessary but not sufficient conditions for its genesis, such as a relatively high sea surface temperature with respect to the air mass above. Further work is needed in order to clarify which necessary conditions become indeed collectively sufficient. The identification of a seed (initial vorticity center) from which the medicane eventually grows is a task to be addressed in the future. Numerical simulations have allowed, besides showing the paramount role of sensible and latent heat fluxes from the sea, beginning to put together a conceptual framework aimed at describing how these cyclones grow and evolve, with the evaporation that feeds the convection and the consequent focused release of significant quantities of latent heat, as important agents in the intensification of the medicane. Moreover, we have also shown the importance of the upper-level disturbances in the development of the cyclone, especially during the first stages, although this finding needs confirmation by studying other cases observed. The detailed and solid knowledge regarding the physical processes involved in medicanes, and their accurate prediction in a timely manner are both crucial challenges that, again, the always interesting Mediterranean weather is unfolding ahead of us.

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