# OBSERVATIONAL ANALYSIS OF A MEDITERRANEAN "HURRICANE" OVER SOUTH-EASTERN ITALY

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**Abstract:** the presence of a subsynoptic-scale vortex, formed over the Mediterranean Sea, has been documented in south-eastern Italy on 26 September 2006. Radar maps, Meteosat Second Generation satellite images and surface stations reveal that the vortex had features similar to those of tropical cyclones.
The Weather Research and Forecasting Model (WRF) has been setup in a configuration including two nested grids. Model results show that the model is able to realistically simulate the origin and evolution of the system, although a strong sensitivity to the specification of the initial conditions is apparent. An analysis of the mechanisms responsible for the development and the maintenance of the cyclone has also been performed.
Simulations show the topographic origin of the vortex, which was initiated on the lee side of the Atlas mountains.

**Keywords:** Mediterranean cyclones; meteorological bombs; tropical cyclones; numerical experiments.

## 1. INTRODUCTION

It is well known that the Mediterranean Sea favours the development of cyclonic storms (Petterssen, 1956; Alpert et al., 1990). Although most of these cyclones have synoptic-scale and baroclinic origins, sometimes intense mesoscale vortices have been observed with features closely resembling those of tropical cyclones or polar lows (Ernst and Matson 1983; Businger and Reed 1989; Rassmussen and Zick 1987).

Hereafter, the presence of a subsynoptic-scale vortex over the Mediterranean sea, which affects south-eastern Italy on 26 September 2006, has been documented and analysed with numerical simulations.

## 2. SYNOPTIC ANALYSIS

A vortex crossed south-eastern Italy (the region inside the rectangular box in Figures 1a-b) in the morning of 26 September 2006. At 06UTC, the ECMWF mean sea level pressure (mslp) analysis map shows a cyclonic circulation affecting the Italian peninsula and the surrounding seas, with a minimum value (C1 in Fig.1a) of about 1001 hPa, approaching the central Tyrrhenian coasts. Another minimum of 998hPa (C2 in Fig.1a), located over the northern Ionian sea, moves north-eastward, deepening by about 4 hPa during the previous 6 h. At 500hPa, a low is associated with the first mslp minimum, close to the central Tyrrhenian coasts. Both at 500 and 850hPa, the Tyrrhenian minimum has a cold core while the Ionian low is associated with a warm tongue. In the following hours, the Ionian minimum (C2) rotates around the larger cyclone C1, which has moved slightly south-eastward, crossing south eastern Italy, and then moving to the southern Adriatic sea (not shown). As we will show in the following Sections, the synoptic analysis has not been able to reproduce the intensity of the minimum correctly.

## 3. OBSERVATIONAL DESCRIPTION

In order to provide a detailed observational description of the event, surface station data, satellite and radar images were employed. The stations used in the present analysis are shown in Figure 2a.

Figures 2b-d shows the observed mslp at different times, during the passage of the minimum inland. This phase is well-represented by the strong pressure fall recorded at the surface stations located along the trajectory of the cyclone. At 09:15 UTC (Fig.2b), the sea-level-pressure minimum of 986hPa is recorded in Nardò, on the south-western side of Salento. At this time, the pressure gradient is very strong, approximately 10 hPa/20 km, and the horizontal dimension of the cyclone can be estimated as approximately 60-70 km. Later, the vortex slowly rises to 988hPa and rapidly moves toward the northeast (Fig.2c). As proceeding inland, the cyclone minimum pressure slightly increases, probably because it is no longer receiving heat and humidity from the sea (Emanuel, 1986; Rotunno and Emanuel, 1987). However, the pressure gradient is still very large and, as a consequence, very strong winds are observed in the region during the entire transit of the vortex across Salento, as it is well documented in Galatina airport station by the local anemometer. Here, the wind reaches its maximum intensity of 78 knots at about 09:30UTC.

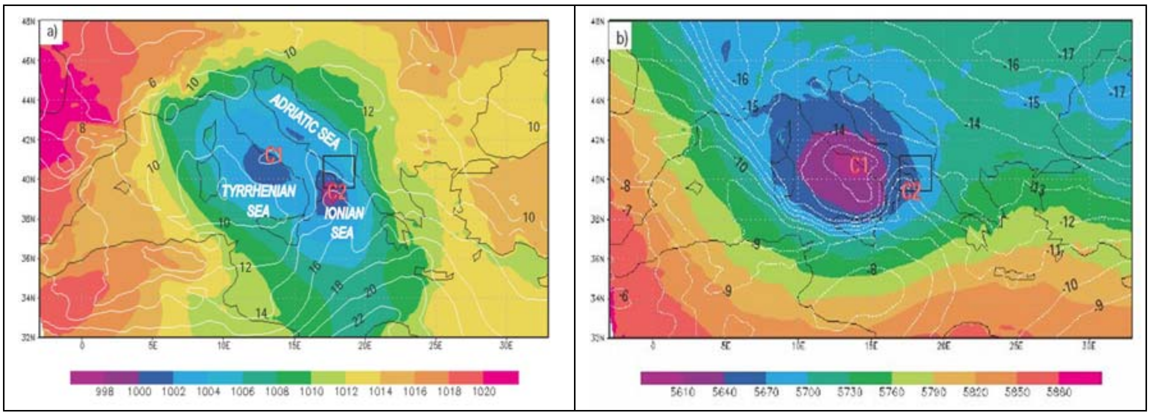


**Figure 1:** ECMWF analysis at 0600UTC, 26 September 2006: mean sea level pressure in hPa (colours), and 850hPa temperature in °C (white contours, c.i.=2°C) (a,); 500hPa geopotential height in m (colours) and 500hPa temperature in °C (white contours, c.i.=1°C) (b,). C1 and C2 denote respectively the position of the Tyrrhenian pressure minimum and of the minimum over the northern Ionian Sea. The rectangular box delimits the Salento Peninsula of south-eastern Italy.

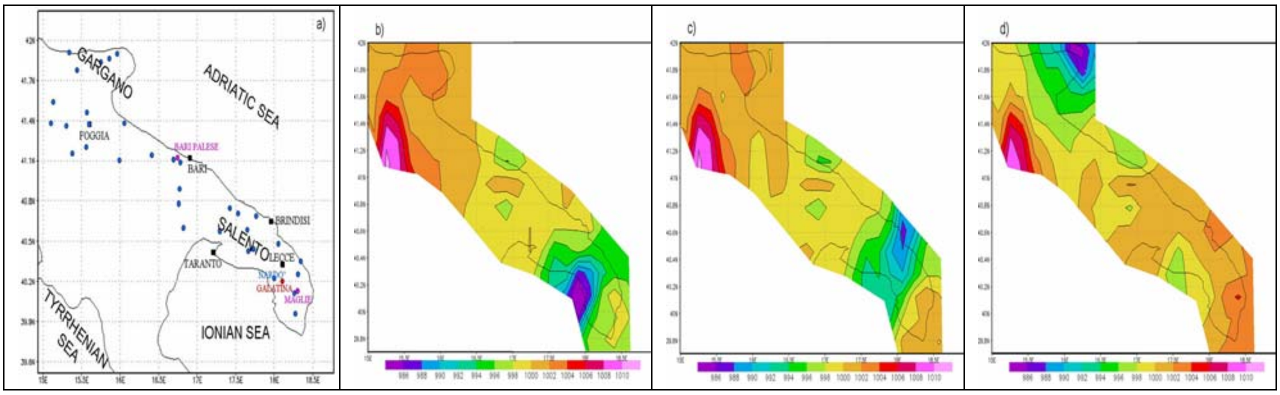


**Figure 2:** Map of south-eastern Italy showing the position of the 33 surface stations (belonging to SMA Spa), the RADAR sites: Maglie (belonging to SMA SpA) and Bari Palese (belonging to Aerotech Srl), and the Galatina airport station, used for the observational analysis. The names of the stations mentioned in the paper and of the main towns of the region are given (a); mean sea level pressure in hPa (colours) at 09:15UTC (b), 09:45UTC (c), 17:15UTC (d) on 26 September 2006. The isobars are plotted using the GRADS graphical package, which interpolates the local measurements from the 33 surface stations, using the Barnes interpolation technique (Barnes, 1964).

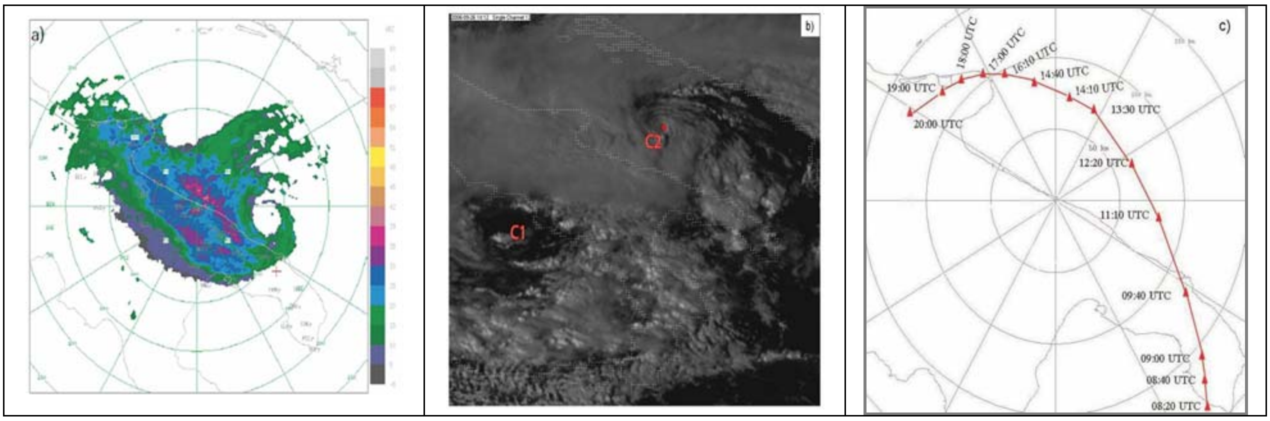


**Figure 3:** Reflectivity maps in dbz from the radar in Bari Palese on 26 September 2006 at 11:10UTC (a); Meteosat Second Generation image at 14:12UTC, 26 September 2006, enlarged over southern Italy (b), the best-estimate of the track of the Mediterranean cyclone between 08:20UTC and 20:00UTC, as reconstructed from the observational data.

In the following hours, it is possible to detect the eye of the cyclone in the radar images provided by the Bari Palese station. The low-pressure centre is now located over the Adriatic Sea and moves north-westward (Fig.3a). During the afternoon, the eye, nearly rotating around the Tyrrhenian minimum, approaches the Gargano promontory, where it is clearly visible in the satellite image at 14:12UTC (Fig. 3b). In the evening, the cyclone moves inland and is still very deep, as shown in Fig. 2d, where a low pressure centre of 988hPa is apparent along the Gargano coast at 17:15UTC. Later, the minimum becomes shallower and moves further inland west-south-westward and finally decays during the night of 26 September. The full track of the Mediterranean cyclone is shown in Figure 3c.

## 4. NUMERICAL SIMULATIONS

In order to further analyse the event, a set of numerical simulations were performed using the Weather Research and Forecasting Model (WRF), version 2.2 (Skamarock et al., 2007). The model has been set up in a configuration including two nested grids. The coarse domain, with a grid resolution of 16km, covers the northern Africa, the central and the western Mediterranean regions. A two-way nesting technique is used to zoom in the nested domain, of 4km grid resolution, covering the south-eastern Italy and the surrounding seas. In the vertical, 31 levels are used for both the grids. The Kain-Fritsch convective parameterization scheme has been activated only for the coarse domain, while the new-Thompson graupel microphysics scheme and the YSU boundary layer scheme are used for both the domains. The sea surface temperature is kept constant during the simulations and is obtained from the NCEP weekly database. Several simulations have been performed, starting from different initial conditions. Although a strong sensitivity to the specification of the initial conditions comes out, model results show that the model is able to realistically simulate the origin and evolution of the system.

Figures 4a and 4b show the results of a 72 hour forecast starting at 00UTC on 24 September 2006, using the 0.5° ECMWF analyses as initial and boundary conditions (the boundary conditions are imposed every six hours).

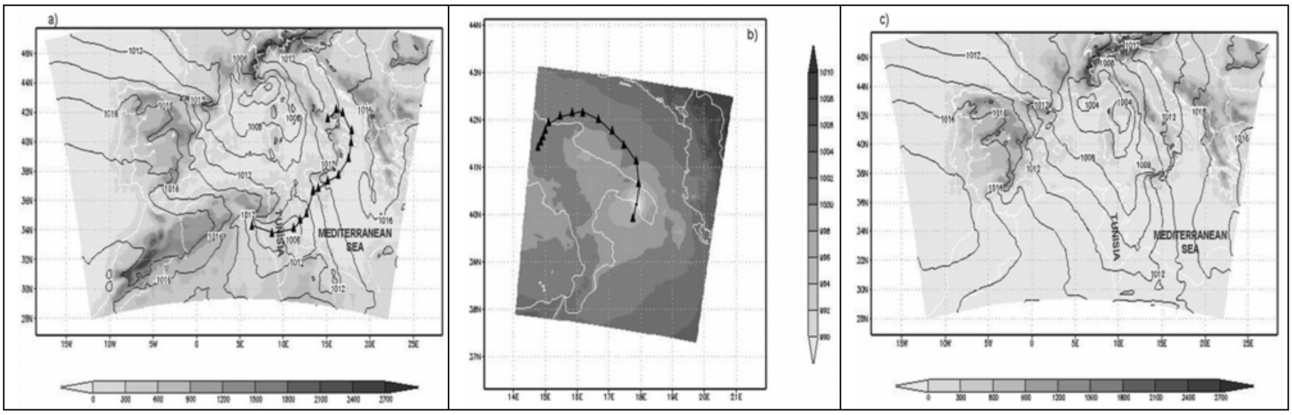


**Figure 4:** Control run results on the coarse grid: model topography (greyscale shaded areas), mslp at 06 UTC, 25 September 2006 (black contours, c.i.=2hPa), track of the cyclone from 00 UTC, 25 September, to 18UTC, 26 September (black triangles indicate the position of the cyclone every 3 h) (left, a); Control run results on the inner grid: mslp at 07 UTC, 26 September (greyscale shaded areas), track of the cyclone from 06 UTC to 20UTC, 26 September (black triangles indicate the position of the cyclone every hour) (middle, b); Sensitivity run results on the coarse grid: topography (greyscale shaded areas), mslp at 06 UTC, 25 September 2006 (black contours, c.i.=2hPa).

During 24 September, the numerical simulation shows a mslp low of 1008hPa in the lee of the Atlas Mountains, west of Tunisia, in Northern Africa. The pressure minimum forms east of the mountains at 12 UTC, where it remains stationary for the following 12 hours. Afterward, it moves eastward, reaching the Mediterranean sea, east of Tunisia, at 06UTC, 25 September (Fig. 4a). Then, the minimum slowly deepens while it moves over the Mediterranean sea; the track is oriented north-north-eastward in the morning, and north-eastward in the evening (Fig.4a). In the early morning of 26 September, the vortex deepens quickly in the Ionian Sea, reaching a minimum of 993hPa, and moves inland at 07UTC.

Figure 4b provides a zoom of the cyclone track and intensity after its first landfall, as simulated in the inner grid. The minimum value of 989hPa, predicted at 07UTC, is close to the lowest observed pressure value (986 hPa): the observed and simulated trajectories are similar, even if the simulation anticipates the movement of the cyclone inland of a couple of hours; also, the cyclone trail is slightly shifted to the west in the morning and to the north in the evening (figures 3c-4b). The coarse domain results are similar, although they underestimate more the intensity of the low.

Afterward, a sensitivity study of the mechanisms responsible for the development of the cyclone has been performed. Since the numerical simulation suggests an orographic origin of the minimum (Pedgley, 1972; Buzzi and Tibaldi, 1977), a simulation has been performed with the same initial and boundary conditions as the control run, but removing the African orography. The experiment results show that, at the beginning of the run, a minimum is still present in northern Africa, but it rapidly dissolves in the evening of 24 September. Comparing fig.4c with fig.4a, it is apparent that the absence of the pressure minimum persists at 06UTC, 25 September. Later on, the sensitivity simulation does not show any vortex moving over the Mediterranean Sea.

## 5. CONCLUSIONS

In this paper, the presence of a mesoscale vortex in the Mediterranean Sea has been documented and analysed numerically. Model results show that the model is able to realistically simulate the evolution of the system. Sensitivity experiments proved that a cyclogenesis on the lee side of the Atlas Mountain is responsible for the generation of the cyclone.

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