# An EF3 Multivortex Tornado over the Ionian Region

## Is It Time for a Dedicated Warning System over Italy?

BY MARIO MARCELLO MIGLIETTA AND RICHARD ROTUNNO

On 28 November 2012, an intense tornado affected southeastern Italy. At approximately 1050 LT (0950 UTC), this tornado, initially formed as a waterspout over the Ionian Sea, moved inland near the port city of Taranto, the third-largest in southern Italy, and hit the ILVA, the largest steel plant in Europe (Fig. 1). The tornado blew down the operator's cabin from a crane on which an employee was working in the harbor; his body was recovered some days later, 100 m farther out to sea. Fortunately, most of the ILVA workers were at home due to a temporary production stoppage, otherwise the outcome could have been far worse. The estimated damage to the plant was €60M, of which €20M was reported in the port area first crossed by the vortex.

An early warning message was sent out by the Italian Civil Protection Department (DPC), which has been in charge of issuing warnings since 2004, at an ordinary criticality level. The message warned of gale-force winds and the possibility of occasional thunderstorms or showers. Unfortunately, as in the majority of European countries (Rauhala and Schultz 2009), in Italy there are no procedures to warn for tornadoes and severe thunderstorms, which in our opinion is rather inadequate considering their potential threat.

**FIG. 1. Map of (left) the central Mediterranean, (middle) southeastern Italy, and (right) a detail of the Taranto area. The tornado track is shown with a thick red line, while the later supercell movement is shown with a dashed red line (Source: Google Earth). The names of the places and stations mentioned in the text are shown. The box in the left (central) panel identifies the area shown on the middle (right) panel.**

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**TRACK AND CHARACTERISTICS.** Early in the morning of 28 November, several convective cells were generated along the west side of the Ionian Sea. After crossing the relatively warm sea (the sea surface temperature measured in Taranto was 18.6°C), one of the cells assumed supercellular characteristics, and a waterspout was generated. In this phase, a fairly unique measurement of sea level was made by a buoy located just a few hundred meters to the east of where the tornado made landfall at the port of Taranto (Fig. 1): after a small decrease, the sea level increased rapidly by 30 cm, followed by a period of oscillations of decreasing intensity (Fig. 2).

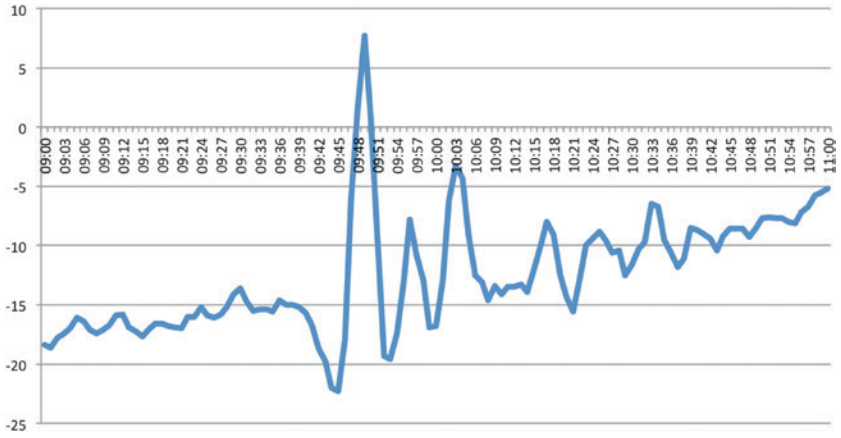


**Fig. 2. Sea level height (cm) with respect to the mean value. Data are provided by the station of Taranto from the national tide gauge network belonging to Servizio Mareografico ISPRA.**

After landfall, the vortex motion slightly deviated, moving from south to north for about 12 km, from west of Taranto to the small town of Statte (Fig. 1). When the supercell started crossing the Murge hills, it deviated northeastward; the funnel cloud lifted from the ground in this phase. After crossing the hills, significant damage was again caused to vegetation (hardwood trees were uprooted) and to a tourist village near the Adriatic Sea (as documented in Venerito et al. 2013), nearly 50 min after and about 50 km away from the location of the landfall. Unfortunately, no Doppler radar data are available in the area.

From the damage recorded at the ILVA, following the "Enhanced Fujita (EF) Scale Damage Indicators (DI) and Degrees of Damage (DOD)" (McDonald and Mehta, 2006), the event can be conservatively classified near the lower end of the category EF3,[1] with a maximum wind speed of approximately 230 km $h^{-1}$, which is the expected wind speed for the reported damages—collapsed rigid parts of metal structures (DI = 21, DOD = 7), significant damage to some external and internal building walls (DI = 17, DOD = 6), and removal of electricity pylons (DI = 24, DOD = 6). Also, in the area,

**Fig. 3. (top) Collapse of metal structures in the port area; (middle) a crane weighing several tons lifted; and (bottom) a concrete chimney completely destroyed (courtesy ILVA S.p.A.).**

[1] Since the degree of damage measures is based on U.S.-specific construction practices, the wind speed may have been underestimated. The application of the International Fujita Scale, adopted at the European Severe Storms Laboratory, would suggest an estimated wind speed of 324 km $h^{-1}$ (weak brick structure with walls partly collapsed).

**Fig. 4. Photograph taken near the tornado landfall, extracted from** www.youtube.com/watch?v=9ZOaOHKI0_A **(courtesy Giovanni Viscardi).**

cranes weighing several tons were lifted and a concrete chimney was completely destroyed (Fig. 3). The path width was estimated to be about 300 m just after landfall. Several photos and videos are available on the Internet (see, for example, Fig. 4). Some of them show the presence of a multivortex structure during this phase (www.youtube.com/watch?v=h7RbLqWt9Ns), with the presence of some minor vortices around the main structure, which in some cases were temporarily able to touch the ground, a typical behavior of such events (Bluestein 2013, p. 313).

Along the northern part of its track, near the city of Statte (Fig. 1), where the cyclonic circulation was still very intense and the canopy of a gas station was destroyed, the tornado of Taranto took extraordinary horizontal dimensions (among the largest ever photographed in Europe) similar to the so-called "wedge" tornadoes (Hill and Bronski 2009), since the diameter of its visual funnel[2] appears comparable to the lifting condensation level (LCL), which in the present case was about 700 m AGL (www.youtube.com/watch?v=NcL3LuATIxE).

**STORM ENVIRONMENT.** The synoptic environment was characterized by a deep upper-level trough over the Tyrrhenian Sea, associated with a mean sea level pressure minimum over Corsica. An intense upper-level southwesterly flow of relatively cold and dry air affected the Ionian region, while at lower levels a warm tongue extended northward up to northern Europe, producing conditions of potential

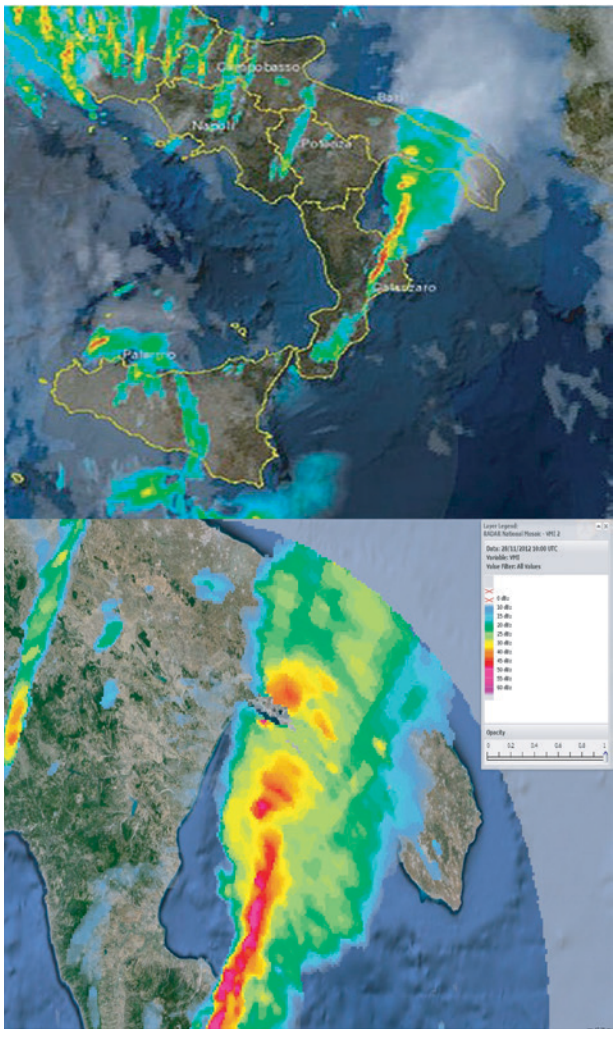


**Fig. 5. (top) Radar reflectivity (Vertical maximum intensity) at 1100 LT (Source: website of the Italian Civil Protection Department–Presidency of the Council of Ministers) over southern Italy and (bottom) zoomed in on the Ionian regions. In the top panel, heavy rainfall is denoted by red, moderate/heavy by orange, moderate by yellow, moderate/weak by green, weak by cyan, and cloudy but with no precipitation by gray.**

instability. Radar reflectivity maps (Source: Italian Civil Protection Agency) clarify the genesis of the event: the lifting induced by the Apennines appears to have triggered convection and generated a series of convective cells elongated in the direction of the upper-level wind, from south-southwest to north-northeast (Fig. 5). The same genesis mechanism was identified for other severe convective events in the region (e.g., Mastrangelo et al. 2011).

The vertical profile from Brindisi (the closest in time and space to the event) at 1200 UTC on 28

[2] A path width of about 500 m was estimated in this phase using geomorphological methods (Venerito et al. 2013).

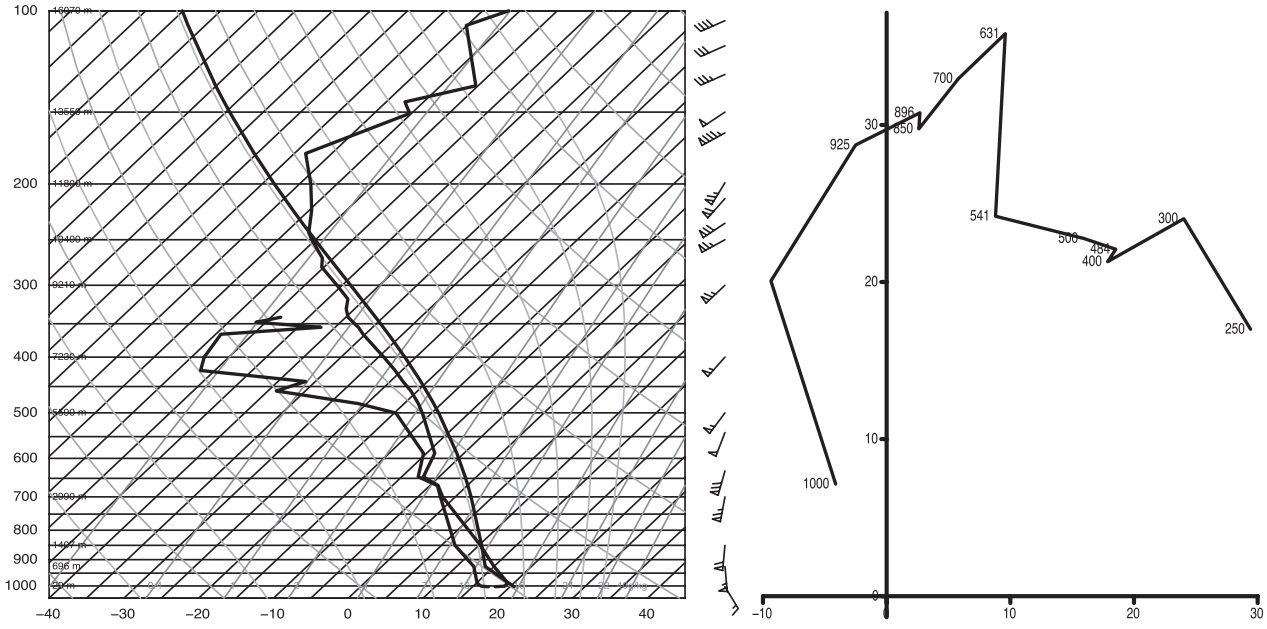


**FIG. 6. (left) Skew-*T* diagram and (right) hodograph from Brindisi at 1200 UTC, 28 Nov 2012. In the Skew-*T*, wind units are in knots, temperature in °C, and pressure in hPa; in the hodograph, wind units are in m s$^{-1}$. (Source: University of Wyoming)**

November 2012 (Fig. 6a) shows the presence of very moist air in the lower levels, advected by the southerly flow below 500 hPa, with the atmosphere close to saturation near the ground. A strong pressure gradient is consistent with the intense wind speed over the region, with the low-level wind reaching 56 kt at 686 m above sea level (57 kt at 606 m, 12 h later), an absolutely extraordinary value. As a consequence, a very large vertical wind shear was present in the lowest km of the atmosphere.

The hodograph shown in Fig. 6b indicates a sharp increase in wind speed with altitude and implies a flow with large values of horizontal vorticity; the curved hodograph is typical of tornadic supercells in the United States (Maddox 1976). The storm-relative helicity (SRH) was 686 m$^2$ s$^{-2}$ in the layer 0–3-km AGL (553 m$^2$ s$^{-2}$ in the lowest km) in the Brindisi sounding (Source: Plymouth State Weather Center). The 0–3- (0–1)-km Energy-Helicity Index (EHI) reached the high value of 3.4 (2.7), although only moderate instability was present [the surface-based convective available potential energy (CAPE), obtained by lifting a parcel from 2-m height and including the virtual temperature correction, was 970 J kg$^{-1}$].

**COMPARISON WITH CLIMATOLOGY.** Comparing these values with the only existing climatology of tornadoes in Italy extracted from 10 years of data (Giaiotti et al. 2007), it is found that the low-level vertical wind shear for this event was more than twice the climatological mean for F3 tornadoes. Also, the values of 0–3-km SRH and EHI turned out to be the largest.

Even compared with U.S. tornadoes, the tornado of Taranto shows some unique characteristics. Considering the 0–1-km wind difference of 24.8 m s$^{-1}$ and the mixed-layer LCL of about 700 m shown in the Brindisi sounding, the environment of this tornado fell into the high end of the two-dimensional distribution associated with U.S. tornadoes (cf. Fig. 7.4 in Bluestein 2013, and Fig. 10.13 in Markowski and Richardson 2010). The storm motion, estimated from the nearby hodograph, was from the south-southwest with a speed of 45 kt.[3] Considering this value as a proxy for the translation velocity, the tornado would fall above the 75th percentile of the Alexander and Wurman (2008, their Fig. 3) distribution.[4]

[3] The storm motion was calculated using the scheme proposed in Bunkers et al. (2000), but changing the layer for the calculation of mean wind from 0–6 km to 0–8 km, as discussed in Ramsay and Doswell (2005).

[4] However, this distribution is biased toward the U.S. Great Plains states, a region where typically, relatively slow right-moving supercells are favored.

Together with the favorable wind profile, other local factors may have favored the development of the tornado. The Taranto bay called Mar Grande (Fig. 1) may have locally enhanced the instability shown in the Brindisi sounding, behaving as a source of high equivalent potential temperature, due to its low bathymetry. Also, the high surface temperature of the Ionian Sea (about 2°C higher than the climatology) may have played an important role in producing intense sensible and latent heat fluxes and in providing energy to convection. This would also explain the occurrence of the tornado late in the season, compared to the peak in tornado activity, which is generally observed over Italy in late summer and early fall.

The possibilities offered by the Internet to post and share images and videos of tornadoes and waterspouts and the storm report archiving in the European Storm Weather Database have made it apparent that the frequency of their occurrence over the Mediterranean has been largely underestimated. Together with a large number of weak events, large and moderate-to-intense vortices are regularly observed. From Giaiotti et al. 2007, it appears that at least 3 F2 tornadoes occur per year, with an F3 event every 1.5 years. A significant fraction of Europe's deadliest recorded tornadoes occurred in Italy [see Groenemeijer and Kühne (2014)'s Table 1]. Although the information is increasingly fragmented when going back in time, three events of intensity greater than F3 are estimated to have affected Italy in the last century, the strongest one (F4/F5) occurring in northeastern Italy (Montello) in 1930, while 36 casualties were reported in an F3/F4 tornado near Venice in 1970.

The distribution of past events suggests that their occurrence is concentrated in some specific areas [see Groenemeijer and Kühne (2014)'s Figs. 1 and 2b], and Salento (Fig. 1) appears to be one of these. In particular, in the last few years, several weak and small waterspouts, which remained mostly confined over the sea, have been photographed offshore of the port of Taranto. A detailed study of historical chronicles and newspapers has been carried out in Gianfreda et al. (2005), showing that the earliest documented tornado in Salento dates back to 1546. Most of the historical events appear to have a similar propagation from the Ionian Sea inland, in a few cases producing severe damage and casualties. In particular, the tornado affecting the region in September 1897 killed at least 55 people, which is among the highest number of fatalities caused by a tornado ever documented in Europe.

**OPPORTUNITY FOR A DEDICATED TORNADO WARNING SYSTEM.** From the evidence presented here, it is clear that, although rare, tornadoes having EF2 or stronger intensity can occasionally affect the Italian territory, while weaker events are more frequent. Just as an example, according to the European Severe Weather Database (ESWD; Dotzek et al. 2009), from the beginning of October to mid-November 2014, 25 tornadoes were identified over Italy, one being classified as F2 and four as F1. The detection and prediction well in advance of the possible occurrence of these events appears to be a necessary task for civil protection purposes, which, we believe, cannot be further postponed.

Following the complex evolution of the Italian National Weather Service discussed in Visconti and Marzano (2008), the institution by law of the National Distributed Weather Service in 2012 (although its organization and implementation is still a work in progress[5]) is the result of a long discussion started in the early 1990s. The new service will merge together the activity of the DPC, the Air Force Weather Service (until now the Italian National Service "de facto"), and the Regional Hydrometeorological Services, and should allow for a more rational organization of a system where, until now, competencies and tasks have often overlapped. The situation is critical mainly in southern Italy, where the Civil Protection Agency regional offices are still under development, and observational sites are distributed among a plethora of different institutions, often with no specific competency in meteorology.

However, the new organization is not expected to issue alerts for the prediction of localized severe thunderstorms, and we believe that several obstacles need to be overcome in order to establish a dedicated warning system.

First, detailed and accurate statistics of the intensity and distribution of these events is still lacking over Italy. The only climatological study for tornadoes specific for Italy is incomplete and not up to date, and only a few case studies (mainly affecting northeastern Italy) have been the subject of a detailed analysis and have been published in the scientific literature (e.g., Alberoni et al. 2000; Bechini et al. 2001). Also, very few studies are

[5] The Presidential Decree that would establish the organization of the National Distributed Weather Service has been submitted to the Italian government (Davolio et al. 2015).

available dealing with the climatology of thunderstorms (Cacciamani et al. 1995), hail (Morgan 1973), and lightning (Feudale and Manzato 2014), and are limited to the Po Valley.

The ability to predict a tornado's precise path and intensity is an extremely complex process, requiring years of experimentation. Even if such a long-term goal is still very far off, at least some initial steps should be taken toward the identification of possible risk scenarios. The conditions associated with tornadoes have been extensively studied and include contributions from an environment conducive to deep moist convection and a source of easily stretched low-level vertical vorticity (Doswell et al. 2012), either vertically advected from a strongly sheared environment or converged from preexisting fields of vertical vorticity. Considering the morphology of the Italian territory, where complex circulations induced and/or modulated by the presence of the sea and of the orography may especially affect the meso-gamma scale, it appears that the conceptual models developed for the U.S. Midwest should be modified or adapted to the peculiar Mediterranean environment. In particular, the role of the warm Mediterranean sea surface and the presence of a very long and complex coastline should be properly investigated and analyzed.

In the United States, watches and warnings are issued mainly based on observed data; as discussed in Brotzge and Donner (2013), weather radar is the primary tool for the detection of supercell thunderstorms, allowing the identification of the rotation that precedes tornadogenesis. It is clear that in areas with limited Doppler radar coverage, as in Italy, the detection and forecasting of tornadoes is severely hampered. The radar reflectivity mosaic recently (finally!) made available in real time over Italy can help detect dangerous situations. Some regional operational Doppler and a few polarimetric radars can be very helpful, where available, to discover tornado signatures and to represent the wind field correctly, although these provide only limited coverage.

Finally, the chains of limited-area models (deterministic or ensemble) operationally implemented over Italy do not include sufficient guidance to assist in forecasting localized severe convection among the output fields. This limitation precludes the possibility of forecasting the presence of dangerous conditions well in advance.

The recent cooperative effort during the Hydrological Cycle in Mediterranean Experiment (HyMeX; Ducrocq et al. 2014) has made clear that, even without dedicated funding and without the official support of the Air Force Weather Service, it is possible to share resources and expertise from the different regional services and the scientific community (Ferretti et al. 2014; Davolio et al. 2015) and overcome—at least temporarily—the traditional fragmentation of the Italian system. The institution of the National Distributed Weather Service should accelerate this process and give new impetus to the research, which has often been neglected in the scarcity or even absence of specific funding from the operational centers and from the central government, and to the academic education in the field. Currently, Italian universities do not offer any five-year educational training specific to atmospheric physics and meteorology.

The new organization should plan to establish an office dedicated to the diagnosis, monitoring, and forecasting of severe thunderstorms and tornadoes. A potential model for this organization could be the Storm Prediction Center (SPC; www.spc.noaa.gov/) in the United States, a forecast center that issues convective outlooks, mesoscale discussions, and watches. The European Storm Forecast Experiment (www.estofex.org; Brooks et al. 2011) is experimenting with producing a European-centric version of SPC's convective outlooks. However, to properly satisfy the needs of a warning system at the national level, information at finer horizontal and temporal scales is needed, possibly issuing high-resolution warnings for selected regions that can take into account the inhomogeneity of the Italian territory—similar to the practice of the Bureau of Meteorology in Australia. This would represent a relevant improvement in a country where, until now, the meteorological information provided—but also that required by the final users—has often been of low quality (Tibaldi 2014).

Finally, the population should be educated to deal with alerts. The recurring floods over Italy in the last few years have surely increased the awareness of the risks associated with severe weather and made clear the need to adopt more precautionary behavior. However, there is still a long way to go to reach an acceptable level. An increased consciousness regarding tornadoes and severe localized convection is a necessary objective. This task requires some substantial background research, not just in meteorology but in social science (see for example, Simmons and Sutter 2011), identifying whether a hazard-information flow

substantially different from the U.S. system would be more appropriate.

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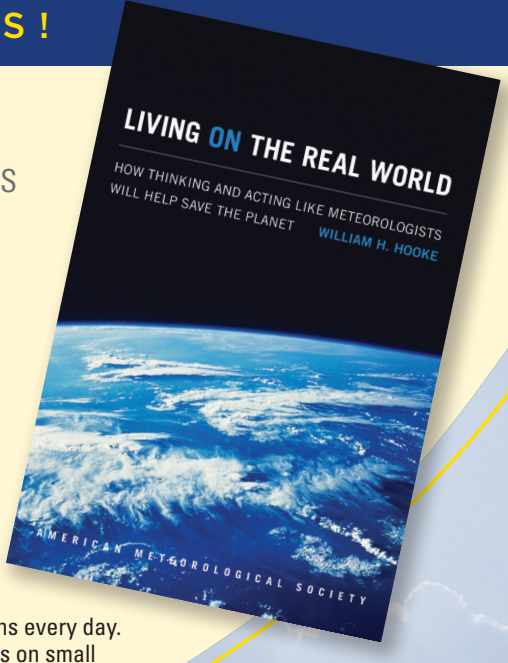


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