Meteorological precursors of significant tornadoes in Italy for the period 2000-2017

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Introduction

- Tornadoes are relatively common in Italy, occurring mostly on flat terrains in the north and along the coasts in the south of the peninsula (Giaiotti et al. 2007; Miglietta and Matsangouras 2018).
- The occurrence of significant tornadoes is not so frequent in Italy, although some of them have caused fatalities and significant damages in the past, such as the tornado (EF3) in the Taranto area, in November 2016, when a worker in the ILVA complex died and caused 60 millions euros of damage (Miglietta and Rotunno 2016) or the Tornado (EF4) between Mira and Dolo that, in July 2015, caused one death and 20 millions euros of damage (ARPAV 2015).
- During the past years, only few works have analysed the precursors of tornadoes and their climatology in Italy, despite of the importance and the risks associated with these events. For this reason, a focus on some of parameters related to tornadoes is necessary.
- An analysis of the precursors is provided by means of two reanalyses provided by ECMWF: ERA-INTERIM and ERA-5. A previous work (Brooks 2003) provides the support to an approch based on reanalysis output showing patterns that are qualitatively similar to other analysis by means of satellite observations.
- There are several studies to identify parameters linked to tornado events and to define good forecast precursors. This task is not simple because of the difficult to create a complete database of the past events.

Fig.1: EF4 tornado in Mira and Dolo, in July 2016, on the left and EF3 tornado in Taranto, in November 2012, on the right . Source: 3bMeteo and TvDaily

Objective

The aim of this study is to evaluate three potential precursors, in order to check their temporal evolution in the hours before the tornado time and their potential role in triggering the tornadogenesis.
These precursors are: wind shear (magnitude vector difference between 0-1 km and 0-6 km, here referred to as WS01 and WS06) and wmax, the maximum vertical velocity related to CAPE in the simple parcel theory.

Data and Methods

The data set used for the analysis of the tornado events was created from Miglietta and Matsangouras (2018), which is based on the European Severe Weather Database (ESWD) - managed by the European Severe Storm Laboratory (ESSL) - , the regional agencies (e.g. ARPA) and even the amateur reports, that provide an important contribution to the scientific research on tornadoes.
Only significant events (EF2+) were included in this data set.

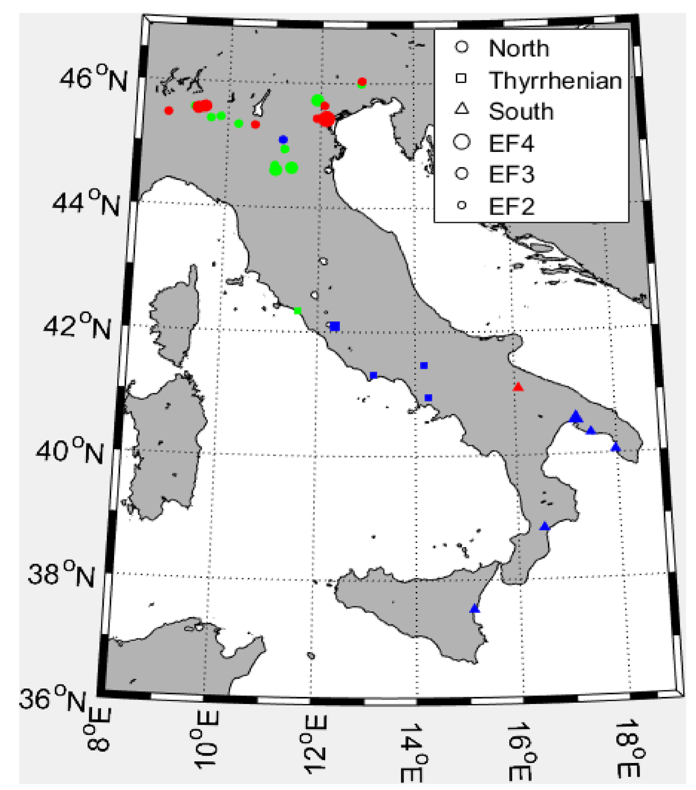

Fig.2: Map with the location of significant tornadoes (category EF2 or stronger) considered in this study in the period 2000-2017. Colors of dots denote season (green for spring, red for summer and blue for autumn) and their size the three different recorded category of tornadoes (EF2-EF3-EF4). The different markers represent the three different macro-regions: bubbles for north Italy, squares for Tyrrhenian area and triangles for the southern regions.

A total of 32 EF2+ events were analyzed (Fig.2), 11 for Spring April-May-June) and Summer (July-August-September) and 10 for Autumn (October-November-December).

ERA-INTERIM has approximately a 80 km resolution on 60 vertical levels from the surface up to 0-1 hPa, while ERA5 provides hourly estimates of meteorological and climate variables and is based on a 30km grid resolution with 137 levels from the surface up to a height of 80km.

In order to obtain comparable parameters, a process of standardization of the three meteorological precursors was developed and three different indices were calculated. For every tornado, four timesteps - those occurred just before the event - have been selected in order to check the temporal evolution of the precursors, so a temporal range of 18-24 hours is covered because of the 6 hours resolution of the reanalyses. The time step closest to the time of the tornado is denoted as timestep 1.

Results

- The WS01 panel, on the left in Fig. 3, is consistent with the idea that high values of WS01 play an important role in the tornadogenesis, as it can be seen from the greater aggregation of markers at the top of the panel. In fact the 50% of WS01 indices are over the value of 2, in contrast to WS06 index, for which only the 15% of the values is over this threshold.
- At the same time, the CAPE, although shows few large values, is not characterized by negative index values. A particular relationship between high values of the three parameters and the tornado intensity (represented from the size of the markers) is not clear.

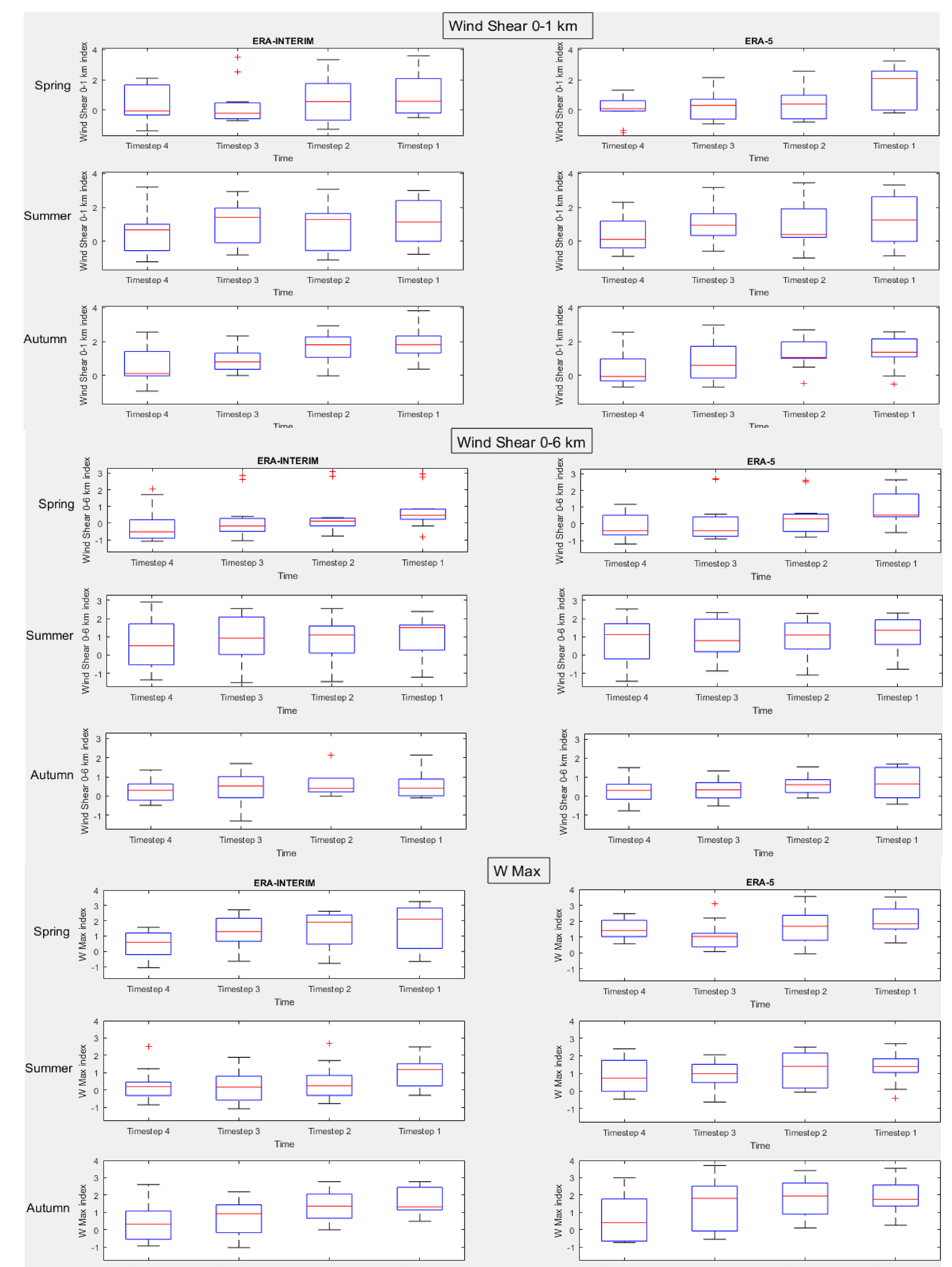

Fig.4: Boxplots for 0-1 km wind shear (top), 0-6 km wind shear (middle) and wmax (bottom) . The red line, inside the box, represents the median, the upper and lower limit of the boxes the 25th and 75th percentile, while the value considered for the whiskers is approximately +/–2.7σ. The red crosses represent the outliers. Each panel refers to a different season: spring (top), summer (middle), autumn (bottom). Timestep 1 is the latest available step before the occurrence of the tornadoes. Former steps 2, 3 and 4 are 6, 12 and 18 hours before timest 1, respectively.

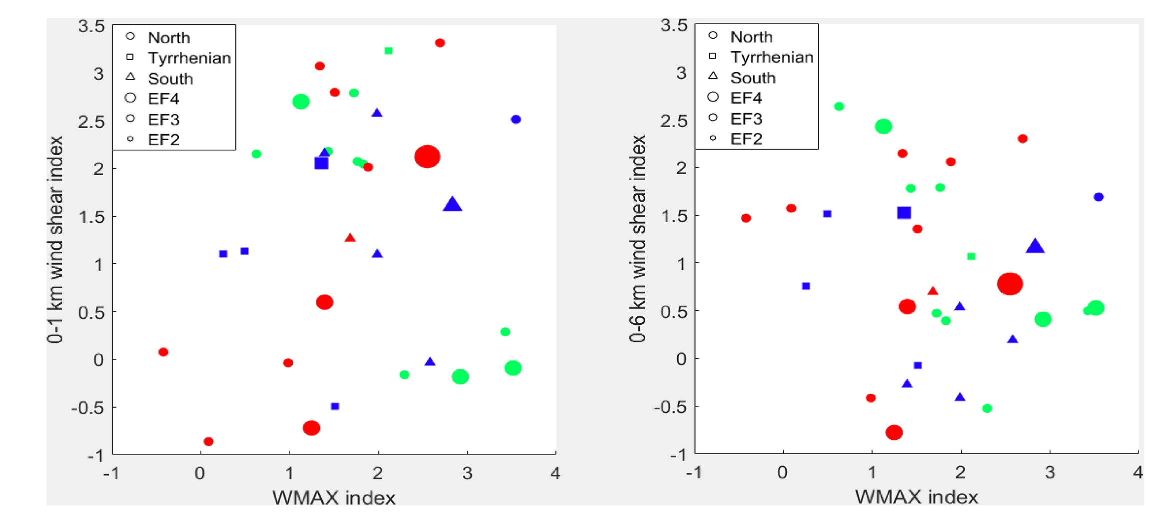

Fig.3: Relationship between WMAX and WS01 (on the left) and WS06 (on the right) based on ERA-5 reanalysis. Colors, markers and their size represent the same as in Fig.2

- Fig.4 shows the temporal evolution for every precursor. The boxplots show, generally, a tendency to increasing values of the precursor as the timesteps become closer to the event. The difference between the timestep 1 and timestep 4 is statistically significant (the Mann-Whitney test at the 5% significance level has been used) in Autumn for WS01 and wmax (but only with ERA-INTERIM) and in Spring for W06 in both reanalyses. Moreover the timestep 1 for WS01, calculated in Autumn, by means ERA-INTERIM reanalysis differs from the reference climatology. It is the only case for wind shear variables. On the contrary, wmax, calculated at timestep 1 in ERA-5, differs from climatology for each season, while in ERA-INTERIM denotes this difference only in Autumn.
- In general the ERA-5 reanalysis shows higher values for the Wind Shear and WMAX climatologies compared to ERA-INTERIM data set.

Conclusions

✓ High values (over the value of 2) of Wind Shear Index, calculated between 0-1 km, are reported in 50 % of the cases. On the contrary, only the 15 % of the tornadoes shows WS06 values over this threshold.

✓ The WMAX parameter calculated at the closest timestep to tornado time differs from the climatology in each season for ERA-5 reanalysis, while only the Wind Shear, calculated between 0-1 km in autumn, for ERA-INTERIM data set, differs from climatology. This suggests that WMAX denotes a better performance, as precursor, compared to Wind Shear.

✓ ERA-5 data set shows, generally, higher values of the two precursors and higher significance of their anomalies, especially close to event time.

Perspectives

A more robust analysis of the three precursors will be provided by future availability from 1950 of ERA-5 data set, which will allow to consider a wider sample of recorded tornadoes than that considered in this preliminary study.

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