A significant tornado event near a dryline bulge in northern Italy

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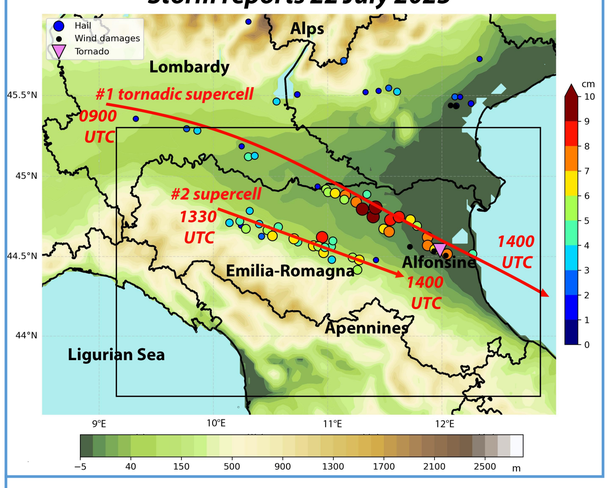
MOTIVATION

On 22 July 2023, a tornado measuring **1.5 km in diameter** and grading 3 on the International Fujita (IF) scale struck parts of Alfonsine, northeast Italy. The event was investigated via radar and sounding data, ground weather stations and extensive damage surveys. The supercell responsible for it went through progressive intensification in three different phases, culminating in tornadogenesis as it approached a dryline bulge. Despite its intensity and rain-wrapped nature, the tornado caused **only 14 injuries**.

STORM EVOLUTION

Topography (scale at the bottom) of northern Italy with hail (filled colored dots, hail size according to the scale to the right), wind damage (black dots) and tornado (purple triangle) reports from the StormReport database for 22 July 2023. The black box is the domain for Figure 3.



An initially hail-bearing supercell became tornadic as it approached a dryline bulge and a maritime air mass with very high-theta-e values. Before tornadogenesis occurrence, the supercell significantly turned right and generated a damaging RFD surge, with unusually cold wind gusts. A dry and hot air mass from the southwest was partially ingested by the mesocyclone just before the tornado developed.

OBSERVATIONS

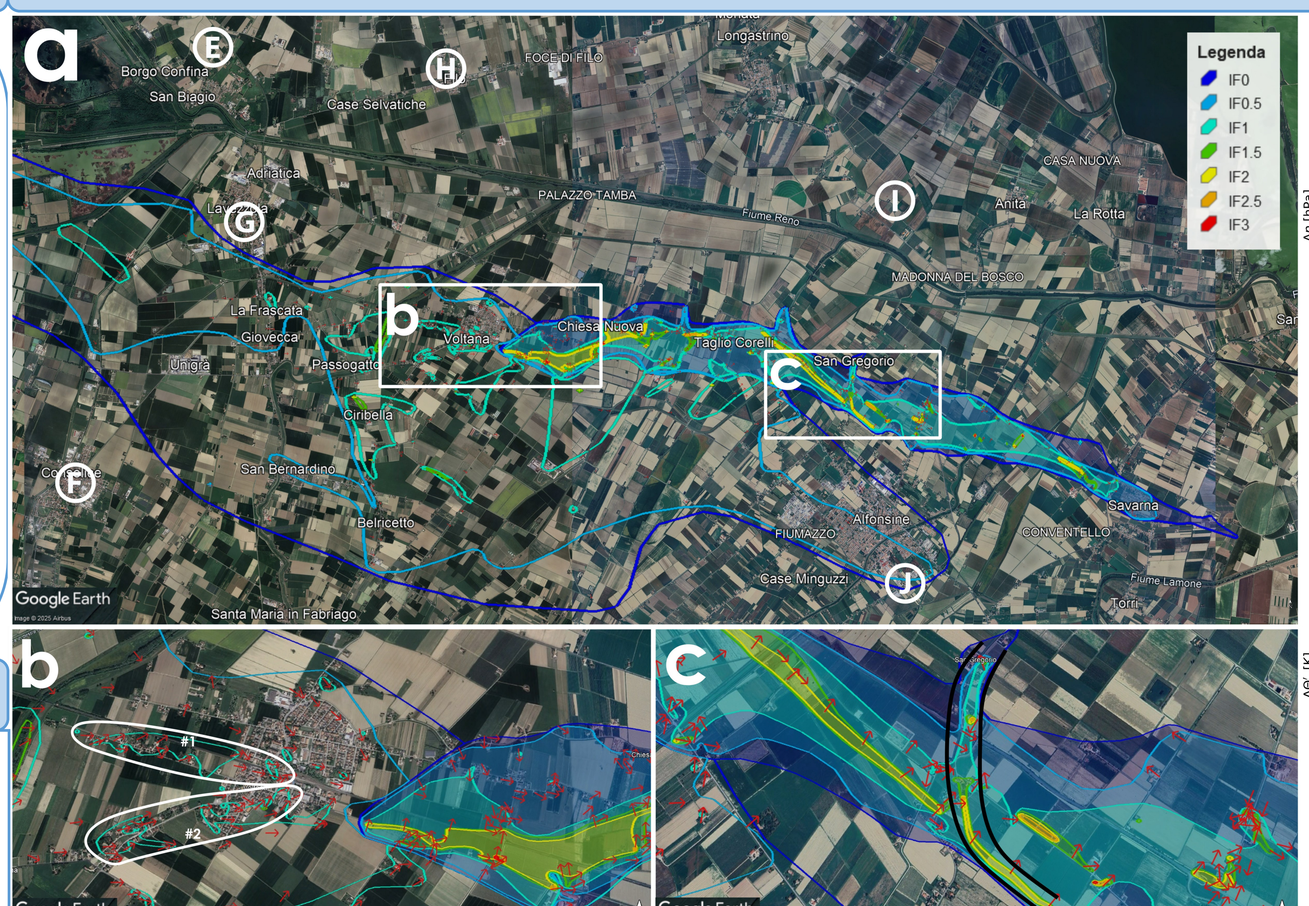


Figure 1: Reconstruction of the tornado and Rear Flank-Downdraft (RFD) damage path. Red arrows indicate the damage pattern, colored polygons correspond to International Fujita (IF) scale intensities and circled letters show weather stations used for the analysis (Figure 2). Two zooms (b and c panels) show the transition from straight-line wind damage to tornado damage and a possible tornadic subvortex, respectively.

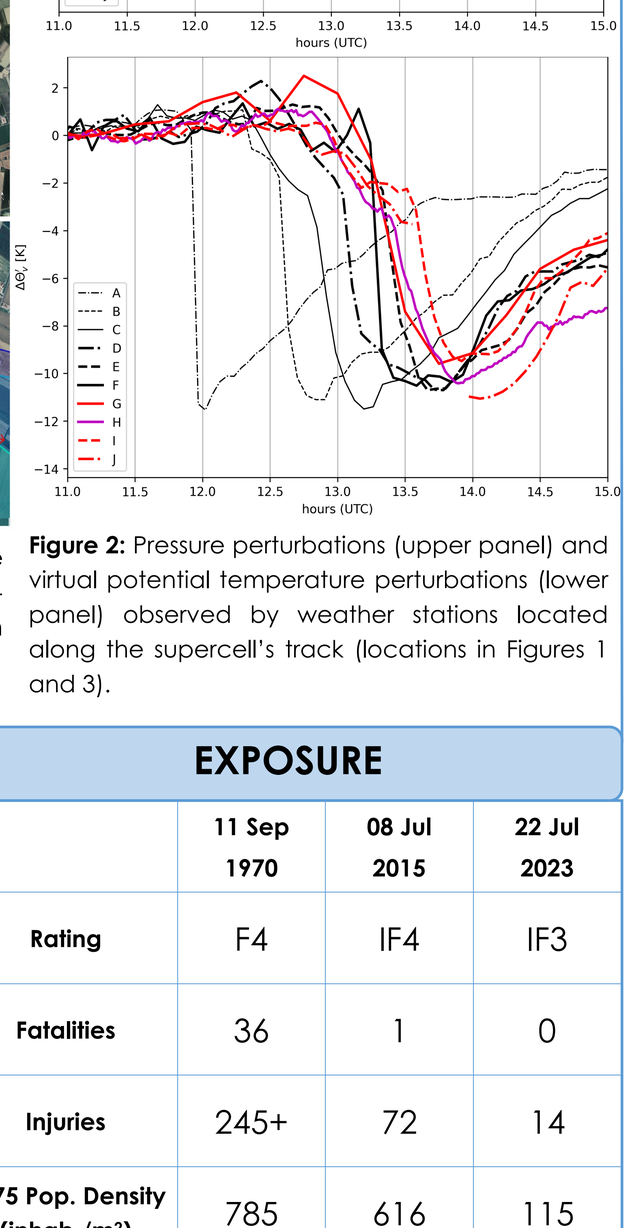


Figure 2: Pressure perturbations (upper panel) and virtual potential temperature perturbations (lower panel) observed by weather stations located along the supercell's track (locations in Figures 1 and 3).

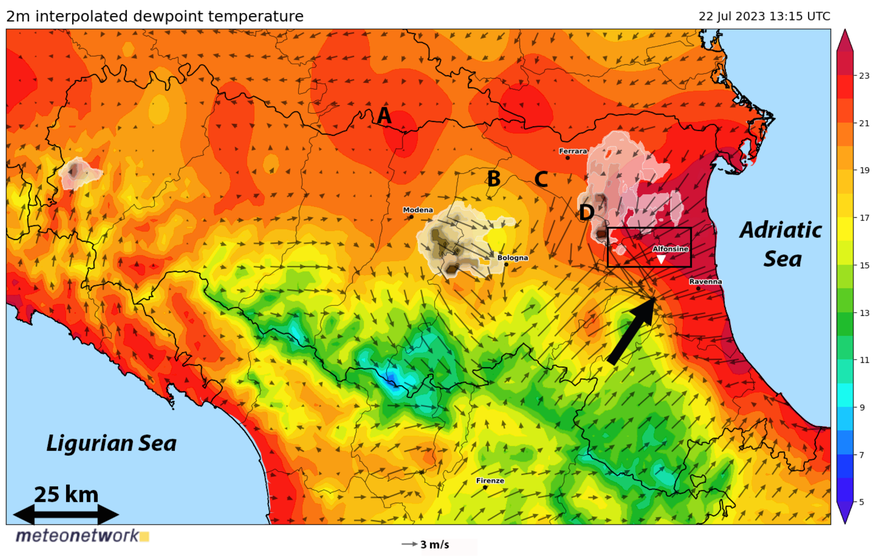


Figure 3: Interpolated 2 m dewpoint temperature from the MeteoNetwork weather stations network. Winds are plotted as black arrows, reflectivity from the National Civil Protection Department radar composite is plotted as grey-shaded areas and specific weather stations used for the analysis are labeled with letters. The dryline bulge in front of the tornadic supercell is highlighted with the larger black arrow. The black square represents Figure 1a.

EXPOSURE

	11 Sep 1970	08 Jul 2015	22 Jul 2023
Rating	F4	IF4	IF3
Fatalities	36	1	0
Injuries	245+	72	14
1975 Pop. Density (inhab./m²)	785	616	115
2020 Pop. Density (inhab./m²)	877	676	137

Table 1: Data of three significant tornadoes in NE Italy. Population density is computed from a 6-km-wide box around the tornado center's paths.

NUMERICAL SIMULATIONS

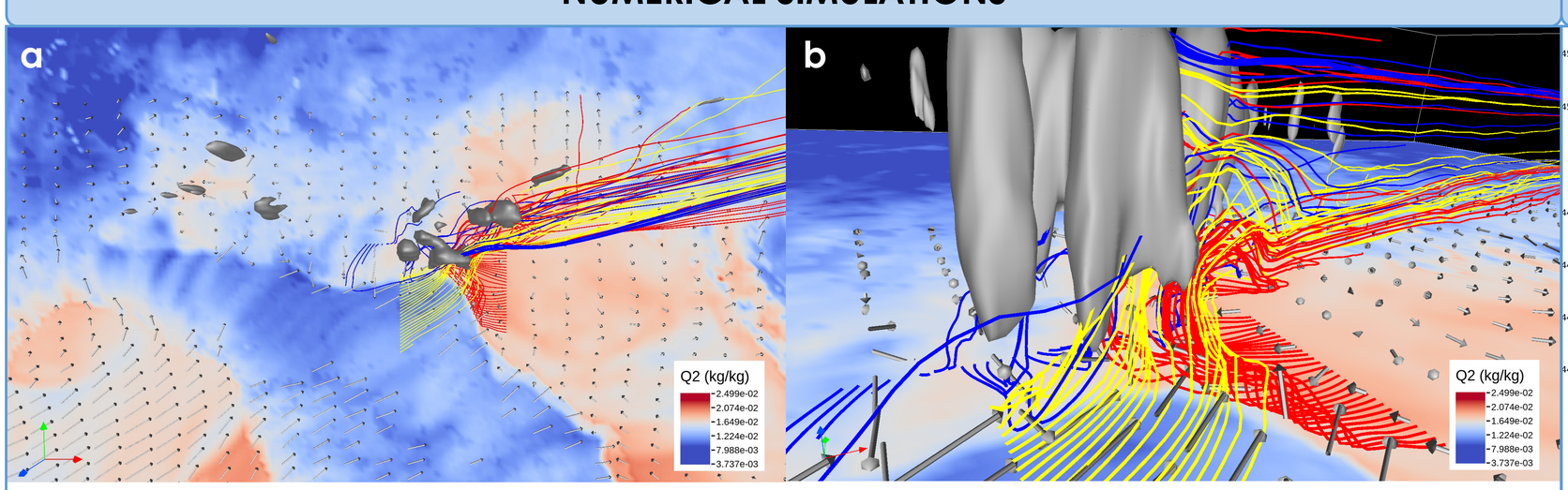


Figure 4 (above): Results of a WRF simulation initialized at 12 UTC on 21 July 2023 with ICON-EU that successfully reproduced the supercell. (a), specific humidity at 2 m (kg kg^{-1}; color shading), vertical velocity ≥7 m s^{-1} (gray patches), wind at 10 m (arrows), trajectories of 30 seeds released in the dry air mass (yellow lines), in the cold pool (blue lines), and in the moist maritime air mass (red lines) at 13 UTC on 22 July 2023 using VAPOR; (b) as in (a) but with a three-dimensional view from the southwest.

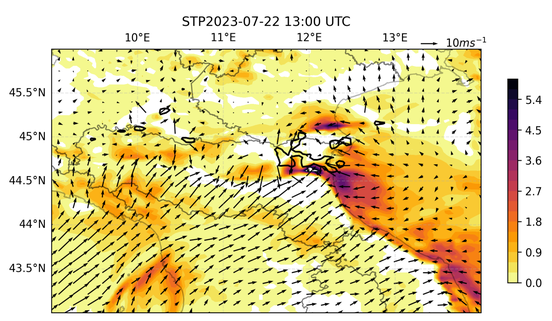


Figure 5 (right): Significant Tornado Parameter (color shading), 10 m winds (arrows) and simulated reflectivity (black line) at 13 UTC of 22 July 2023. Results of the same simulation of Figure 4.

CONCLUSIONS

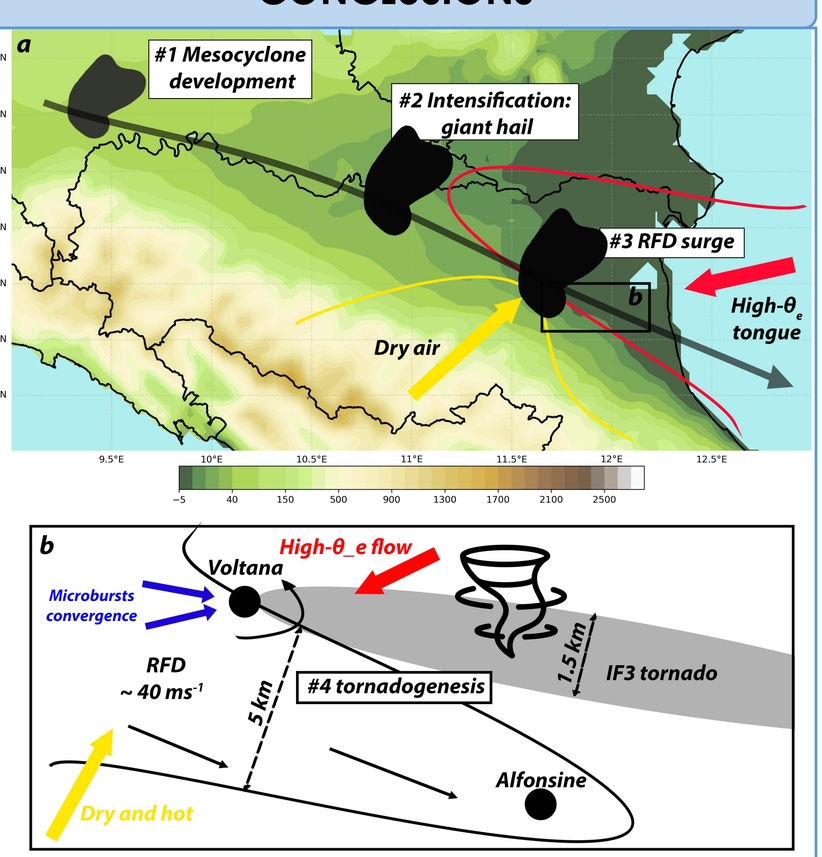


Figure 6: Conceptual model of the Alfonsine tornado event: (a) three stages of the supercell evolution in the Emilia-Romagna region; (b) a sketch of the tornadogenesis process that occurred within the black box in (a).

REFERENCE

De Martin, F., Pavan, F., Carlon, N., Cioni, G., Rozoff, G., Poli, V., Carpentari, S., Miglietta, M. M. (2025), A Significant Tornado Event near a Dryline Bulge in Northern Italy, *Wea. Forecasting*, **40-11**, 2293-2315, https://doi.org/10.1175/WAF-D-25-0071.1