“Evaluation of severe rainfall events environmental characteristics using radar, in situ and NWP data”

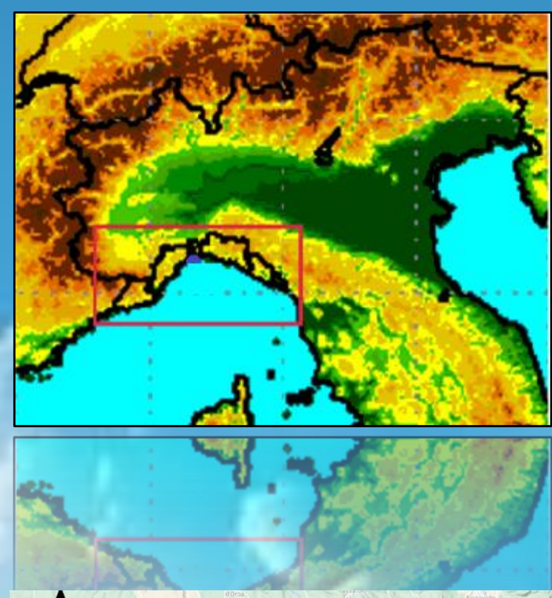
Enrico Solazzo[1], Antonio Iengo[1], Davide Sacchetti[1], Francesco Battaglioli[2]
[1]Regional Agency for Environmental Protection - Weather, Hydrological and Climate Centre
[2]European Severe Storms Laboratory

The Liguria region is located in the Northwestern part of Italy and is characterized by a steep and complex orography nearby the coastal areas with a rather complex rain regime. The amount of precipitation increases proceeding from the coast towards the inland and from West to East (Figure 1). Short and intense rainfalls often hit the region and have shown an increasing frequency in the recent decades. These rainfalls, especially if concentrated on mountains not far from the coasts, can generate the phenomenon of flash floods along the short streambeds that have significant slopes [1-3]. This can cause damage and fatalities.

The present study aims to identify the environmental atmospheric features typical of a severe storm, meaning as "severe" a storm event that has been characterized by rainfall exceeding the 50mm/1h threshold (corresponding to a 5 years return period). For this purpose, starting from the rain gauge database of Liguria network stations, 69 severe rainfall events occurring between the years 2019 and 2021 have been selected, and have been investigated to obtain information about typical convective ingredients of the storm environment.

Rapid Developing Thunderstorm (RDT) algorithm of DPCN has been used to identify the “thunderstorm objects” (Figure 2) associated with the previously selected rainfall threshold over the Liguria domain. The thunderstorm object “representative” of the event that led to the exceedance of the 50mm/1h threshold is the one with the maximum Surface Rainfall Intensity (SRI) in the neighborhood of the rain-gauge, considering a tolerance margin of +/- 30 minutes.

In order to identify environmental atmospheric features of each event, a subset of parameters from the deterministic meteorological models have been investigated in a 33*33 km² centred around the lat-lon position of the thunderstorm. Forecast model fields from ECMWF model and the High Resolution Non-Hydrostatic Limited-Area Model MOLOCH have been used in order to identify the convective environment. In order to allow the correct sampling of the convective environment, the closest runtimes to the event were chosen. From each of these models, some of the most representative convective parameters have been considered. These include CAPE, CIN, Specific Humidity, Relative humidity, Dew Point Temperature Depression, Lapse Rate, Integrated Water Vapour and Wind Shear at different levels.



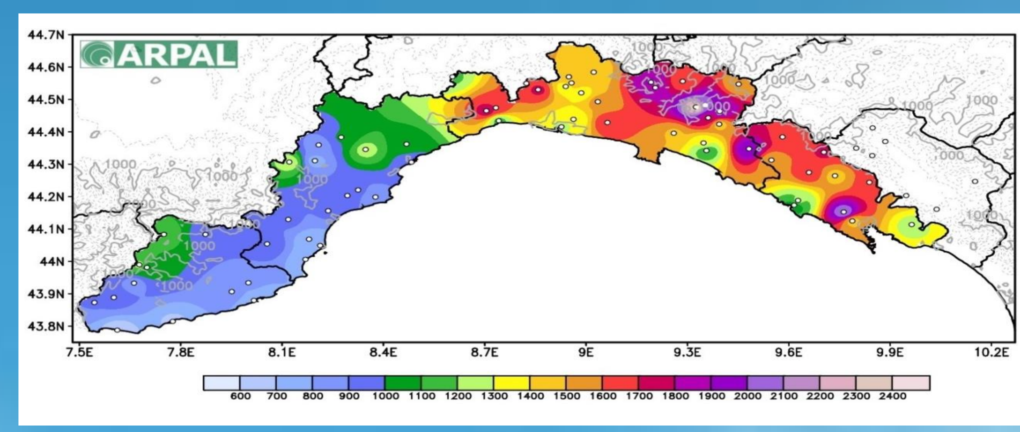


FIGURE 1. Cumulative precipitation [mm]. Annual mean total precipitation 1961-2010 (reference period)

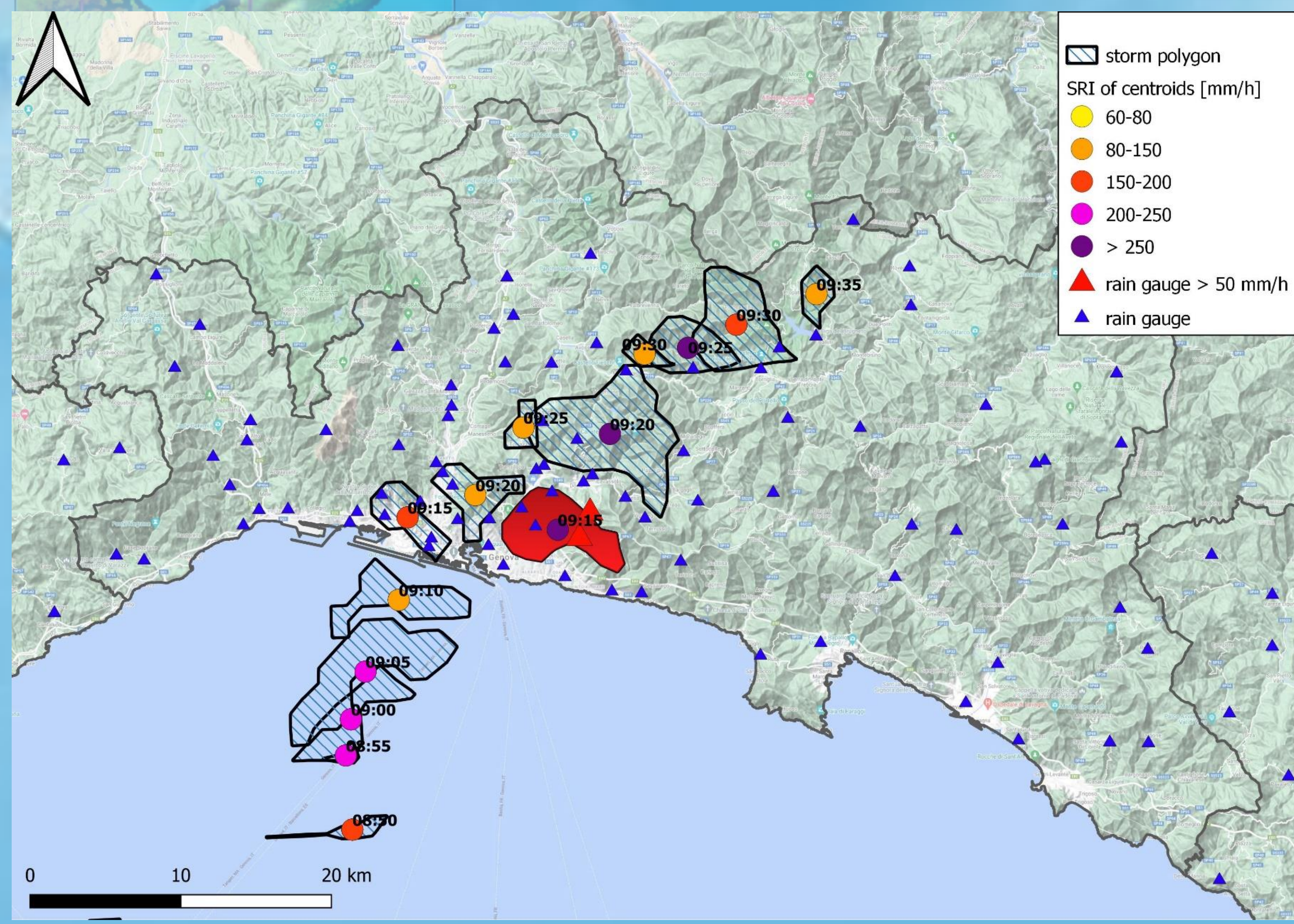


FIGURE 2. An example of “thunderstorm objects” identification. Red polygon identifies the thunderstorm that led to the exceedance of the 50/1h (red triangles)

SEVERE STORM ENVIRONMENT

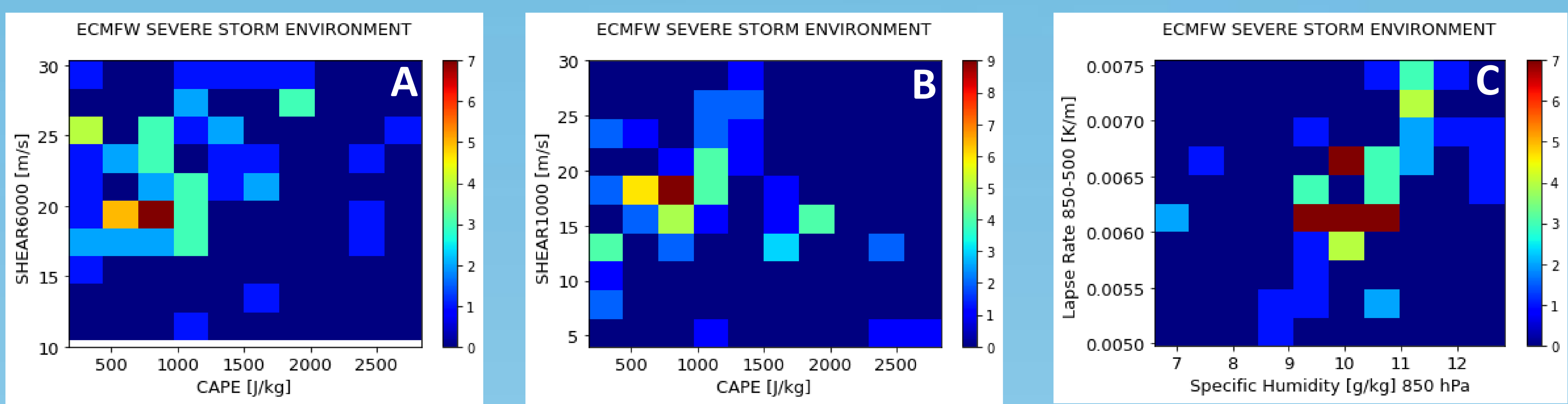


FIGURE 3. Environmental atmospheric features in severe events with ECMWF model

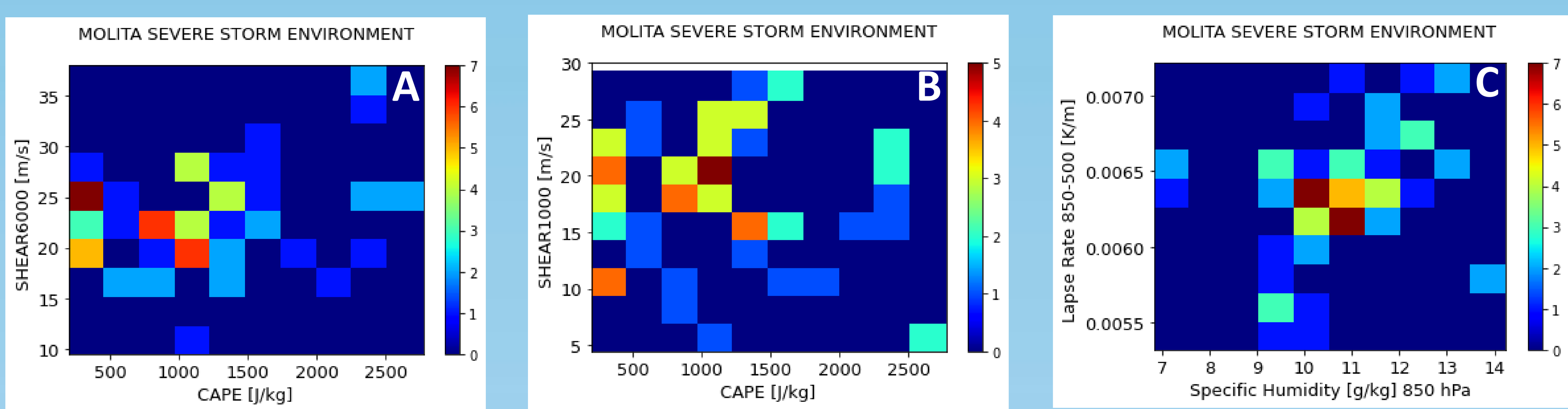


FIGURE 4. Environmental atmospheric feature in severe events with MOLOCH model

As shown in Figure 3A, the majority of the events occurred with high DLS (> 15 m/s) and moderate CAPE (< 1500 J/kg). However, a subset of events characterized by high CAPE (between 1500-2000 J/kg) and strong DLS (between 25-28 m/s) can be identified. We hypothesize that the majority of these events occurred during the summer season.

The results in Figure 3B show that most of the events occurred with high values of 0-1 km Shear (between 15-20 m/s), highlighting the presence of a Low Level Jet (LLJ) roles in extreme events. No steep Lapse Rates (around 6-6,5 K/km) were found for these kind of events, however Specific Humidity values are almost always between 9-11 g/kg (Figure 3C) and Integrated Water Vapour between 35-40 mm. This suggests a conditional unstable profile where the trigger mechanism, for instance low level convergence or orographic lifting, played a key role for the storm initiation. The results shown with Limited Area Model (LAM) MOLOCH are similar compared to the ECMWF fields. However, a general trend for higher instability can be seen in MOLOCH compared to ECMWF. This can be seen comparing Figure 3B and Figure 4B: the almost totality of the events occurred with less than 1000 J/kg CAPE in ECMWF, while MOLOH shows a relevant portion of events occurring with higher instability (> 1000 J/kg).

SEVERE STORM CHARACTERISTICS

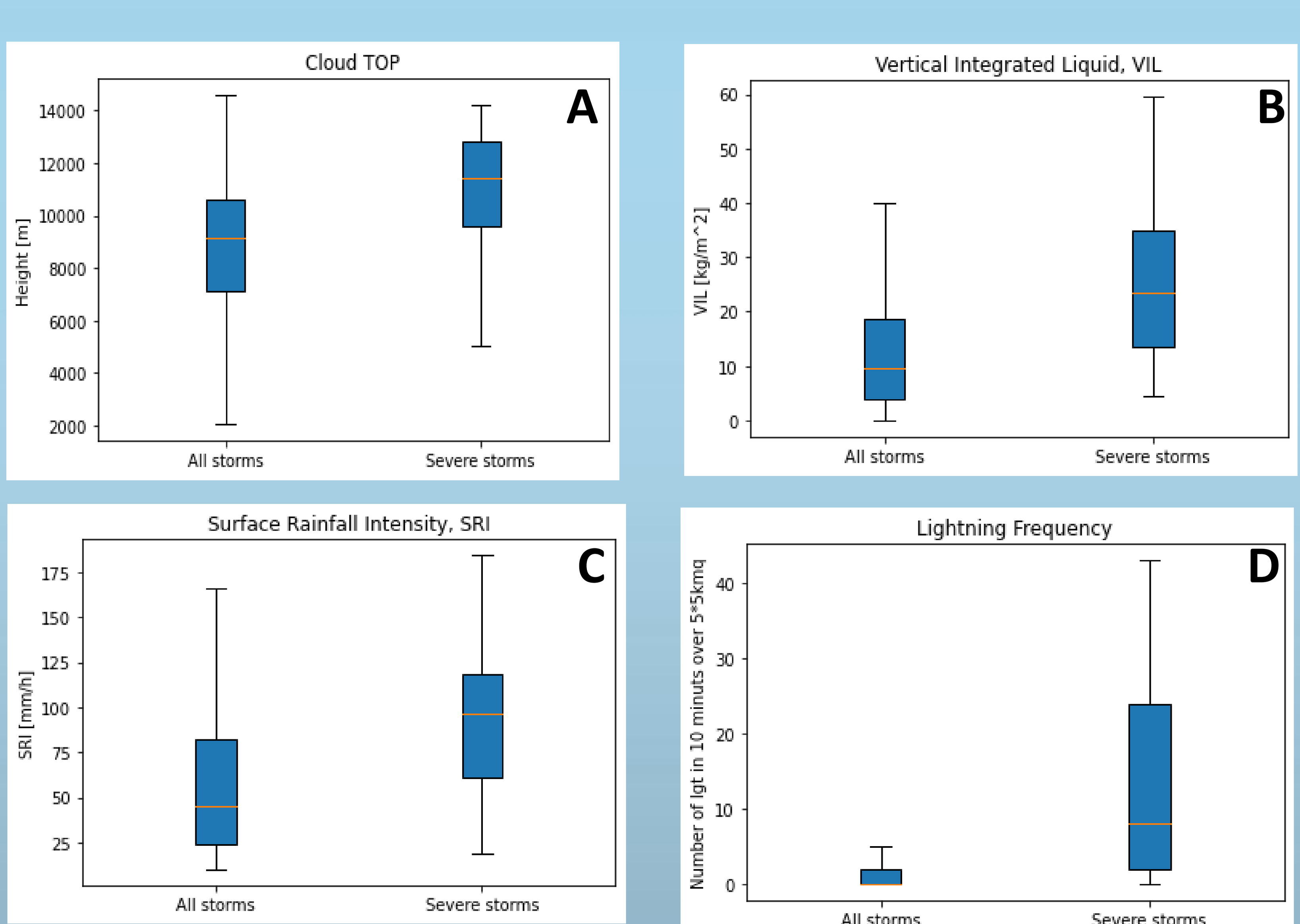


FIGURE 5. Radar features characteristic in severe events compare to the totality of storms

In this section, some radar features of the totality of the storms identified by RDT algorithm between 2019 and 2022 were compared to severe events. Results show a significant increase of values in severe events. In particular:

- severe storms had a pronounced vertical development (average value of Cloud TOP > 11 km, Figure 5A) with some values beyond the high of the tropopause;
- Vertical Integrated Liquid increases significant as well as Surface Rainfall Intensity (Figure 5B-5C);
- Increases the spread of Lightening Frequency between median value and 75’ percentile (Figure 5D).

References:
[1] Faccini, F.; Luino, F.; Sacchini, A.; Turconi, L. **The 4th October 2010 flash flood event in Genoa Sestri Ponente (Liguria, Italy).** Disaster Adv. **2015**, 8, 1–14.
[2] Roccati, A.; Faccini, F.; Luino, F.; De Graff, J.; Turconi, L. **Morphological changes and human impact in the Entella River floodplain Northern Italy) from the 17th century**. Catena **2019**, 182, 104122.
[3] Roccati, A.; Paliaga, G.; Luino, F.; Faccini, F.; Turconi, L. **Rainfall threshold for shallow landslides initiation and analysis of long-term rainfall trends in a mediterranean area**. Atmosphere **2020**, 11, 1367