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ARPA FVG — agenzia regionale per la protezione dell'ambiente del Friuli Venezia Giulia

NUMERICAL SIMULATIONS OF TWO GIANT HAIL EVENTS IN NORTHEASTERN ITALY

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CASE STUDIES

This work is a comparison between two giant hail (≥8 cm) events that developed in Friuli Venezia Giulia (FVG) region in northeastern Italy. These are the main features of the events:

First CASE STUDY - 1 AUGUST 2021

- **one** supercell crossing the region from SW to NE
- early morning
- maximum hail reported: **11 cm**
- **localized** damages at crops, roofs and cars

Second CASE STUDY - 24 JULY 2023

- **two** supercells crossing the region from W to E with almost the same path, a third one passing farther south, mainly over Adriatic Sea
- evening and night
- maximum hail reported: **19 cm** **(European record-breaking hailstone)**
- **extensive and unprecedented** damages with large hail swaths

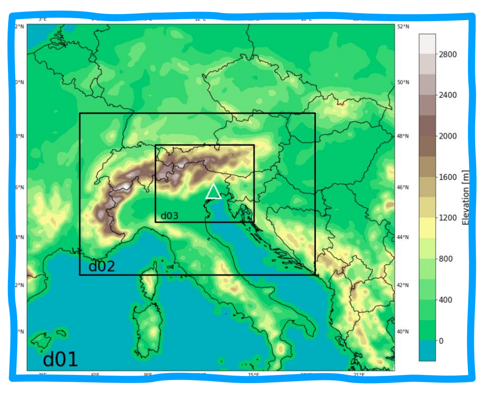
RESEARCH QUESTIONS

1. Can the events be easily simulated with numerical models?
2. Is there a specific setup which gives the best results for both the events?
3. What are the common features of the two events?
4. What are the main mechanisms responsible for the giant hail production?

NUMERICAL SIMULATIONS

DIMENSION OF THE BIGGEST HAILSTONE for 24 JULY 2023 (European Hailstone record) — 19 cm

DIMENSION OF THE BIGGEST HAILSTONE for 1 AUGUST 2021 — 11 cm



- 3 two-nested domains (9 km, 3 km, **1 km**)
- 60 hybrid vertical levels
- same parametrizations for microphysics (WSM6), PBL (YSU) and land-surface (Noah-NP)

1 AUGUST 2021

IC and BC: operative forecasts ECMWF-IFS (every 3 hours)

NUDGING of Udine-Rivolto radiosoundings

↓

Increase of shear and CAPE → a simulated QLCS evolves in a supercell → the nudging IMPROVES the simulation ✓

Perfect spatial evolution

Delayed temporally by 3 hours

HAILCAST simulates hailstones of 70-80 mm in good agreement with observations

24 JULY 2023

IC and BC: reanalysis ERA5 (every 3 hours)

NUDGING of Udine-Rivolto, San Pietro Capofiume, Novara-Cameri radiosoundings

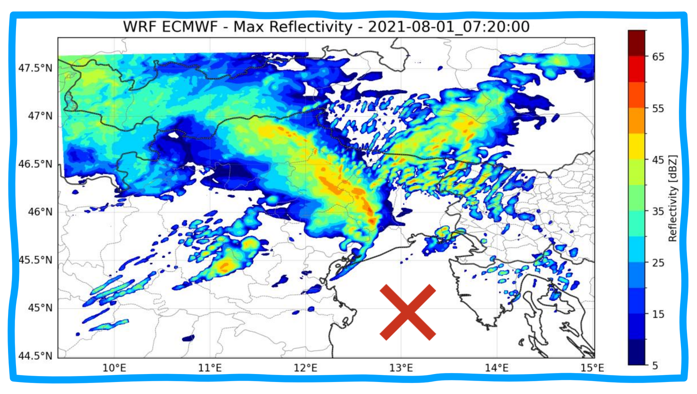
↓

The radiosounding data are too different from the unperturbed simulation → lower LFC and LCL, more instability → unrealistic and excessive convection is simulated → the nudging has a DETRIMENTAL effect ✗

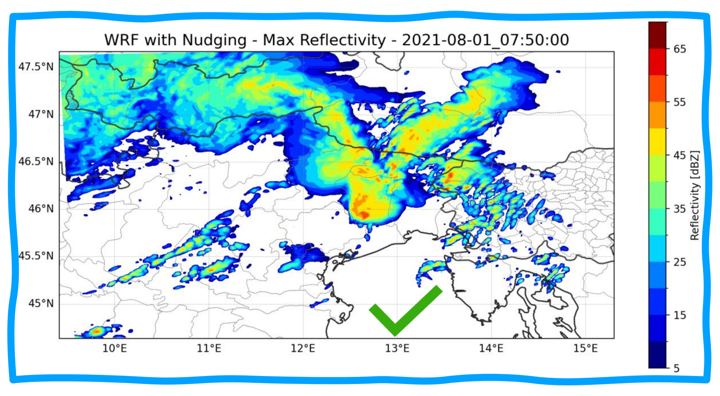
The trajectories are not accurate (the first is too north, the second is too south)

Perfect timing

HAILCAST simulates hailstones of 80-110 mm in good agreement with the majority of the reports; the biggest hailstones are underestimated



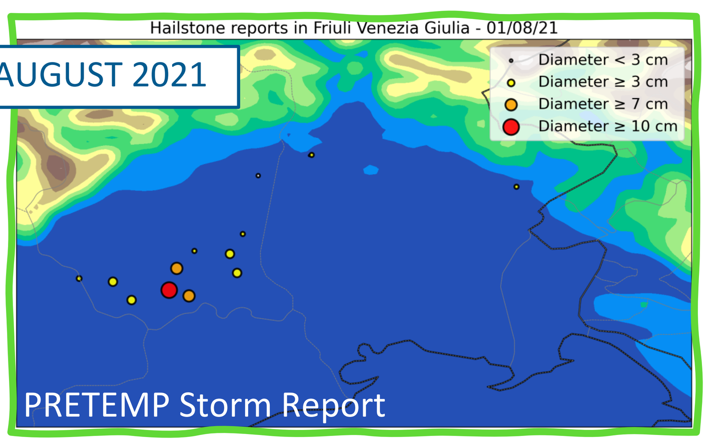
WRF simulation of 1 August 2021: Maximum Reflectivity.
The simulation **without nudging** shows a QLCS.



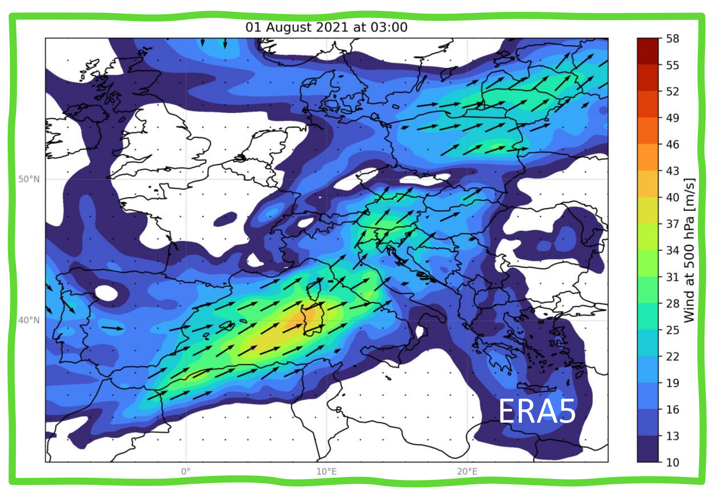
WRF simulation of 1 August 2021: Maximum Reflectivity.
The simulation **with nudging** correctly gives a supercell instead of a QLCS.

SYNOPTIC AND MESOSCALE FEATURES

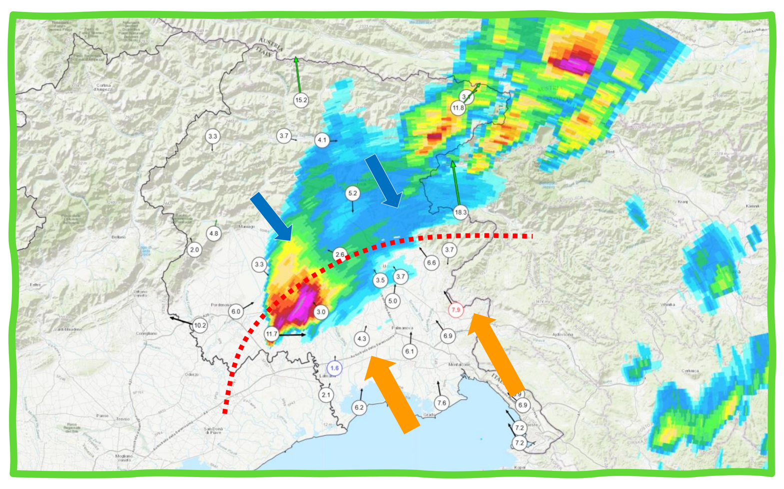
1 AUGUST 2021



- 15 reports (1 with hailstones larger than 10 cm)

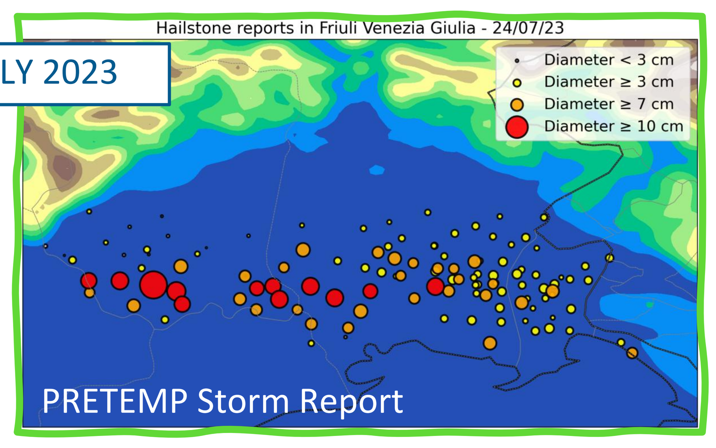


- trough deepening over France → SW winds at 500 hPa → direction of supercells: from SSW to NNE
- jet streak (stronger winds at 250 hPa)

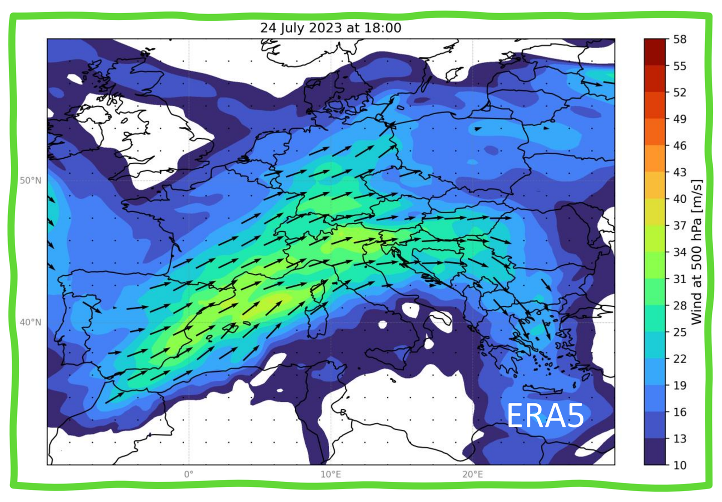


- humid Sirocco winds at the ground directly feeding the supercell
- high values of CAPE (3444 J/kg from UDINE RDS 06 UTC)
- moderate wind gusts with stronger gust of 17 m/s

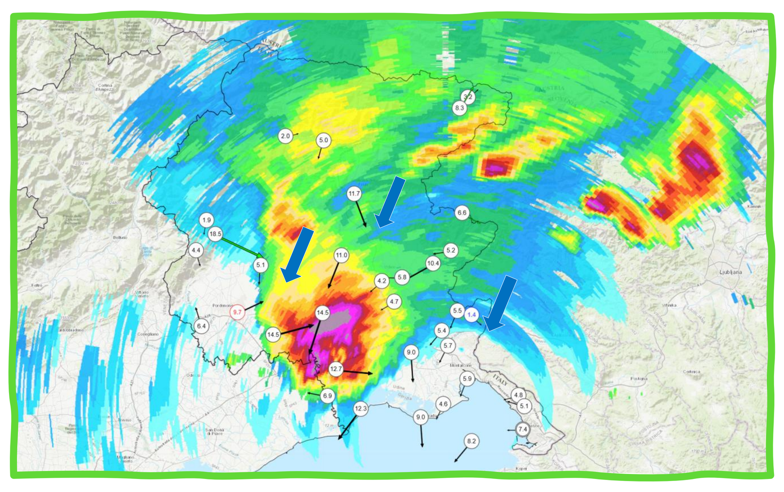
24 JULY 2023



- 119 reports (12 with hailstones larger than 10 cm)



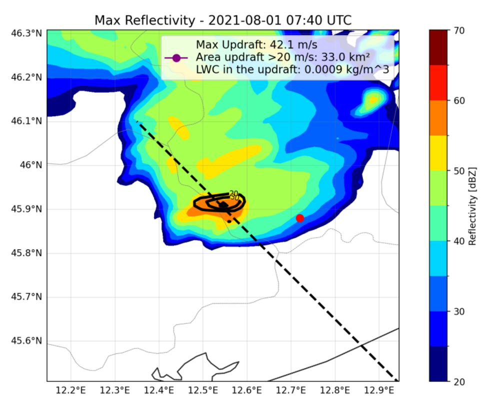
- atlantic trough blocked by strong anticyclone over Mediterranean → SSW winds at 500 hPa → direction of supercells: from W to E
- jet streak (stronger winds at 500 hPa)

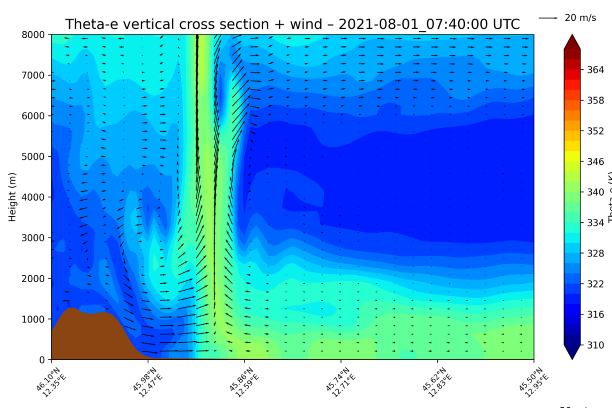


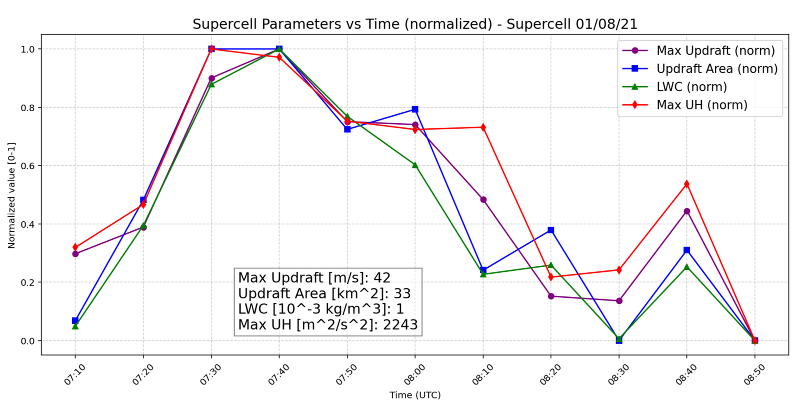
- weak MSLP minimum over northern Adriatic Sea → weak dry north-easterly winds before the storms
- medium values of CAPE (1689 J/kg from UDINE RDS 12 UTC)
- severe wind-driven hail with wind gusts widely above 20 m/s in the entire FVG plain

COMPARING THE UPDRAFTS OF THE FOUR SUPERCELLS

SUPERCELL of 1 August 2021

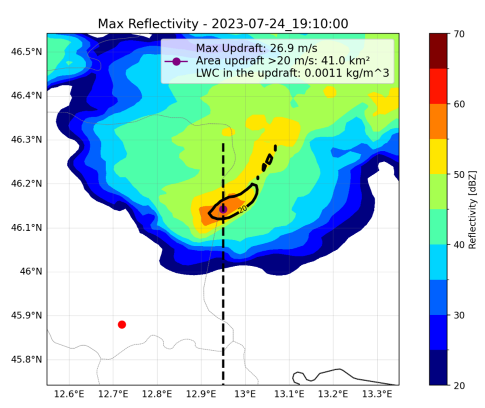


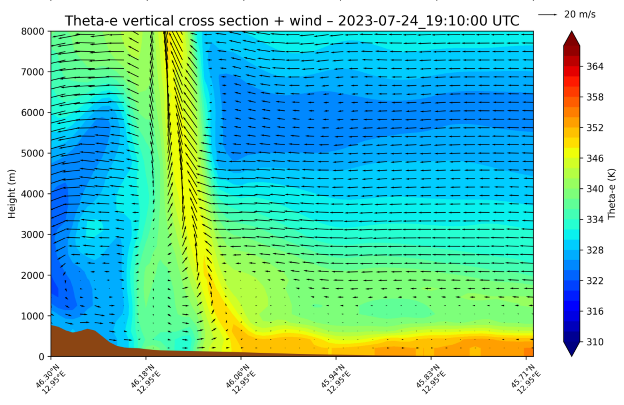


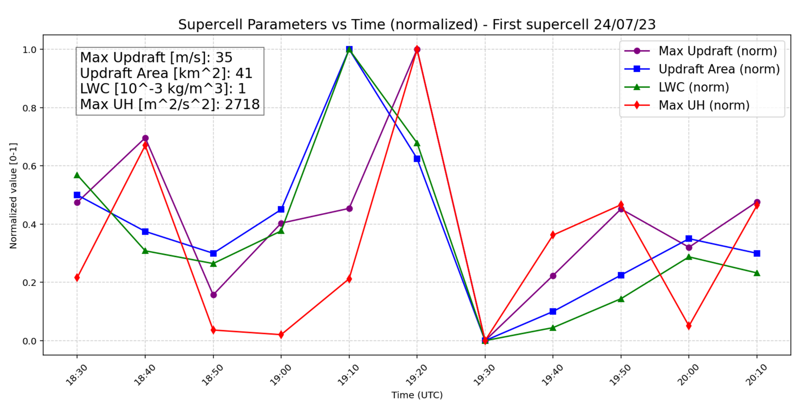


- max hailstone diameter simulated: 9 cm
- CAPE environment before: 2000-3000 J/kg
- hot and humid air at the surface directly feeds the supercell
- smallest LWC and updraft area but high vertical velocity

FIRST SUPERCELL of 24 July 2023

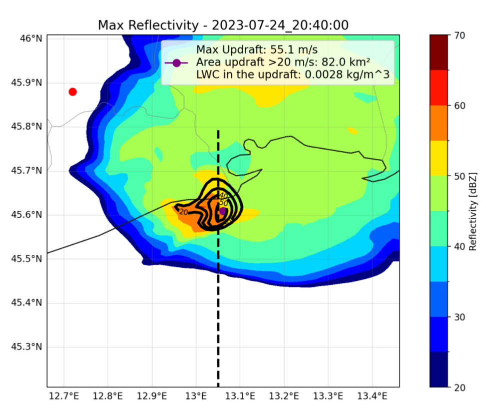


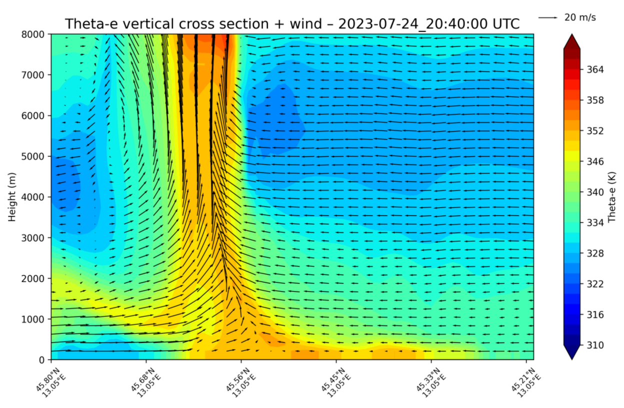


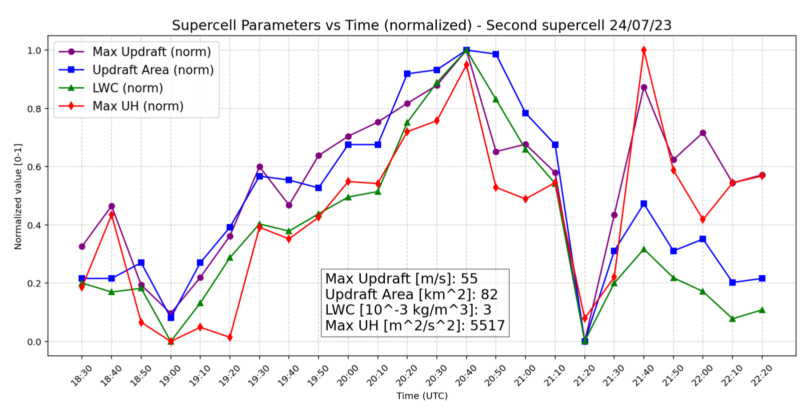


- max hailstone diameter simulated: 6 cm
- CAPE environment before: 3000-4000 J/kg
- scirocco winds at the ground directly feeds the supercell
- the supercell is disturbed by the orography

SECOND SUPERCELL of 24 July 2023

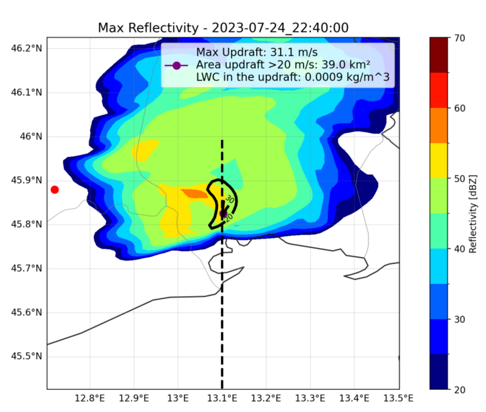


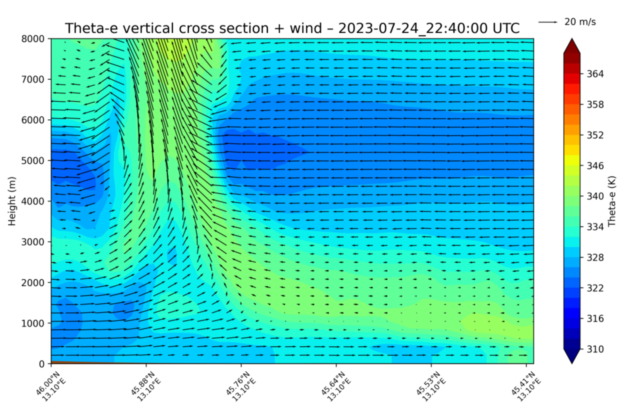


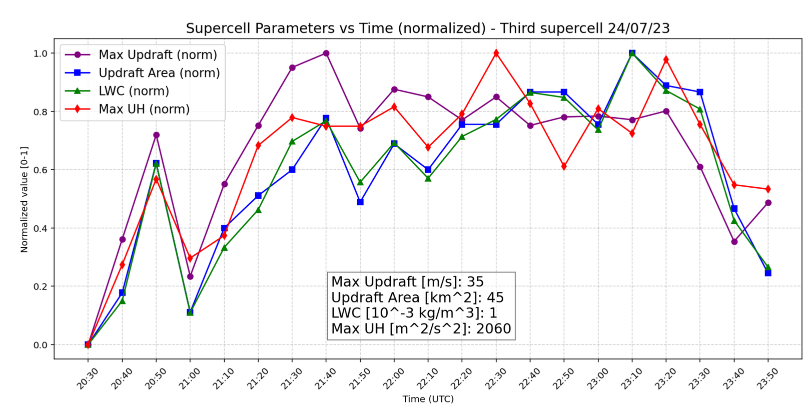


- max hailstone diameter simulated: 10 cm
- CAPE environment before: 3000-4000 J/kg
- cold pools are present from previous supercell
- very high-thetae airmass lifted from the surface
- the updraft is the strongest between the cells studied

THIRD SUPERCELL of 24 July 2023



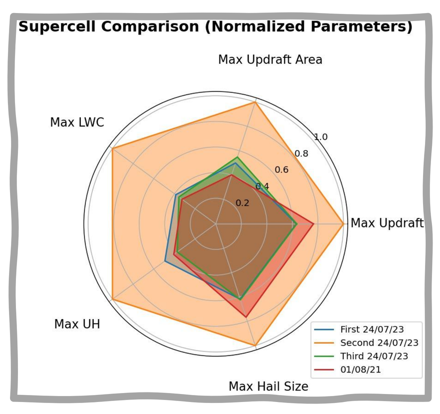




- max hailstone diameter simulated: 6 cm
- CAPE environment before: 500-1500 J/kg
- elevated tongue of thetae (the dynamics of this cell is the closest to the 'real' second supercell, see De Martin et al., 2024)
- despite the reduced CAPE it is able to produce giant hailstones

TAKE-HOME MESSAGES

- WRF simulates the two events better than the main operational weather models of those days (i.e. ECMWF, GFS, ICON-D2);
- We didn't find a unique operational setup that gives good results for both the cases;
- The supercell analysis highlights the critical role of the mixed-phase region within the updraft at 4 to 8 km AGL;
- Consistent with Lin and Kumjian (2022), the results show that **hail size depends** more **on updraft parameters** (updraft area, liquid water content and storm rotation) rather than on CAPE alone;
- **The supercells studied do not seem to have the same mechanism for the development of giant hailstones.** Different dynamic and thermodynamic conditions can lead to giant hailstones over the FVG plain!



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- De Martin, F., Manzato, A., Carlon, N., Setvák, M., & Miglietta, M. M. (2025). Dynamic and statistical analysis of giant hail environments in northeast Italy. Quarterly Journal of the Royal Meteorological Society, e4945.
- Lin, Y., & Kumjian, M. R. (2022). Influences of CAPE on hail production in simulated supercell storms. Journal of the Atmospheric Sciences, 79(1), 179-204.