Analysis of the 4 July 2007 large hailstorm in NE Italy

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meteo.FVG
ARPA FVG - OSMER
Osservatorio meteorologico regionale

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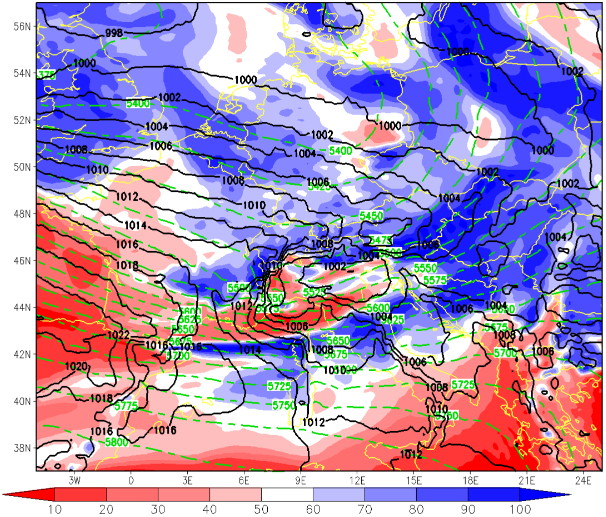
hic sunt futura

Synoptic situation at 12 UTC of 4 July 2007, ECMWF +12

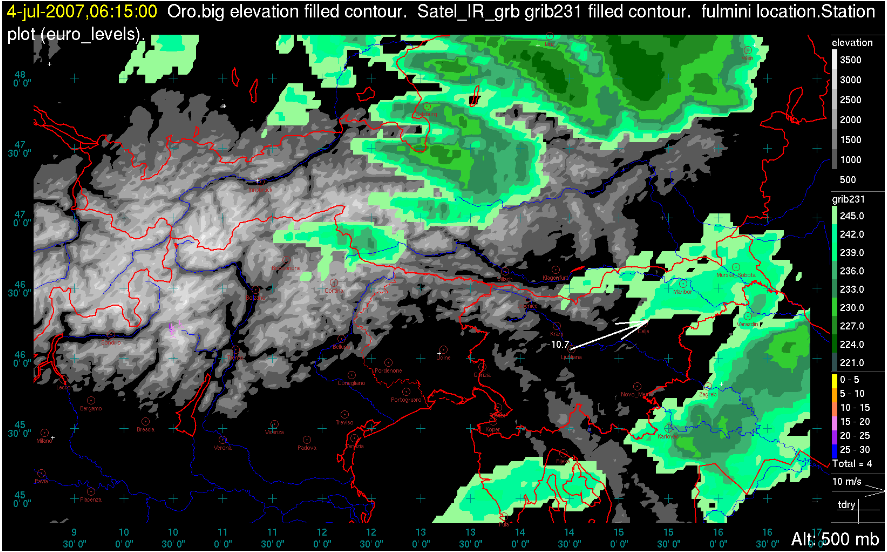


Geopotential height at 500 hPa, Relative–Humidity at 700 hPa, and **MSLP** (courtesy of Arturo Pucillo, OSMER).

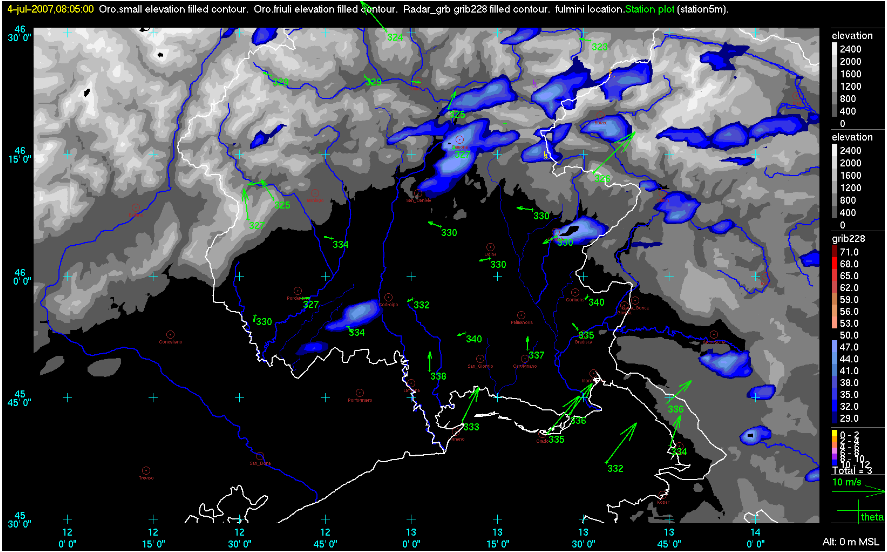
In the afternoon of 4 July 2007 a cold front is crossing NE Italy.

Note the Lee-side alpine cyclogenesis.

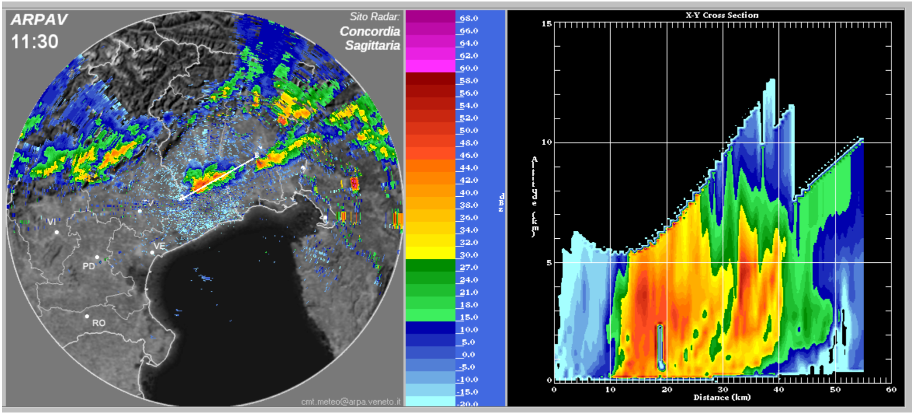
30' MSG-IR10.8 + C2G + RDS@500hPa, 0600-1830 UTC



10' Fossalon VMI + 5' Θ_e & wind + C2G, 08:00-16:10 UTC

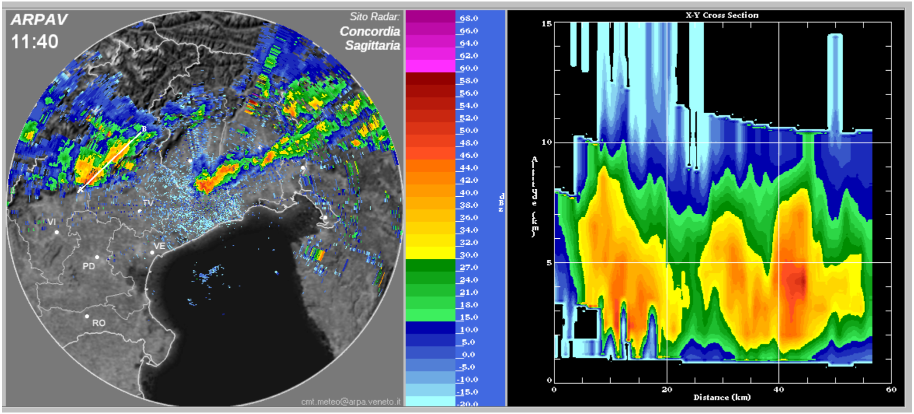


10' Loncon radar VMI + RHI, 11:30-12:40 UTC "South"



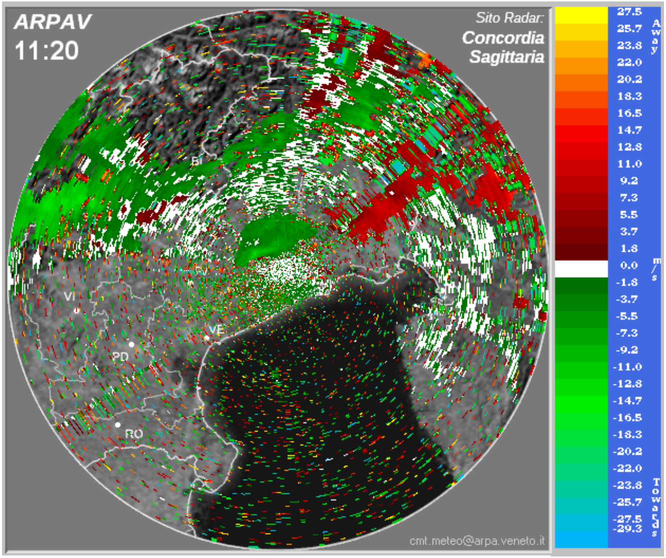
A first cell (10:50–13:00) interests the Southern part of FVG region. Thanks to Giovanni Cenzon and Franco Zardini (ARPAV) for the Loncon–Concordia Saggitaria radar data.

10’ Loncon radar VMI + RHI, 11:40-14:00 UTC “North”



A more severe cell appears on the eastern prealpine part of Veneto region moving westward. Thanks to Giovanni Cenzon and Franco Zardini (ARPAV) for the Loncon–Concordia Saggitaria radar data.

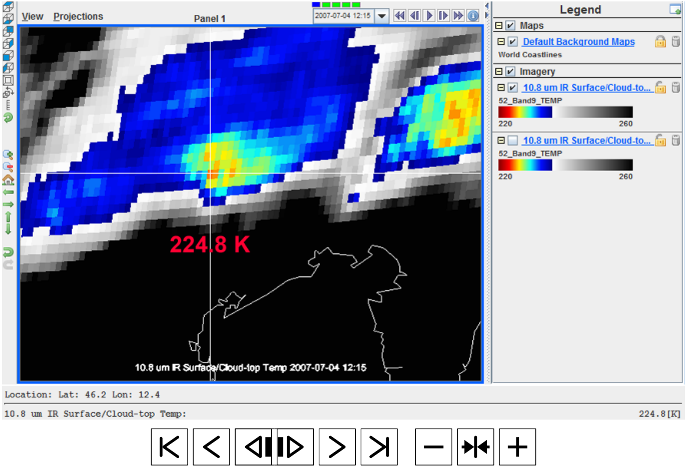
10’ Loncon radar Doppler at 1.5 deg, 11:20-14:00 UTC



At about 12:10 UTC the Northern cell seems to show a meso-cyclone signature, showing typical supercell characteristics.

Thanks ARPAV for radar data.

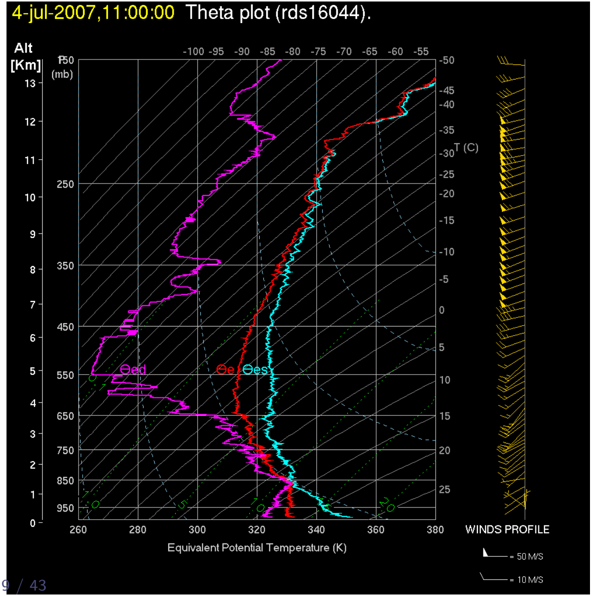
MSG 10.8um min top Temperature, 12:15-12:45 UTC



At 12:15 UTC the Northern cell shows a top temperature lower than 225 K (-48 °C). From the 12 UTC Udine sounding that temperature is found at 11.2 km, i.e. very close to the tropopause height (11.7 km).

Thanks to Jochen Kerkmann (Eumetasat) for these images.

Theta–plot of Udine soundings launched at 11:00 UTC



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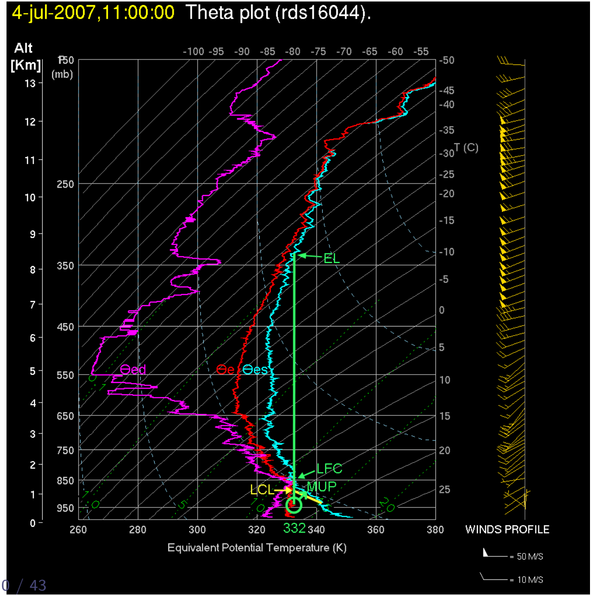

The Most Unstable Parcel ($\Theta_e = 332\,\mathrm{K}$ with mixing ratio of 11.6 g/kg) should reach its Equilibrium Level at about 8.6 km, with CAPE=790 J/kg and MULI=-4.4 K. Note the very *dry layer* above 500 hPa.

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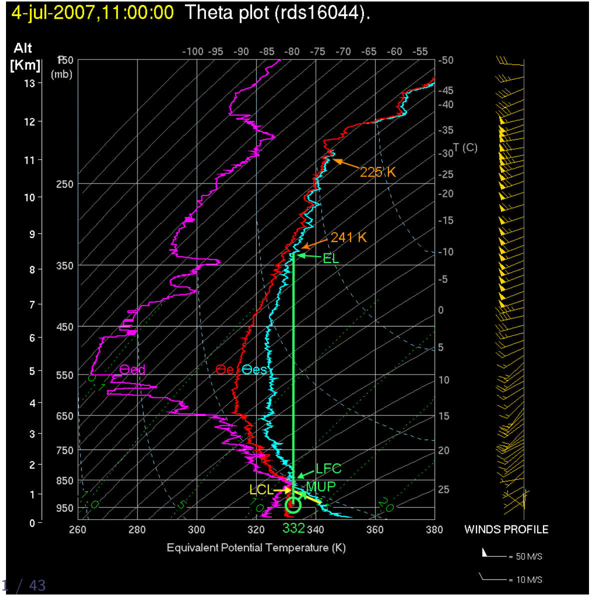
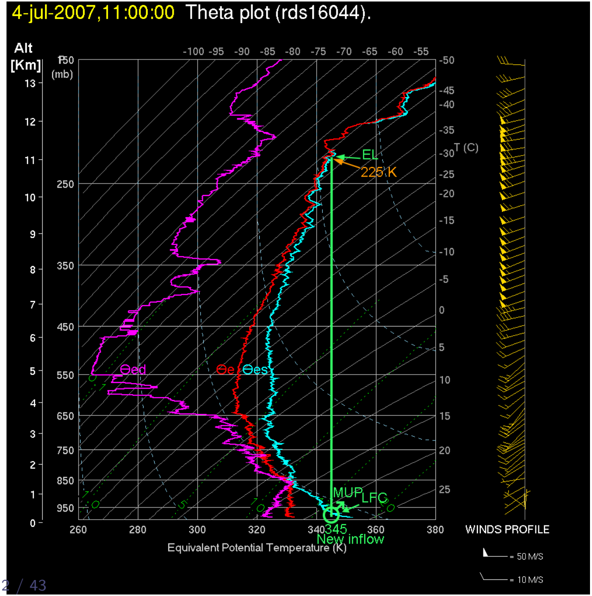


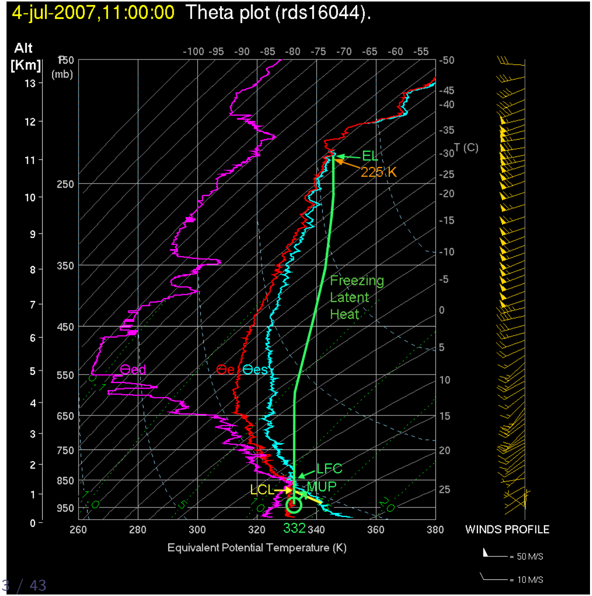
The Most Unstable Parcel ($\Theta_e = 332\,\mathrm{K}$ with mixing ratio of 11.6 g/kg) should reach its Equilibrium Level at about 8.6 km, with CAPE=790 J/kg and MULI=-4.4 K. Note the very *dry layer* above 500 hPa.
EL has an environmental temperature about 16 K warmer than what really observed by satellite.
So, there is a cloud-top height discrepancy of 2.6 km between observation and sounding-derived estimation.

Possible explanations for top temperature discrepancy



1) MUP is due to a new inflow having much higher Θ_e (about 345 K, with mixing ratio of 15 g/kg) and should reach its EL at about 11.8 km, with CAPE=2800 J/kg and MULI=-10 K. Note that the surface max Θ_e was 343 K with $q = 14.5$ g/kg (Codroipo at 10:45 UTC).

Possible explanations for top temperature discrepancy



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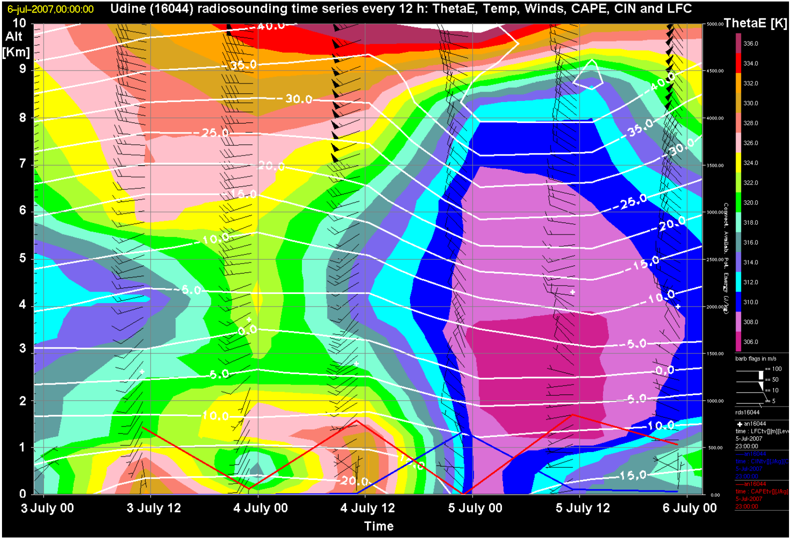
2) Another hypothesis is that there is a lot of latent heat of freezing due to a particularly efficient Hallett-Mossop secondary ice production.

Vertical time series of Udine Soundings (3 days)



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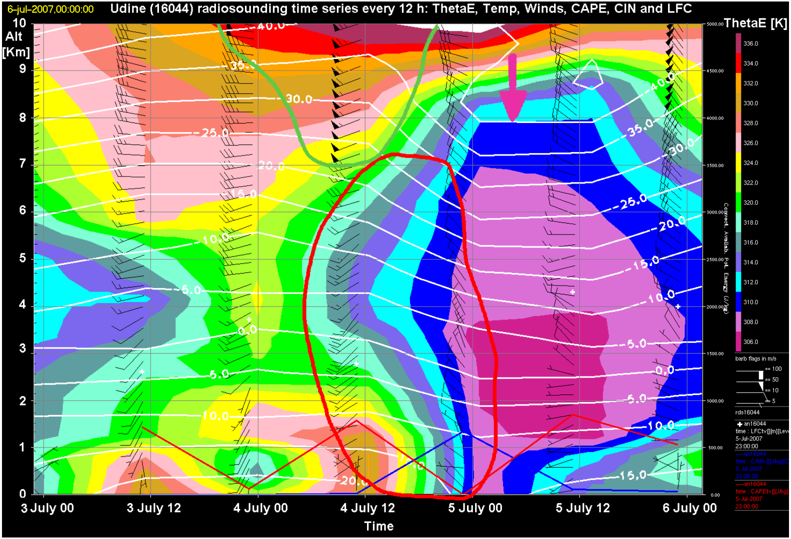


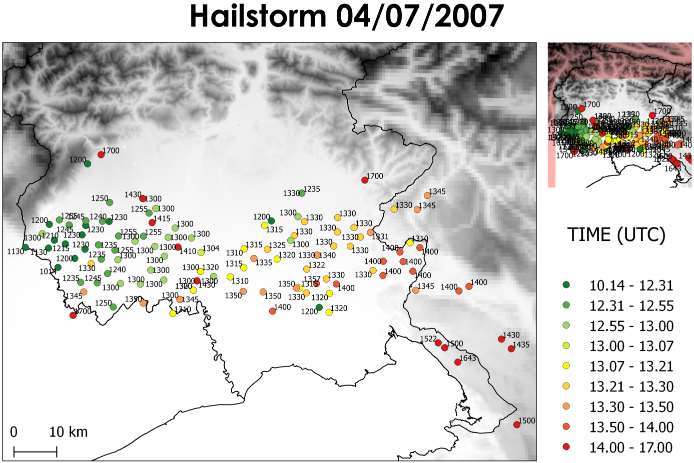
Note the strong Θ_e gradient in the afternoon of 4 July and the wind jet above 7 km associated with the cold front.

At 5 July 00 UTC the tropopause sinks at only 8.2 km.

116 hit hailpads during all the day, (10:30-17:00 UTC)

116 hailpads of the network monitoring the FVG plain were hit during the whole day by different cells. That was the maximum in 1988-2014, followed by:

87 on 05/07/1997
87 on 14/07/2008
84 on 08/08/2008
82 on 04/09/1992
80 on 09/07/2007
71 on 03/06/1989
66 on 24/07/2007

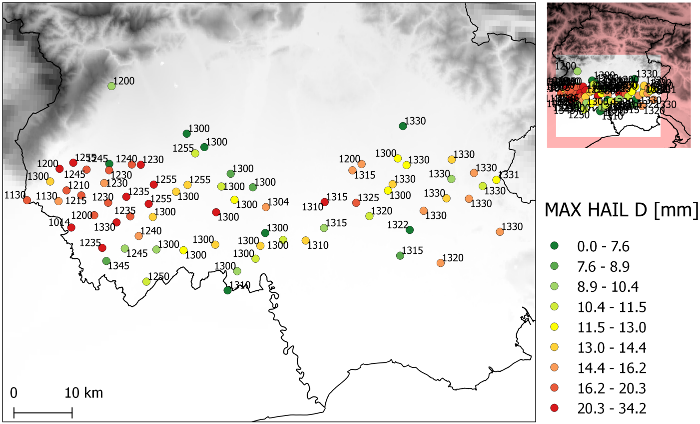


76 hit hailpads by the Northern cell, (12:30-14:00 UTC)

76 hailpads seems to be related to the "Northern" cell (also called "Hailstorm 3").

Before 12:30 the Northern cell was outside hailpad network domain, in Veneto region.

Hailstorm 3

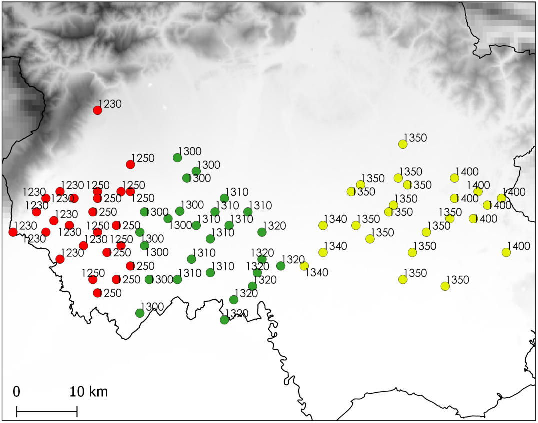


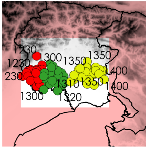
P.S. in this image color indicates class of maximum diameter found in each hailpads. . .

“Hailstorm 3” subdivided in 3 phases

Since volunteers time annotations are not very accurate we changed the original timing using the Fossalon di Grado radar data. The mean difference was $+10'$ ($\sigma = 30'$).

Hailstorm 3



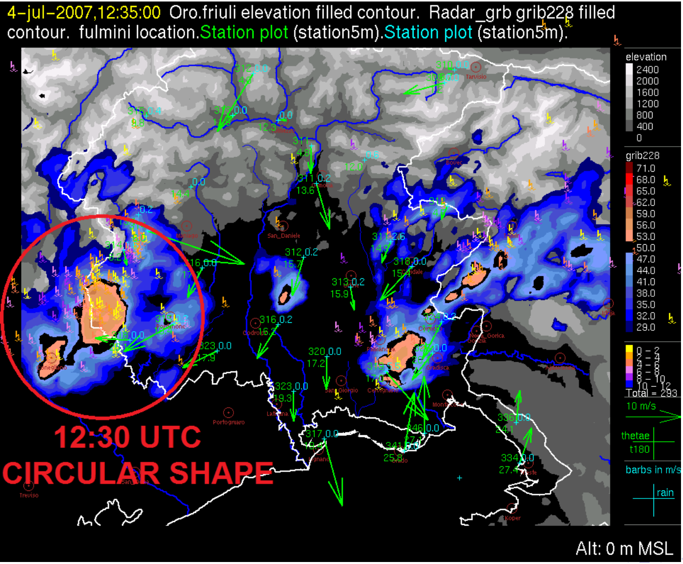


Phases (UTC)

- Phase 1]11.50,12.50]
- Phase 2]12.50,13.20]
- Phase 3]13.20,14.30]

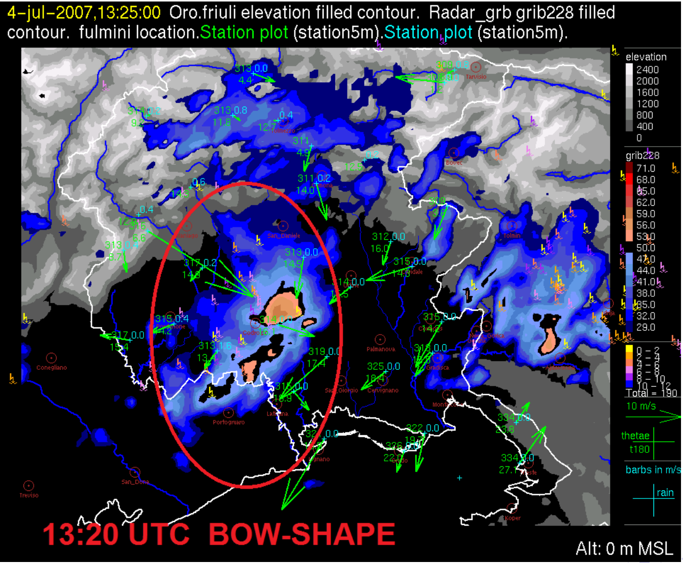
The hailpads were aggregated in three “phases” (25 in phase 1, 26 in phase 2 and 25 in phase 3), according to different VMI forms.

Fossalon VMI features of the three "Hailstorm 3" phases



In the first phase (11:50-12:55 UTC) VMI is large, tall and circular.

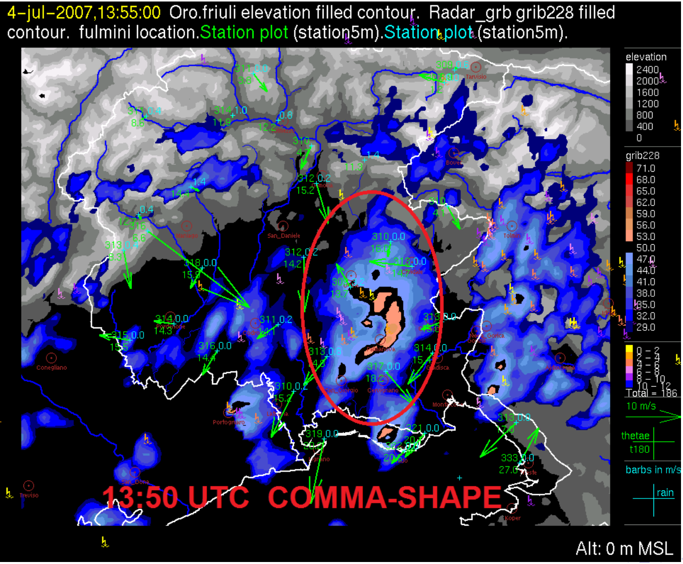
Fossalon VMI features of the three “Hailstorm 3” phases



In the first phase (11:50-12:55 UTC) VMI is large, tall and circular.

In the second phase (13:00-13:30 UTC) VMI is still large but elongated or bow-shaped.

Fossalon VMI features of the three “Hailstorm 3” phases

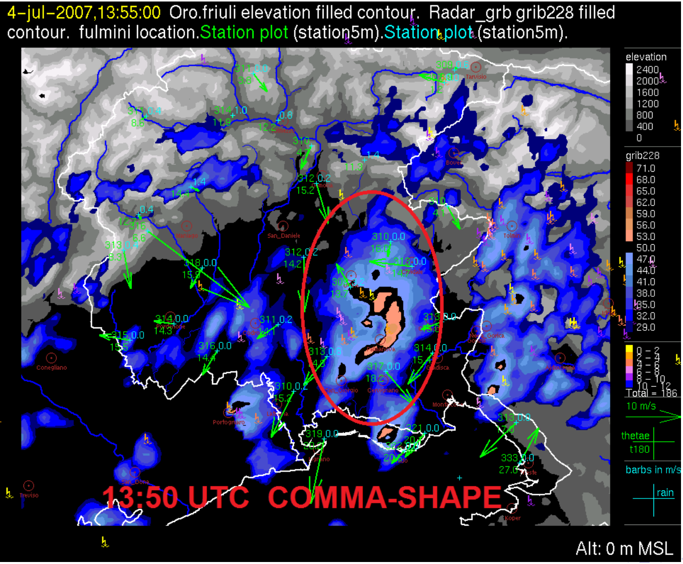


In the first phase (11:50-12:55 UTC) VMI is large, tall and circular.

In the second phase (13:00-13:30 UTC) VMI is still large but elongated or bow-shaped.

In the third phase (13:40-14:30 UTC) VMI is smaller and thin or comma-shaped.

Fossalon VMI features of the three “Hailstorm 3” phases



In the first phase (11:50-12:55 UTC)

elongated or bow-shaped.

Shelf in Premariacco

In the third phase (13:40-14:30 UTC) VMI is smaller and thin or comma-shaped.

Dynamic: isolated (super)cell evolving in small bow–echo?

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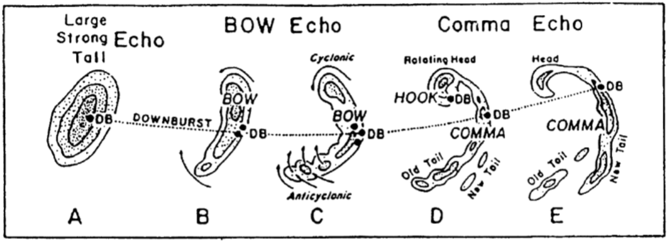
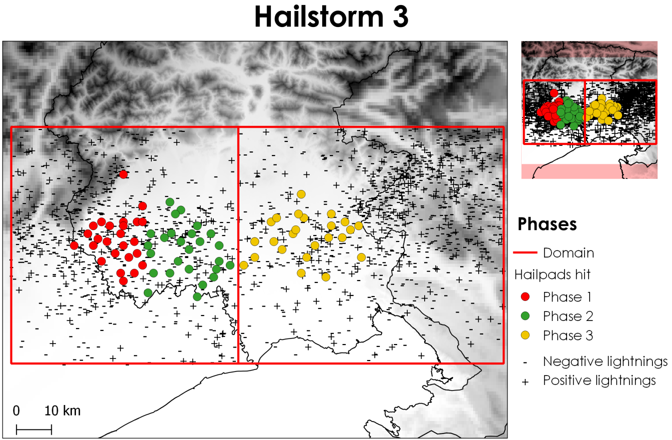


Fig. 6.8. Fujita's model of an isolated bow echo associated with a downburst. (from Johns 1993; courtesy AMS).

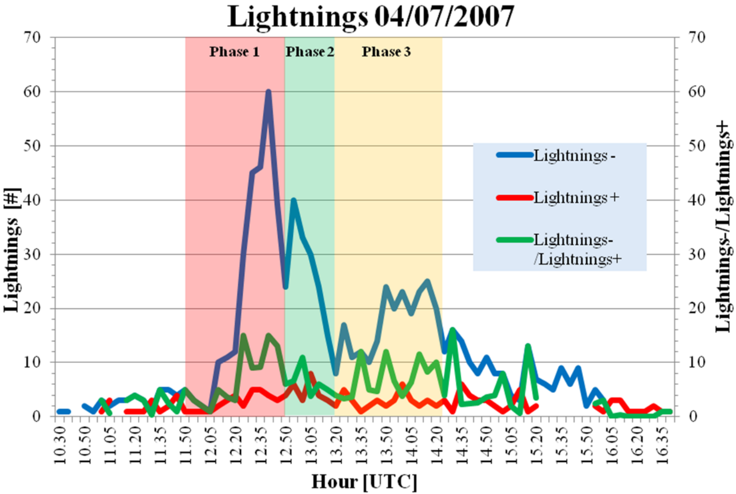
The "Northern" cell evolution resembles the Fujita (1981) – Johns (1993) (Raghavan 2003) dynamic. From 11:50 to 12:55 UTC an isolated cell with sometime meso–cyclone feature (supercell). From 13:00 to 14:30 UTC it evolved in a bow-echo and then a comma-shape radar signature.

Cloud-to-Ground Euclid lightnings during the 3 phases



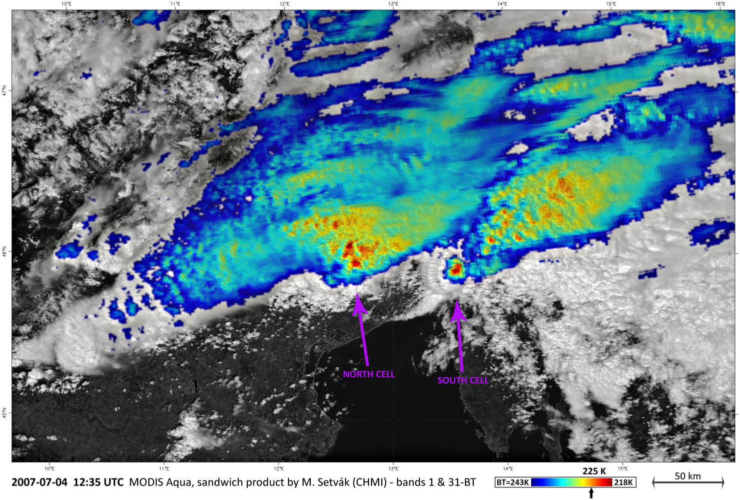
We analyzed the C2G lightning (CESI-SIRF data) in the left red-domain during phase 1 and 2 and in the right red-domain during phase 3.

C2G lightning 5’ time series and negative/positive ratio



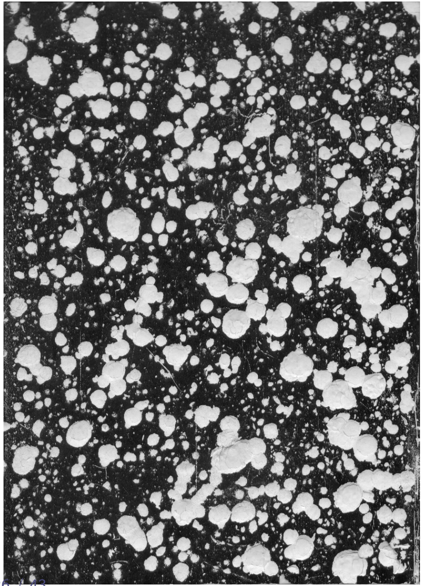
The peak of –mostly negative– C2G lightning density was at 12:40 UTC, during the first phase, reaching 60 lights in 5’ on 4400 km^2.

AQUA polar satellite at 12:35 UTC



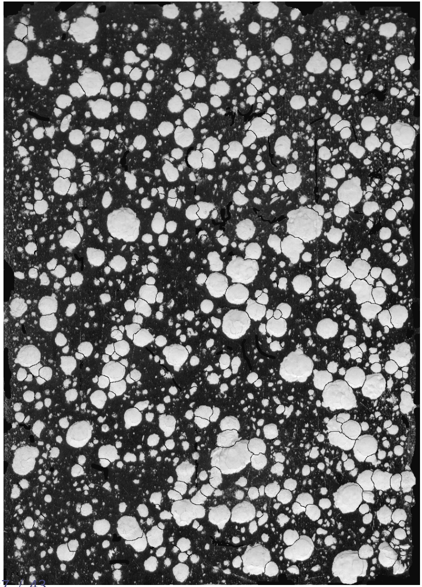
The wonderful "sandwich" image processed by Martin Setvák (CHMI) from data taken by polar satellite rightly at 12:35 UTC (NOAA CLASS).

Hailpad analysis using NCAR–Titan software



We start scanning the hit hailpad covered by black typographic ink.

Hailpad analysis using NCAR–Titan software



We start scanning the hit hailpad covered by black typographic ink.
We manually “correct” it to divide overlapping dents.

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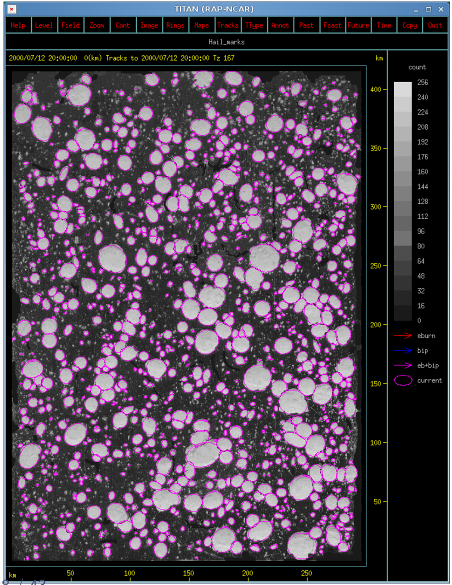

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Then we apply the Titan-Hailpads NCAR software (Dixon and Wiener 1993) to interpolate each dent with ellipses. The minimum diameter of the ellipse estimates the associated hailstone diameter via the calibration fit found in Giaiotti et al. (2001). We discarded diameters < 2.8mm.

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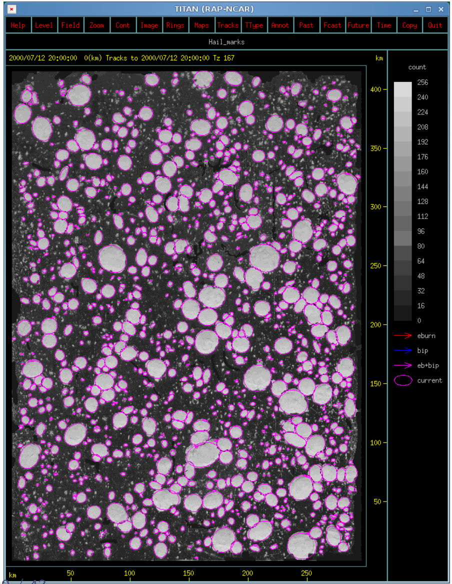

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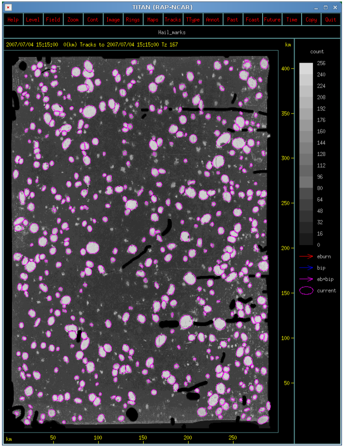
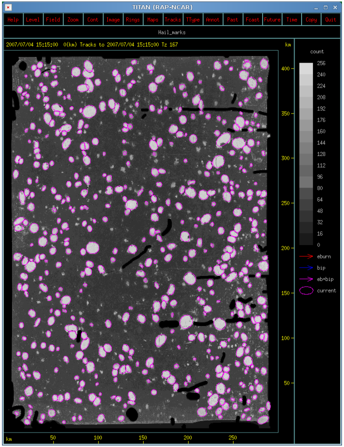
From all the hailstone diameters of every hailpad we compute: density (#/area), Mean and Max Diameter, and Kinetic Energy Flux.

Hailstorm 3: maximum Hail Density and Hail Diameter



The hailpad with maximum density (4498 hailstones/m^2) at 12:50 in S. Quirino-E7.

Hailstorm 3: maximum Hail Density and Hail Diameter



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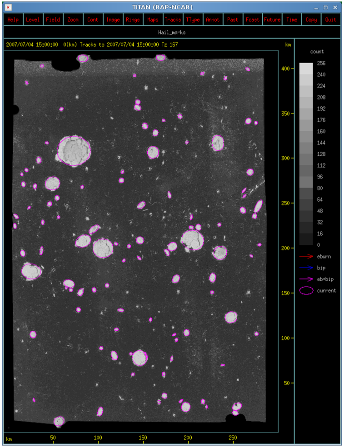
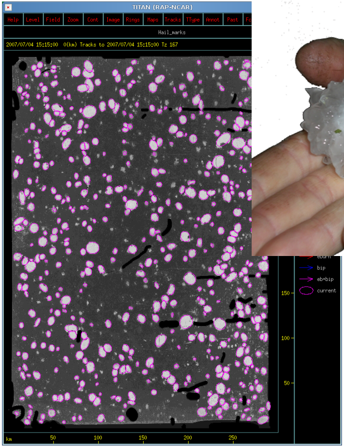
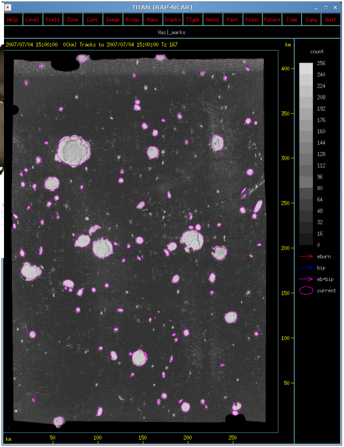


The hailpad with maximum hail diameter (34.2 mm) at about 12:50 in Prata-G3.

Hailstorm 3: maximum Hail Density and Hail Diameter



Observed hail was even larger! Picture taken in Fontanafredda by Alessandro Fiorot.



The hailpad with maximum density (4498 hailstones/m^2) at 12:50 in S. Quirino-E7.

The hailpad with maximum hail diameter (34.2 mm) at about 12:50 in Prata-G3.

Hailstorm 3: maximum hailpad Flux of Kinetic Energy

$$
\begin{aligned}
m &= \rho_{ice}\frac{4}{3}\pi\left(\frac{D_{hail}}{2}\right)^3, \text{with } \rho_{ice} = 0.917[g/cm^3];\\
V_{terminal} &= \sqrt{\frac{4g\rho_{ice}D_{hail}}{3\cdot 0.6\rho_{dry}}} * \text{Weickmann (1953)};\\
KinEn_{hailstone} &= \frac{1}{2}mV_{terminal}^2;\\
KinEnFlux_{hailpad} &= \frac{\sum_1^{N_{stones}} KinEn_{hailstone}}{Area_{hailpad}}.
\end{aligned}
$$

* $withD_{hail}$ [cm] and $V_{terminal}$ [m/s].

Hailstorm 3: maximum hailpad Flux of Kinetic Energy

$$
\begin{aligned}
m &= \rho_{ice}\frac{4}{3}\pi\left(\frac{D_{hail}}{2}\right)^3 \text{, with } \rho_{ice} = 0.9 \\
V_{terminal} &= \sqrt{\frac{4g\,\rho_{ice} D_{hail}}{3\cdot 0.6\rho_{dry}}} * \text{Weickmann (1953} \\
KinEn_{hailstone} &= \frac{1}{2} m V_{terminal}^2; \\
KinEnFlux_{hailpad} &= \frac{\sum_1^{N_{stones}} KinEn_{hailstone}}{Area_{hailpad}}.
\end{aligned}
$$

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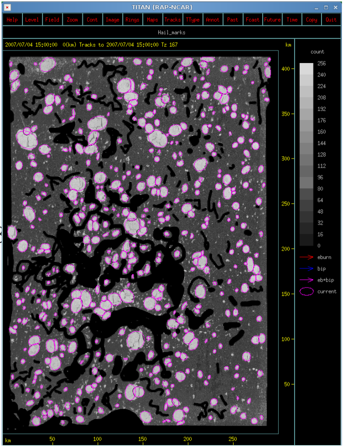
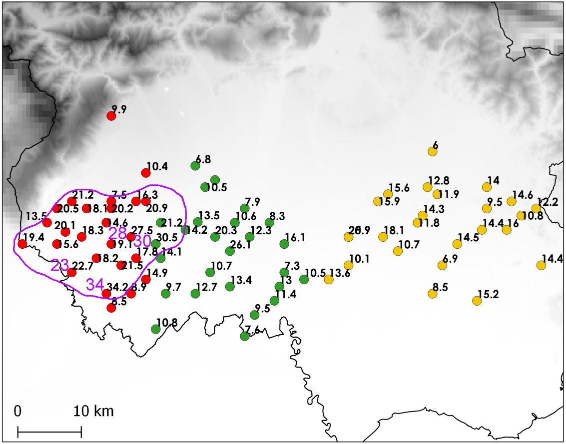
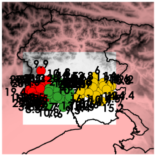


The hailpad with maximum Flux of KinEn (155 J/m^2) at 12:50 in S. Quirino-F7.

Maps of $\text{MaxD}_{\text{hail}}$, Hail Density and KinEn Flux

Hailstorm 3 (04/07/2007)





MAX HAIL DIAMETER [mm]

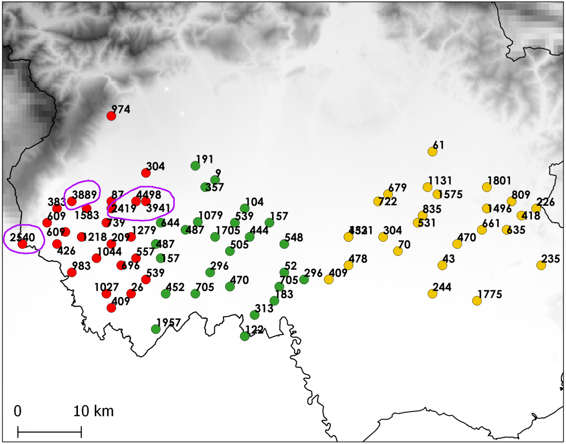
Hailpads hit

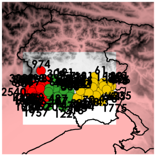
- Phase 1
- Phase 2
- Phase 3

Max Hailstone Diameter: some maximum hailstone diameters in the 2-3 cm range.

Maps of $MaxD_{hail}$, Hail Density and KinEn Flux

Hailstorm 3 (04/07/2007)





HAIL DENSITY [num m-2]

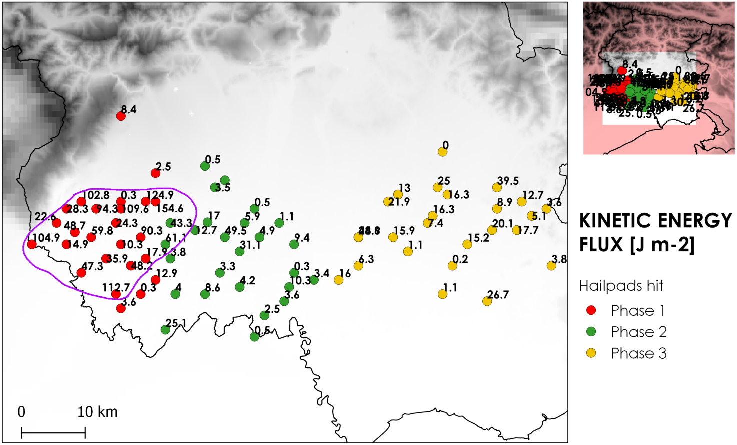
Hailpads hit

- Phase 1
- Phase 2
- Phase 3

Hail Density: some hailpads having 2000-4500 dents per square meter.

Maps of $\text{MaxD}_{\text{hail}}$, Hail Density and KinEn Flux

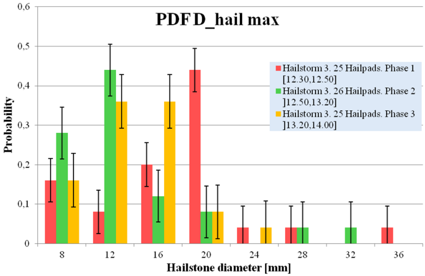
Hailstorm 3 (04/07/2007)



Kinetic Energy Flux:
some hailpads having 90-155 Joule per square meter.

Maximum is always on the western part (phase 1).

How change distributions in the 3 phases of Hailstorm 3



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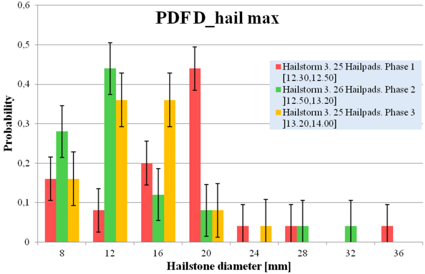
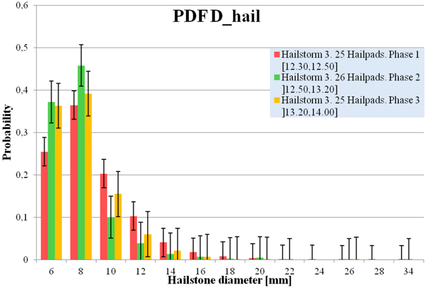
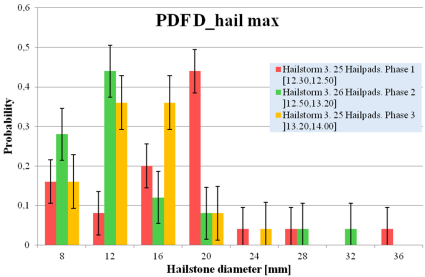
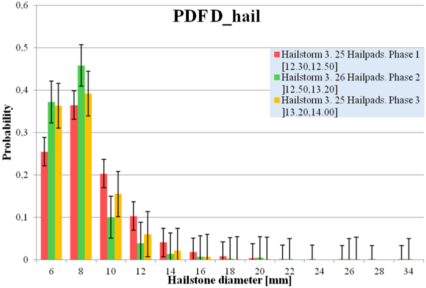
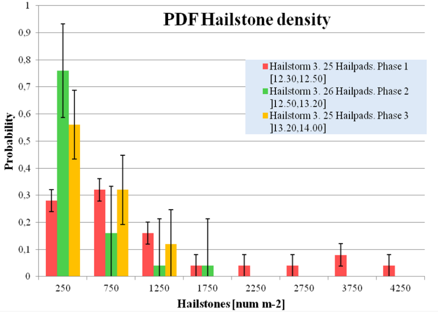




How change distributions in the 3 phases of Hailstorm 3







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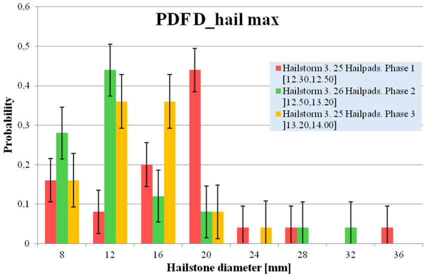

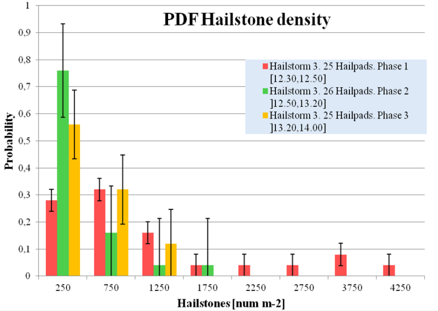

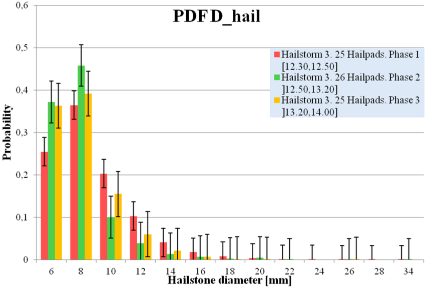

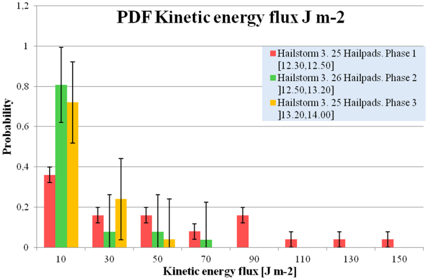

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5. In the third and last phase (VMI with comma-shape) intensity and hail seems stronger than in the previous phase but not comparable with the first phase.

Thanks! For info:

agostino.manzato@osmer.fvg.it

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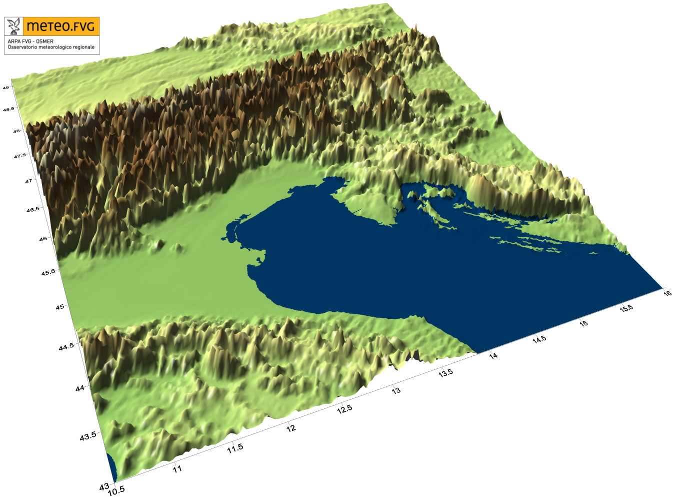

3D orography of the Severe Storm MiniLab (courtesy of Andrea Cicogna).

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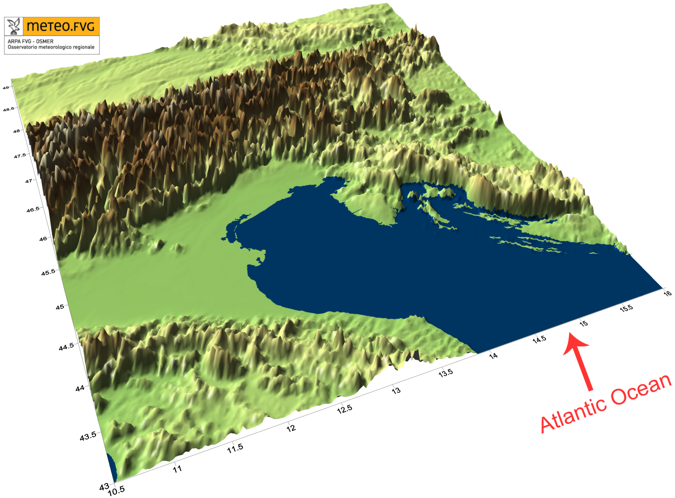

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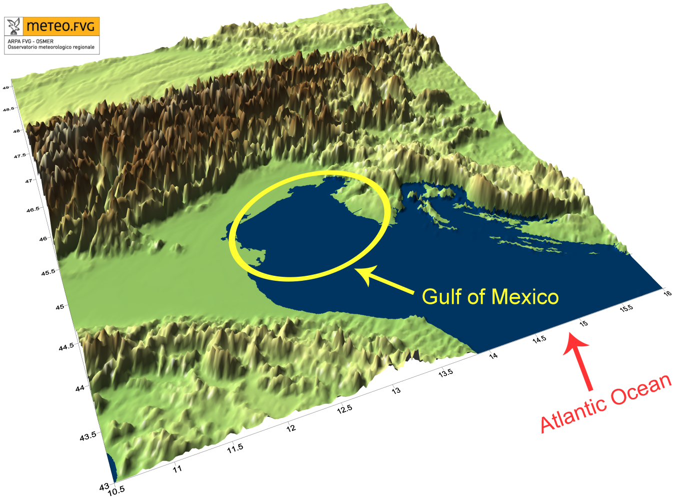

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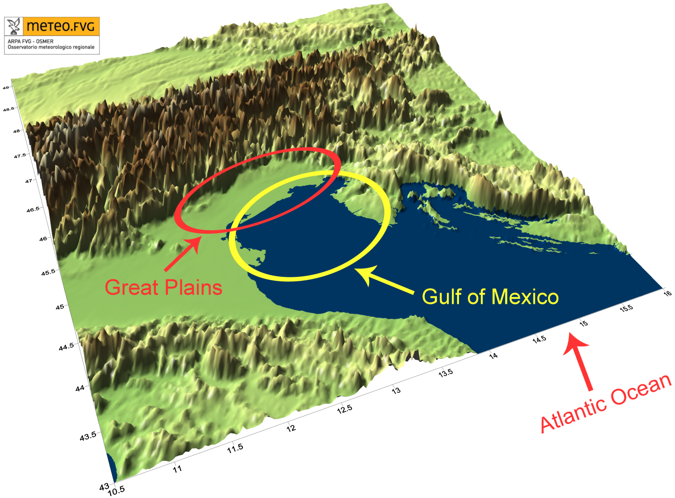

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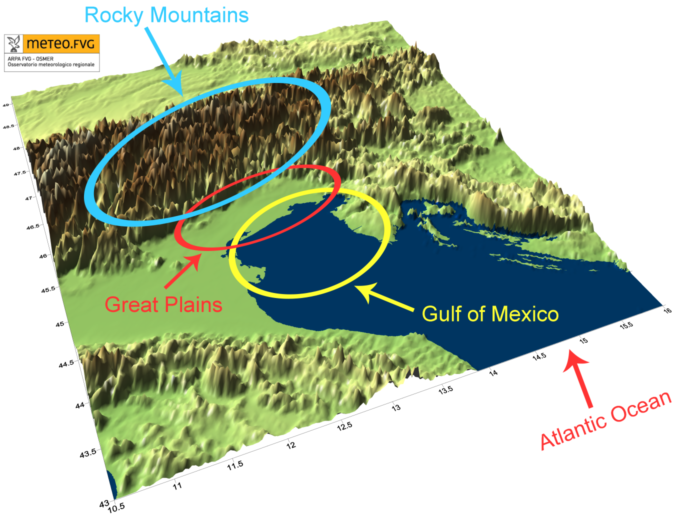

3D orography of the Severe Storm MiniLab (courtesy of Andrea Cicogna). We were able to create -on a smaller scale- the US morphology needed for Severe Storm.

So we were able to reproduce the dynamic of big US Severe Storms in a smaller scale.

Your field campaigns are wellcome!

Acknowledgment & links

- All volunteers of the FVG hail network;
- Alberto Farre (FVG Civil Protection, Appendix Fossalon VMI images);
- Alessandro Fiorot (hailstone picture);
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- Franco Zardini (ARPAV, Loncon radar images);
- Giovanni Cenzon (ARPAV, Loncon radar images);
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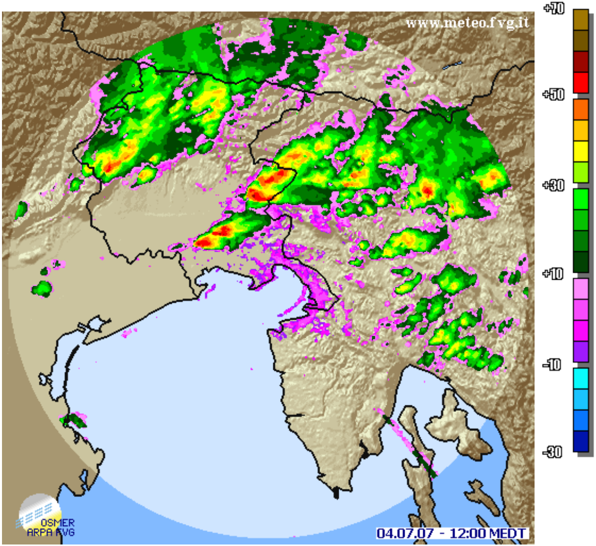
- Mario Marcello Miglietta (ISAC, revision);
- Martin Setvák (CHMI, AQUA satelite image);
- Olivia Romppainen (Bern University, support).

Links:

- http://www.weather-photos.net/gallery/thumbnails.php?album=215
- http://forum.meteotriveneto.it/showthread.php?1006-Udine-4-luglio-ore-15-40&highlight=premariacco
- http://www.youtube.com/watch?v=Ai4How5dZOo&eurl=

Appendix: 5' Fossalon radar VMI, 10:00-16:55 UTC



This movie shows 5' Fossalon di Grado VMI data (FVG Civil Protection). Note that local time is shown (UTC + 2 h).