Analysis of the 4 July 2007 large hailstorm in NE Italy

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In the afternoon of 4 July 2007 a cold front is crossing NE Italy. Note the Lee-side alpine cyclogenesis.

Geopotential height at 500 hPa, Relative–Humidity at 700 hPa, and MSLP (courtesy of Arturo Pucillo, OSMER).
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30’ MSG-IR10.8 + C2G + RDS@500hPa, 0600-1830 UTC
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10’ Fossalon VMI + 5’ $\Theta_e$ & wind + C2G, 08:00-16:10 UTC
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.
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.
At about 12:10 UTC the Northern cell seems to show a meso-cyclone signature, showing typical supercell characteristics.

Thanks ARPAV for radar data.
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

4-jul-2007, 11:00:00 Theta plot (rds16044).
The Most Unstable Parcel ($\Theta_e = 332 \text{ K}$ with mixing ratio of 11.6 g/kg) should reach its Equilibrium Level at about 8.6 km, with $\text{CAPE}=790 \text{ J/kg}$ and $\text{MULI}=-4.4 \text{ K}$. Note the very dry layer above 500 hPa.
The Most Unstable Parcel \((\Theta_e = 332 \text{ K})\) with mixing ratio of 11.6 g/kg should reach its Equilibrium Level at about 8.6 km, with $\text{CAPE}=790 \text{ J/kg}$ and $\text{MULI}=-4.4 \text{ K}$. 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 $\Theta_e$ (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 $\Theta_e$ was 343 K with $q = 14.5$ g/kg (Codroipo at 10:45 UTC).
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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 $\Theta_e$ 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.

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’ ($\sigma = 30’$).

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


Fig. 6.8. Fujita’s model of an isolated bow echo associated with a downburst. (from Johns 1993; courtesy AMS).
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 km².
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.
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**Hailpad analysis using NCAR–Titan software**

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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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Hailstorm 3: maximum Hail Density and Hail Diameter

The hailpad with maximum density (4498 hailstones/m$^2$) at 12:50 in S. Quirino-E7.
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The hailpad with maximum hail diameter (34.2 mm) at about 12:50 in Prata-G3.
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Observed hail was even larger!

Picture taken in Fontanafredda by Alessandro Fiorot.
Hailstorm 3: maximum hailpad Flux of Kinetic Energy

\[ m = \rho_{ice} \frac{4}{3} \pi \left( \frac{D_{hail}}{2} \right)^3, \text{ with } \rho_{ice} = 0.917 [g/cm^3]; \]

\[ V_{terminal} = \sqrt{\frac{4g \rho_{ice} D_{hail}}{3 \cdot 0.6 \rho_{dry}}} \text{ * Weickmann (1953);} \]

\[ KinEn_{hailstone} = \frac{1}{2} m V_{terminal}^2; \]

\[ KinEn_{Flux_{hailpad}} = \sum_{1}^{N_{stones}} \frac{KinEn_{hailstone}}{Area_{hailpad}}. \]

* with \( D_{hail} \) [cm] and \( V_{terminal} \) [m/s].
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The hailpad with maximum Flux of KinEn (155 J/m²) at 12:50 in S. Quirino-F7.
Maps of $\text{MaxD}_{\text{hail}}$, Hail Density and KinEn Flux

Hailstorm 3 (04/07/2007)

Max Hailstone Diameter:
some maximum hailstone diameters in the 2-3 cm range.
Maps of $\text{MaxD}_{\text{hail}}$, Hail Density and KinEn Flux

Hailstorm 3 (04/07/2007)

Hail Density: some hailpads having 2000-4500 dents per square meter.
Maps of $\text{MaxD}_{\text{hail}}$, Hail Density and $\text{KinEn Flux}$

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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PDF D_hail max

PDF D_hail

PDF Hailstone density
How change distributions in the 3 phases of Hailstorm 3

**PDF D_hail max**


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<th>Probability</th>
<th>Hailstone diameter [mm]</th>
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</tr>
<tr>
<td>0.3</td>
<td>12</td>
</tr>
<tr>
<td>0.2</td>
<td>16</td>
</tr>
<tr>
<td>0.1</td>
<td>20</td>
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**PDF D_hail**


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<td>0.1</td>
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**PDF Hailstone density**


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**PDF Kinetic energy flux J m-2**


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<th>Kinetic energy flux [J m-2]</th>
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<td>0.025</td>
<td>130</td>
</tr>
<tr>
<td>0.0125</td>
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Conclusions:

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3. The first phase of this cell evolution is characterized by a round VMI shape, cloud top reaching more than 11 km (not explained by traditional sounding-analysis) at 12:15, some meso-cyclone signature (12:00-12:20), a huge peak of –mostly negative– C2G lightnings (12:40), just 10' before observing the largest hailstone diameters, density and flux of KinEn at surface (12:50). Very likely a supercell.
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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:

tagostino.manzato@osmer.fvg.it
Advertisement for NE Italy Severe Storm MiniLab

3D orography of the Severe Storm MiniLab (courtesy of Andrea Cicogna).
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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.
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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 welcome!
Acknowledgment & links

- All volunteers of the FVG hail network;
- Alberto Farre (FVG Civil Protection, Appendix Fossalon VMI images);
- Alessandro Fiorot (hailstone picture);
- Andrea Cicogna (OSMER, 3D orography base);
- Arturo Pucillo (OSMER, synop image);
- Franco Zardini (ARPAV, Loncon radar images);
- Giovanni Cenzon (ARPAV, Loncon radar images);
- Jochen Kerkmann (EUMETSAT, MSG BT values);
- Mario Marcello Miglietta (ISAC, revision);
- Martin Setvák (CHMI, AQUA satellite image);
- Olivia Romppainen (Bern University, support).

Links:

- 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).