Radar identification of intense thunderstorm cores

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Introduction

On September 16th, 2021 heavy rainfalls occurred over western Lombardy. In particular, the Malpensa airport was one of the most affected structures: an heavy downpour hit the airport around 18:00 local time (16:00 UTC). Such an event could not be detected by using radar reflectivity (Z) only; for this reason, in this work different quantities are used to identify the cell core over Malpensa and to study its evolution along time. Those parameters have also been applied to another cell storm that occurred over the city of Pavia to verify the capability of those parameters to identify the thunderstorm's peak intensity.

Quantities used in this work

Hail can cause severe damages: lots of studies have been focusing on finding useful quantities to compute the so called *Probability Of Hail* (POH). Nonetheless, hail manifests in intense thunderstorm when favourable thermodynamic and fluid dynamic conditions are met: if these conditions do not occur, here it is assumed that parameters, such as the ones used to estimate POH, may be used to identify intense thunderstorm cores even without hail reports.

ΔH

- $\Delta H = H_{45} - H_0$ where H_{45} is the echo-top-45 and H_0 is the 0 °C-level.
- ΔH is introduced in [4] to estimate the POH.
- Different formulas describing POH as a function of ΔH exist due to different climatological conditions (e.g. [4], [2]): in this work, the one in [4] is used (in [1], a plot of this relation is provided).
- $\Delta H \geqslant 1.4\ [km] \Rightarrow POH \geqslant 0\%$
- $\Delta H \geqslant 5.5\ [km] \Rightarrow POH = 100\%$

VIL

- VIL is *Vertically Integrated Liquid water*, i.e. the liquid water within a cloud as detected by radars
- It is defined in [5] as: $VIL = 3.44 \times 10^{-6} \int_0^{+\infty} Z^{4/7} dz$ [kg/m^2].
- There is no threshold level defining intense thunderstorms; generally $VIL \approx O(10)$ is a good indicator of intense thunderstorms.
- VIL values depend on air masses in which clouds are immersed.

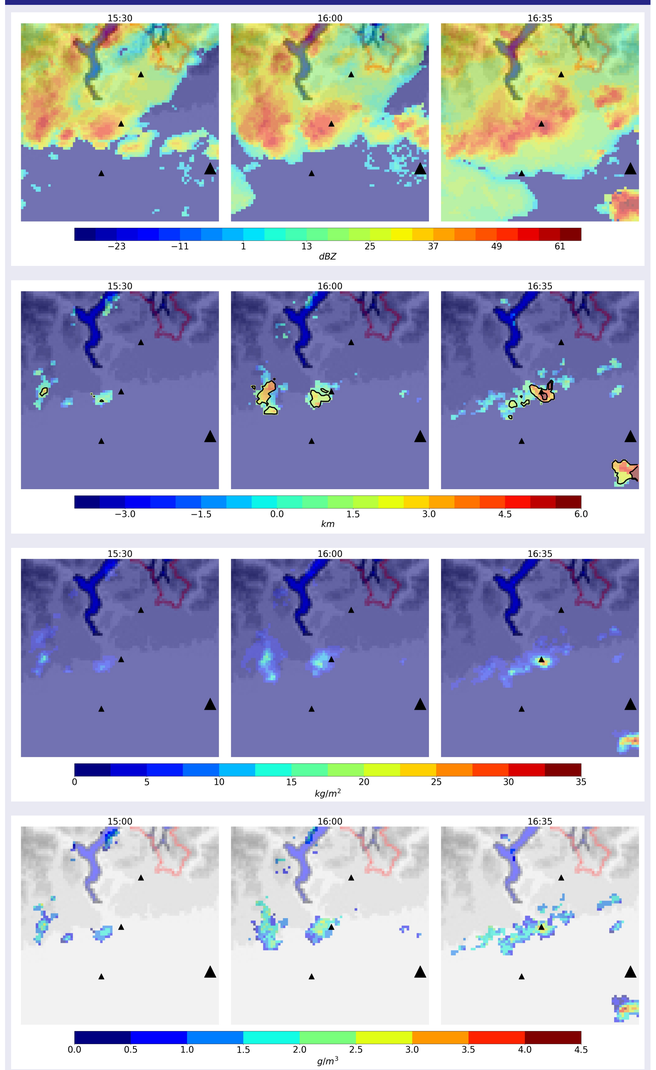
VILD

- VILD is the VIL density as defined in [3]: $VILD = VIL/H_{45}$.
- VILD is the measure of liquid water within the core of a cloud.
- VILD values do not depend on air masses.

Data

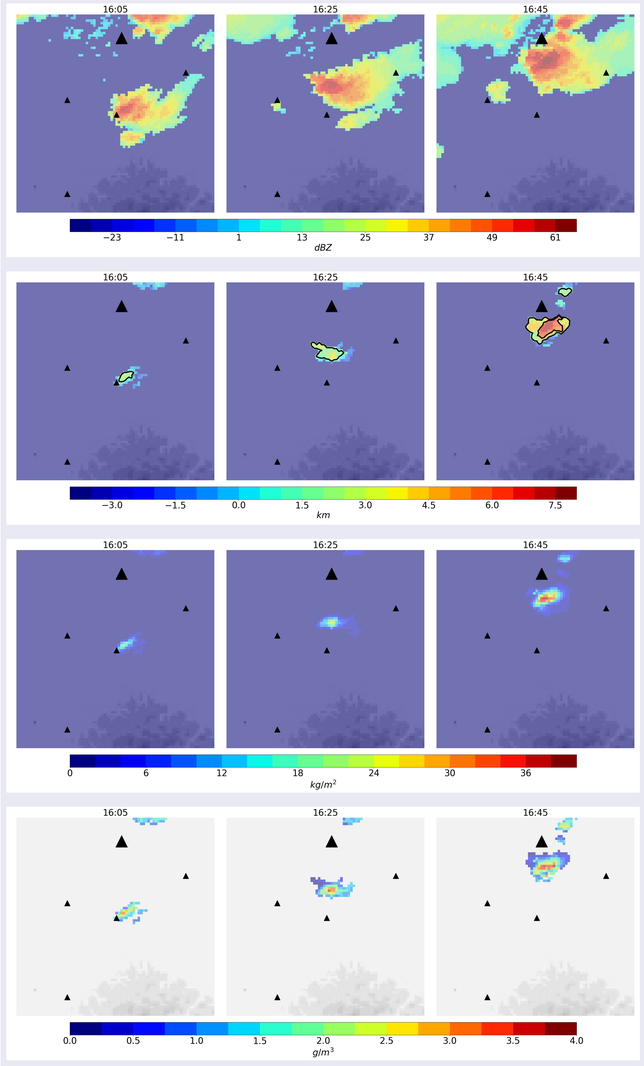
- Radar data were supplied by MeteoSwiss as RGB images along with conversion tables to convert RGB values into physical quantities (Z, H_{45}, VIL), and along with the image of the radar domain to georeference RGB images.
- Meteo Expert supplied the H_0 levels to compute ΔH.
- Python was used as programming language to post-process images.

The Malpensa airport



Figures show Z, ΔH, VIL, and VILD from top to bottom. These images cover a surface of 40 × 40 km^2 centered in the Malpensa airport (central triangle); the city of Milan (bigger triangle south-east to Malpensa), Varese (triangle north-east to Malpensa), and Novara (triangle south-west to Malpensa) are also shown. The images display the configuration at 15:30, 16:00, and 16:35 UTC showing the intensification of the cell core over the airport. At 16:35 UTC Z, ΔH, and VIL reached their maxima over the Malpensa airport. Black lines in ΔH represent the 1.4 km ($POH \geqslant 0\%$) and 5 km levels ($POH \geqslant 90\%$).

The cell of Pavia



Figures show Z, ΔH, VIL, and VILD from top to bottom. These images cover a surface of 40 × 40 km^2 centered in the city of Pavia (central triangle); the city of Milan (bigger triangle north to Pavia), Voghera (triangle west to Pavia), Tortona (triangle south-west to Pavia), and Lodi (triangle north-east to Pavia) are also shown. The images display the configuration at 16:05, 16:25, and 16:45 UTC showing the intensification and the north-eastward movement of the cell core. At 16:45 UTC, all quantities reached their maxima south to the city of Milan. Black lines in ΔH represent the 1.4 km ($POH \geqslant 0\%$) and 5 km levels ($POH \geqslant 90\%$).

Results

The Malpensa airport

- Z does not allow to clearly identify the cell core above Malpensa: high values of Z are shown all over the 40 × 40 km^2 around the airport.
- ΔH points out the evolution of an almost stationary cell core above Malpensa: at 16:35 UTC, ΔH reached 5.8 km, i.e. 100% of POH.
- VIL intensifies within an hour as well as ΔH: the greatest value of VIL (31.0 kg/m^2) was also reached at 16:35 UTC.
- VILD reached its maximum at 16:25 UTC (3.45 g/m^3); such an high value is characteristic of intense thunderstorm.

The cell over Pavia

- The cell over Pavia appears more isolated than the one over Malpensa, just by looking at Z: $Z = 64.5$ dBZ at 16:45 UTC.
- ΔH confirms the intensity of this thunderstorm: ΔH attained 7.39 km ($POH = 100\%$) within 45 minutes.
- Also VIL reached an high value of 39.0 kg/m^2.
- In particular, VILD achieved 3.75 g/m^3: such an high value is associated to severe hail storms.

Conclusions

- Using ΔH, VIL, and VILD, it has been possible to recognize the intense cell core occurred over the Malpensa airport on September 16th, 2021.
- These quantities can identify thunderstorm cores and their intensities, along with cell extensions and evolution over time, in a clearer way than Z alone.
- ΔH, VIL, and VILD have been applied to another cell allowing to recognize an intense cell core. Even though the latter was characterized by greater peaks, there were no reports about damages. Future works may focus on physical aspects about this difference between the cell over Malpensa and the cell over Pavia.

References

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