ERAD 2024 9-13 September 2024 - Rome, Italy

COMPARATIVE ANALYSIS OF TWO ALGORITHMS FOR ESTIMATING LARGE HAIL OCCURRENCE USING RADAR DATA.

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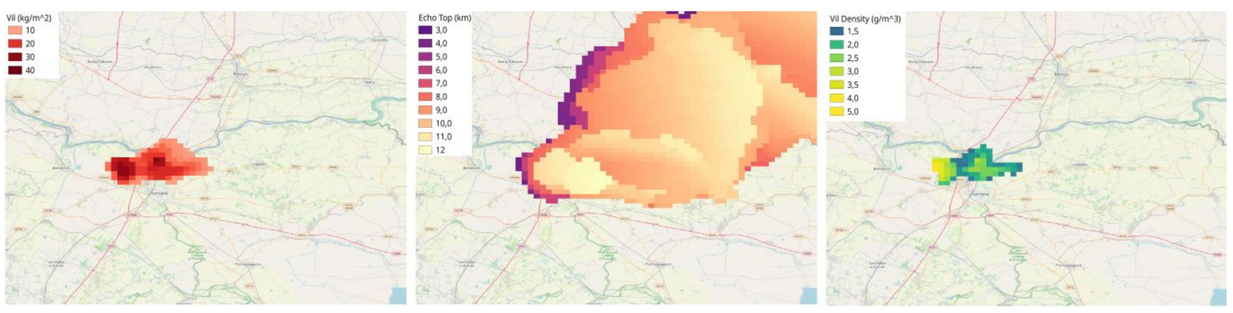
ABSTRACT

Large hail is one of the most relevant meteorological topics in these last years, as it happens more and more frequently, causing huge amount of damages to agricolture, buildings, vehicles. An affordable tool to detect such phenomena, based on available instruments measurements, would be thus very useful. In literature many algorithms to detect the presence of large hailstones and estimate their diameter using weather radar data have been proposed, allowing a wide spatial coverage, together with high temporal and spatial resolution. ARPA Piemonte and ARPAE Emilia-Romagna, agencies for environmental protection of the respective Regions, operate a total of four C-band polarimetric weather radars whose data are ingested in two algorithms implemented and operationally run by the two agencies to estimate large hail occurrence. In particular ARPA Piemonte implemented the so called "50 dBZ hail nomogram" algorithm, originally proposed by Australian Bureau of Meteorology, taking as input the 50 dBZ reflectivity echo top height (ETOP50) together with the freezing level height (FL), stating the presence of hailstones larger than 2, 4 or 6 cm as the difference between ETOP50 and FL increases. ARPAE Emilia-Romagna has instead implemented the algorithm proposed by Amburn and Wolf in 1997, setting a threshold for VILD (Vertically Integrated Liquid Density) to discriminate severe hail (diameter > 1.9 cm) . In the framework of a partnership between ARPA Piemonte, ARPAE Emilia-Romagna and National Civil Protection Department we are seeking which algorithm gives the best performances, in order to apply it on the whole Italian weather radar network. In this preliminary study it is shown a comparative evaluation of the two described methods, applying both on different events of large hail happened during summer 2023 in Piemonte and Emilia-Romagna regions. The algorithms outputs are compared with the reports of large hail collected by Meteonetwork-Pretemp organization, to first understand which algorithm corresponds most closely to verified events.

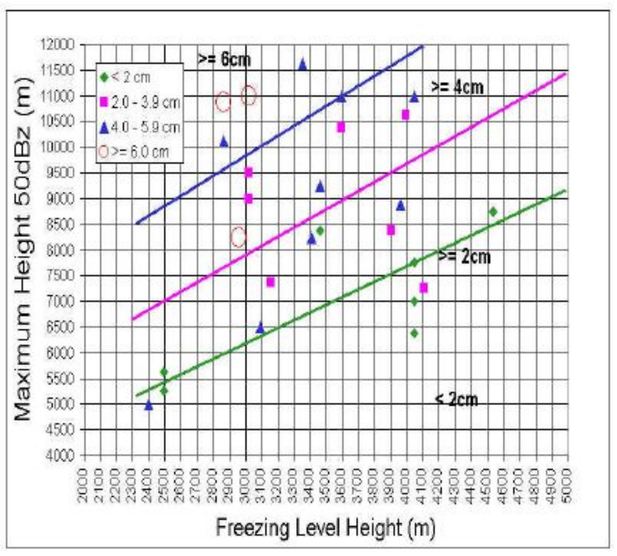
ALGORITHMS DESCRIPTION

VIL Density (VILD)

The VILD algorithm is operationally running in ARPAE–Emilia Romagna, and is used to report cases of severe large hail, with hailstones diameters greater than 1.9 cm. The algorithm is based on the following products: VIL (Vertically integrated liquid, Green and Clark, 1972) and Echo Top at 18.5 dBZ, to obtain VILD from the quotient of these two fields (Amburn and Wolf, 1997). VIL data are filtered considering values >= 10 kg/m^2, while Echo Top minimum threshold is 6 km, meaning only deep convection is considered. According to the study of Amburn and Wolf the VIL density threshold of 3.5 g/m^3 is used to separate non-severe (< 1.9 cm) and severe hail (>= 1.9 cm) but other studies propose different thresholds (e.g. 3.28 g/m^3 , Lahiff, 2005).



50 dBZ echo top Hail Nomogram (50HN)



The 50HN algorithm, running operationally at ARPA Piemonte, is essentially based on two products: the 50 dBZ Echo Top, derived from the radar measurements, and the freezing level height (in our case we use the field provided by numerical weather prediction models COSMO or ECMWF). The algorithm follows the work of Richter et al., 2007. It refers to empirical observations in Australia, and relates the altitude of the thermal zero to the maximum echo height at 50 dBZ, to assess the presence of hail with diameters greater than 2, 4, and 6 cm respectively, according to the diagram in the figure.

DATA SELECTION

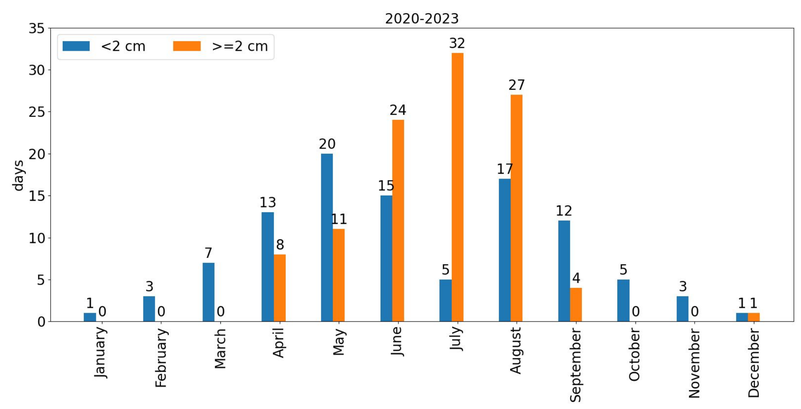
The comparison between the two methods is performed using the storm report collected by PRETEMP-Meteonetwork in Emilia-Romagna and Piemonte regions, during the summer of 2023 (June, July and August) to avoid the presence of graupel reports. These reports contain, among others, the information of the maximum diameter of the hail stone, datetime, municipality, coordinates of the municipality centroid, and whether the report was valid for ESWD (European Severe Weather Database). The reports are accompanied by photos of the stones.

STUDY AREA

REPORT EXAMPLE

event: hail
hail diameter: 6.0
accumulation: NA;
datetime: 2023-07-06 15:00:00
region: Piemonte
place: Cortemilia
centroid latitude: 44.5799858
centroid longitude: 8.193961
report id: 18116,
is_valid: Y
insertion date: NA
eswd valid: Y
fatalities: NA
injured people: NA

HAIL DISTRIBUTION IN THE MONTHS



The reports are divided into two categories: diameter >=2 cm and diameter < 2 cm because the VILD algorithm is able to distinguish between these two categories. The figure on the left shows how the days with maximum observed stone diameter larger or equal or smaller than 2 cm are distributed in the four-year period 2020-2023: June July and August are the months with the greatest presence of large hail.

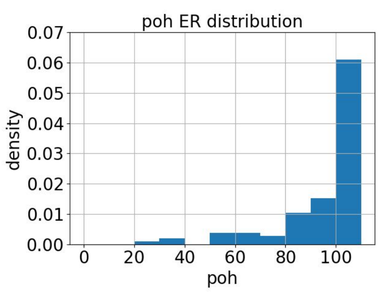
RESULTS

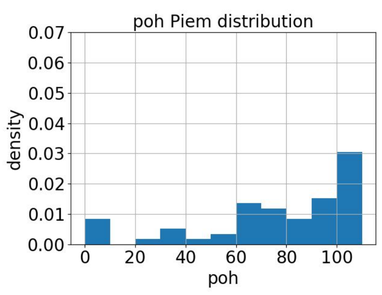
To define a mask for the hail size maps, we considered the Probability of Hail (POH) product. Since two different POH algorithms are implemented by the two regional agencies (Holleman, 2001 in Piemonte and Foote et al., 2005 in Emilia-Romagna), we characterized the POH distribution based on observations for the two regions.
We calculated the POD and Missed percentages over the whole 2023 and in the summer (JJA) 2023, obtaining the worst POH scores when also the cold months are considered.
Considering the threshold of 3% missing events, the lowest probability of no hail/hail was set to 20% for Piemonte and 50% for Emilia Romagna.

The masks were used to filter the VILD and 50HN maps.

Then, we calculated the performance scores, against daily observations, and respect to a threshold of hail size of 2 cm, for different thresholds of VILD and for 50HN

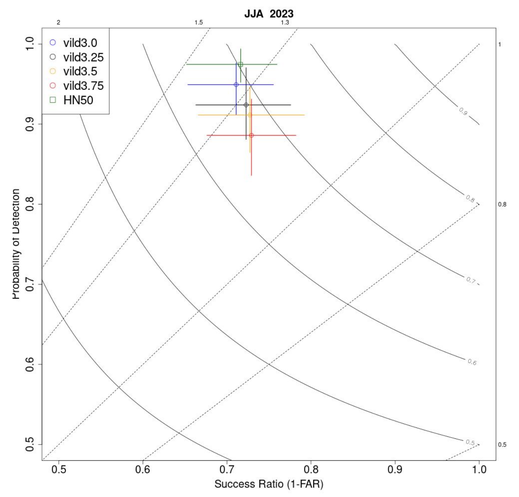
- The 3.5 g/m^3 threshold provides the lowest FAR and best CSI .
- 50HN outperformes respect to VILD





Maximum POH distribution density on municipalities with hail reports on summer 2023 (JJA) in Emilia-Romagna and Piemonte

	PIEMONTE (Holleman, 2001) JJA 2023 sample=170		EMILIA-ROMAGNA (Foote et al., 2005) JJA 2023 sample=111	
poh threshold	pod	miss	pod	miss
10	0.97	0.03	1.0	0.0
20	0.97	0.03	1.0	0.0
30	0.96	0.04	0.99	0.01
40	0.95	0.05	0.97	0.03
50	0.94	0.06	0.97	0.03
60	0.93	0.07	0.93	0.07
70	0.88	0.12	0.90	0.10
80	0.84	0.16	0.87	0.13
90	0.81	0.19	0.76	0.24



June-Aug 2023 - vil density scores
Emilia-Romagna and Piemonte
sample=244

algo	thres	pod	ma	far	csi
VILD	3.0	0.95	0.05	0.29	0.68
VILD	3.25	0.92	0.08	0.28	0.68
VILD	3.5	0.91	0.09	0.27	0.68
VILD	3.75	0.89	0.11	0.27	0.67
50HN	-	0.97	0.03	0.28	0.70

The Performance diagram and scores table of the VILD (4 thresholds) and HN50 hail size estimation methods. It is verified whether the methods are able to discriminate between hail size < 2 cm and >= 2cm. The daily maxima of size observed and estimated in each municipality are compared. Sample: hail events observed during summer 2023. In orange are the scores of the chosen VILD threshold (3.5 g/m^3). In green the best scores method (HN50).

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