Applicability of cloud radar observations for an intra-event analysis of runoff on a steep vineyard

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1. Motivation

Runoff, a natural process where water that falls on land eventually flows back to the ocean, is a vital part of the hydrological cycle. The runoff significance extends to various aspects:

Economic Impact: Runoff influences river water levels, affecting transportation and hydropower generation.

Safety and Infrastructure: Excessive runoff during heavy rainfall can result in floods, impacting safety and infrastructure planning.

Agriculture: Runoff plays a role in soil erosion, impacting crop productivity and land quality.

Water Quality: It can transport chemicals and pollutants from urban areas, roads, and agricultural fields into groundwater.

Intra-event analysis of runoff may help to better understand the runoff formation, and the sensitivity of the runoff amount to rain characteristics and properties of ground. An analysis on a field scale is especially advantageous since sampling effects are mitigated. The sampling effects may results from different measurement tools and spatial homogeneity of precipitation and ground properties

2. Comparison of rain observing instruments

Weather radar
Big sampling volume: 15000 m^3 (6 Olympic swimming pools)
Large covered area
Low resolution: ~100 m
Retrievals required
High operational costs

Optical disdrometers
Small sampling area: 50 cm^2 (half of smartphone size)
Sampling effects
Direct DSD measurements
Low cost

Polarimetric W-band cloud radar [1]
Sampling volume: 150 m^3 (4 ship containers)
Good spatial resolution (3 to 30 m)
Observation area up to few km^2
Intermediate operational costs
Accurate calibration
Accurate retrievals based on spectral polarimetry
Estimation of DSD profiles, rain rate, kinetic energy, liquid water content, median diameter

3. Rain observations with a cloud radar

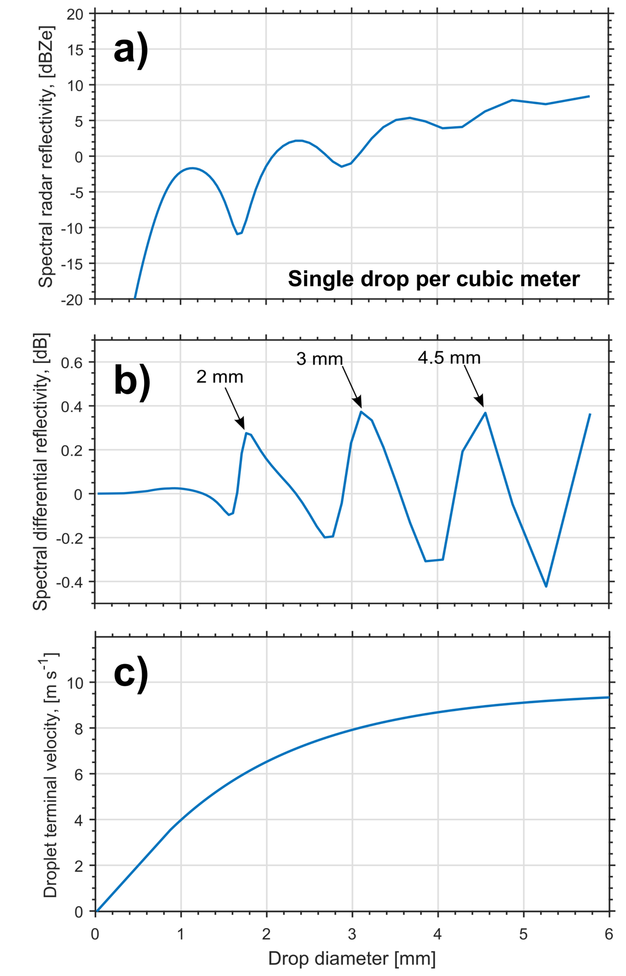

Fig. 1. Modeled reflectivity (a), modeled differential reflectivity (b), and empirical terminal velocity of raindrops. T-matrix and spheroidal approximation are used to model the scattering properties.

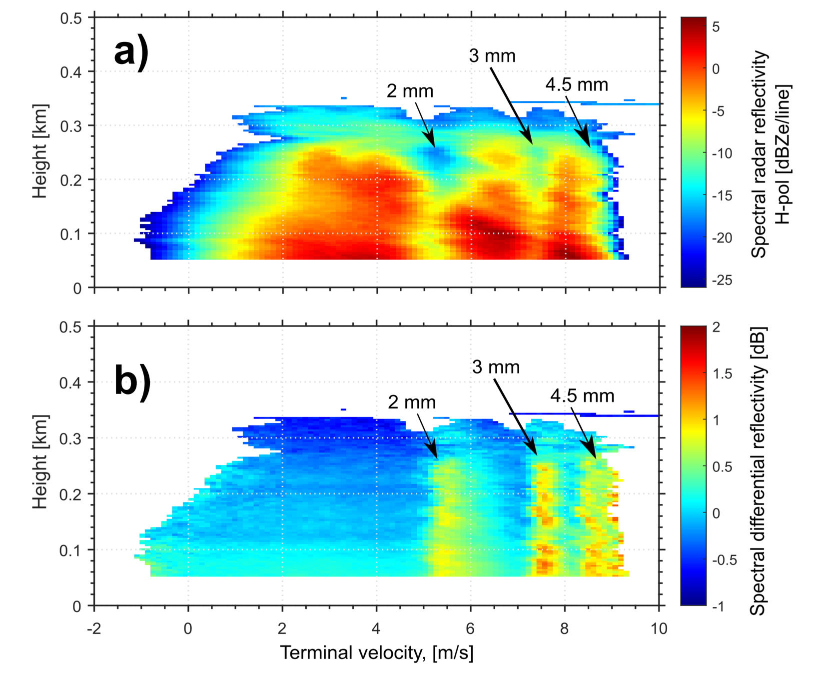

Fig. 2. Spectral reflectivity (a) and spectral differential reflectivity (b) measured by a W-band cloud radar in rain. Measurements were taken at 30° elevation. Distinct polarimetric signatures agree well with the scattering model and allow for assignment of velocity bins to drop sizes even at low elevation angles.

Observed polarimetric spectra allow for estimation of drop-size-distribution and rain rate with high temporal and spatial resolution.

4. Measurement site

Location [2]: Tenuta Cannona operational site in the Alto Monferrato area (Piedmont, NW Italy, Fig.3)

State-of-the art soil-sediment catching and runoff sampling tools:

- sedimentation trap (Fig.4c),
- 12.2 L tipping buckets (Fig.4d),
- sample tank (Fig.4a)
- moisture sensors at 5 different levels (10 cm spacing);

In May 2023 the site was complemented by the demonstration cloud radar from RPG (Fig.5)

Fig. 3. The view over the tilled row at the Tenuta Cannona site

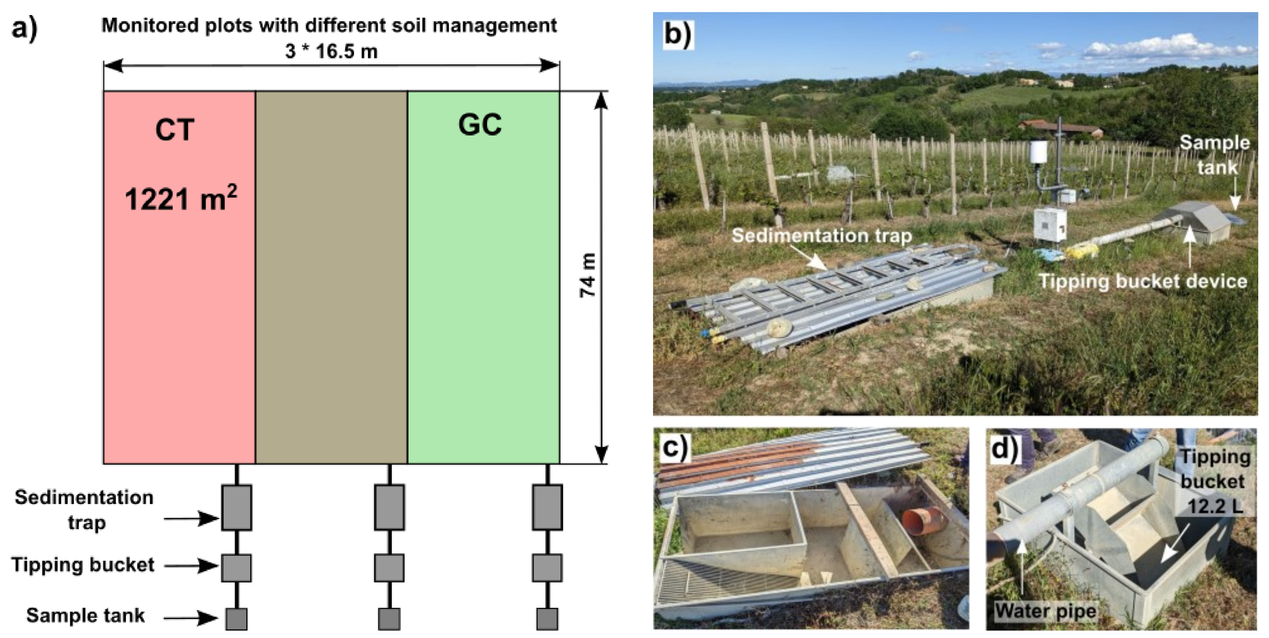

Fig. 4. Instrumentation at the Tenuta Cannona operational site in the Alto Monferrato vine-growing area of Piedmont, NW Italy. (a) - a schematic representation of the Tenuta Cannona monitored plots, runoff collection and measurement systems. CT denotes the plots with soil managed with conventional tillage, GC indicates the plots with controlled grass covered soil. (b) - instrumentation of the site for soil observations. (c) - the sedimentation trap and (d) - the tipping buckets at the site.

Fig. 5. The polarimetric W-band cloud radar at the Tenuta Cannona site. The radar is located about 100 m from the plots. The radar is pointed to 30° elevation.

5. Case study (12 June 2023)

We estimate soil properties (saturated water content and conductivity) by fitting modeled and measured soil moisture and accumulated runoff.

1D Richards equation is used as a forward model [3]:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left[D(\theta)\frac{\partial \theta}{\partial z} - K(\theta)\right]$$

Diffusivity and conductivity are parameterized following [4]

Rain rate from the radar and soil moisture at 40 cm depth are used as boundary conditions

Soil moisture profile from moisture sensors are used as initial conditions

1 s time resolution and 1 cm depth resolution are used

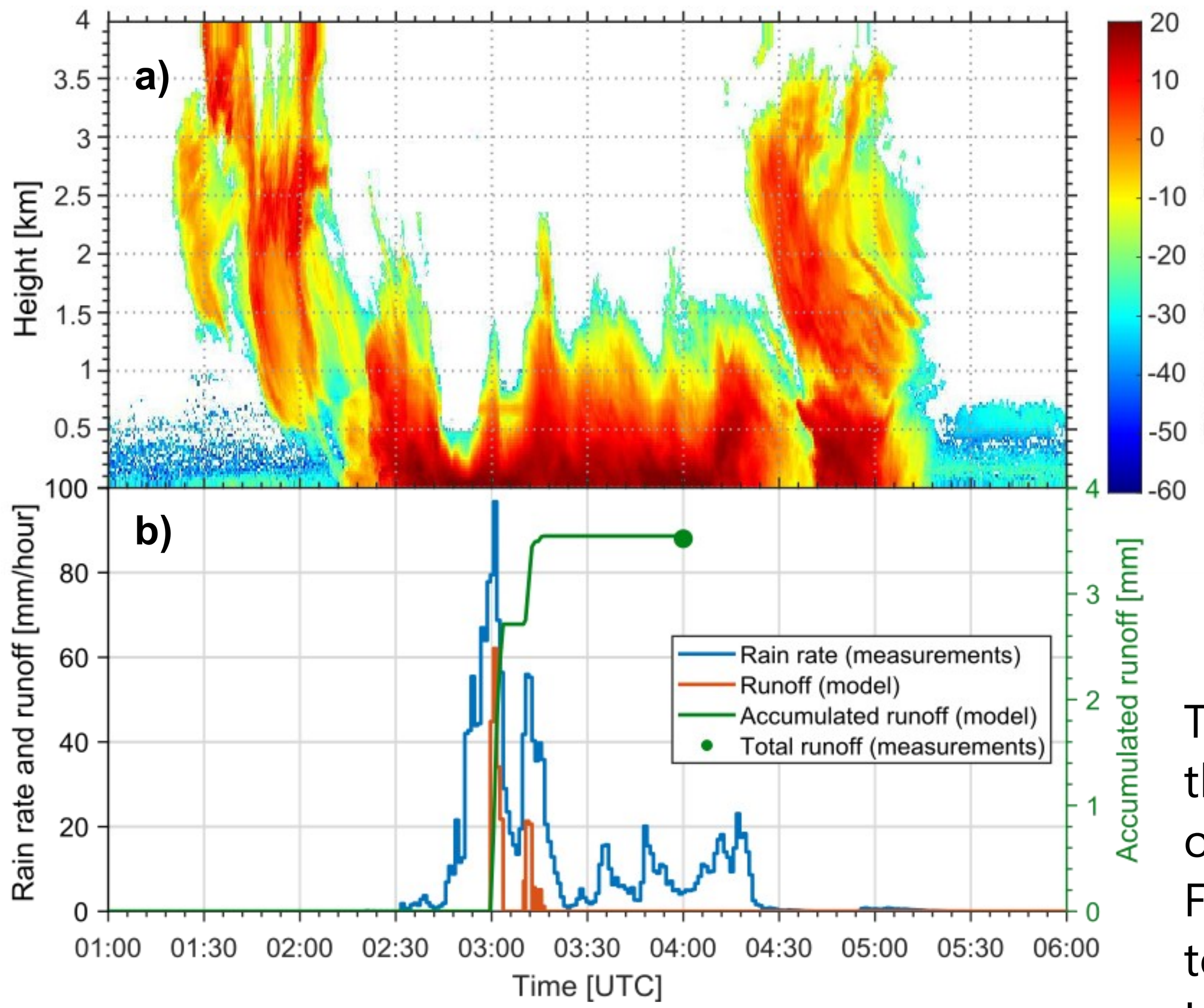

Fig. 6. Radar reflectivity (a) measured by the cloud radar during the rain event on 12 June 2023. The panel (b) shows time profiles of the estimated rain rate, modeled runoff, and the accumulated runoff. The green dot indicated the value of the accumulated runoff from the

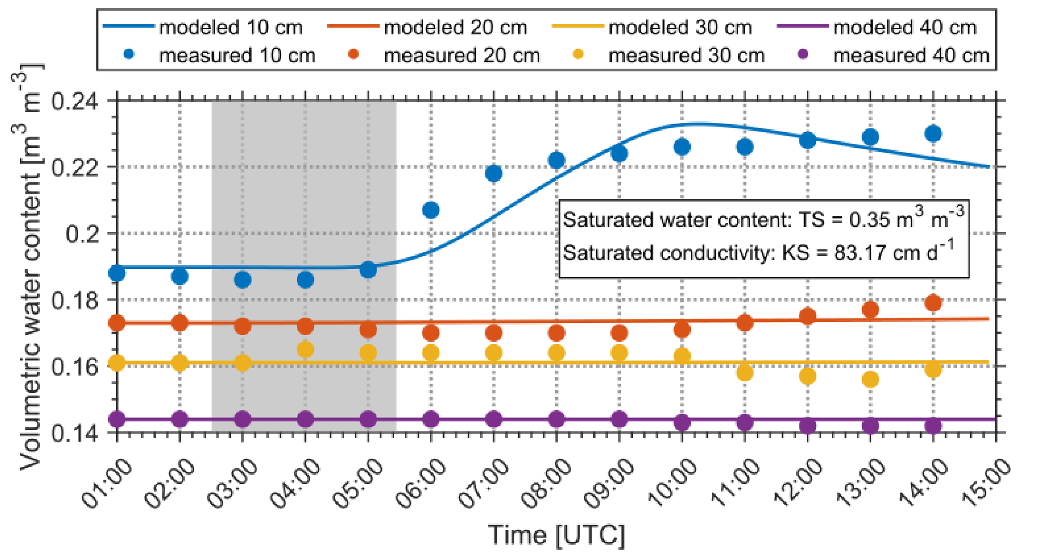

Fig. 7. Fit of the simulated soil moisture (continuous lines) to hourly measurements (dots). Different color corresponds to different depths. Grey area denotes the rain event.

The presented case study shows that rain rate from the W-band cloud radar can be used to model runoff on field-scale.
Further work will include an extension of the approach to 2 dimensions to fit the time evolution of runoff
In addition, all cases collected during the measurement campaign will be analyzed

6. Acknowledgements

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7. References

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