Evaluation of the precipitation space-time variability for EarthCARE validation purpose in the sites of Rome and Lampedusa

Consiglio Nazionale delle Ricerche

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I - Motivations

Validation of geophysical parameters retrieved from satellite would require independent measurements collected from instruments at ground collocate with satellite estimates.

Precipitation is characterized by high variability in time and in space and intrinsic intermittency that poses specific challenges in obtaining significant correlative measurements during satellite overpasses, especially for satellite equipped with profiling instruments like the EarthCARE's CPR, due to the lack of co-location.

Sources of correlative precipitation measurements include in-situ ground instruments (rain gauges and disdrometers), though the lowest satellite measurement unaffected by ground clutter is hundreds of meters above them, or ground-based weather/cloud radars.

Weather/cloud radar profilers have adequate vertical resolution for matching satellite profile measurements, but co-location with profiles of precipitation collected from the satellite is unlikely. Using more sparse profilers is thought to mitigate this issue.

Scanning radars can be used for validation, provided that the different sampling volumes of satellite and ground-based radars are considered. They have a wider vertical resolution and lack of sensitivity compared to the high sensitivity EarthCARE CPR.

This study, using the 2D precipitation fields estimate from GPM-DPR satellite scanning radar and operational weather radars investigates space-time variability of rain phenomena at small scale to understand the uncertainty induced by the lack of co-location at EarthCARE validation sites of Rome and Lampedusa. (See Poster 4.6 for a description of the Rome and Lampedusa sites).

II - Datasets and methods

Satellite data over Italy were obtained from the Dual-frequency Precipitation Radar (DPR) of the Global Precipitation Measurement (GPM) mission (2ADPR-FS Ver. 7, measurements form May 22, 2018, to November 6, 2023).

The scan pattern includes 49 footprints, each ~5 km in diameter. Validation sites are the Atmospheric Observatory of Lampedusa and CNR-ISAC in Rome (Fig. 1).

Surface Rainfall Intensity (SRI) data provided by the Department of Civil Protection (DPC) using the C- and X-band radars of the federated nation weather radar network , are also used, covering February 7, 2022, to April 10, 2024, for Rome, being DPC data unavailable for Lampedusa.

The coefficient of variation CV is used to express the relative variability of rainfall fields [1]. It is the ratio of the standard deviation (σ) to the arithmetic mean (μ):

$$CV = 100 \cdot \frac{\sigma}{\mu} \quad [\%].$$

For DPR data, CV is calculated for radii from 5 to 20 km in 5 km increments. For DPC data, due to higher spatial resolution, CV is calculated for radii from 1 to 20 km in 1-km increments. For each radius, calculated are the experimental semivariogram and the Δε metrics [2]

$$\Delta\varepsilon = 2 \cdot 100 \cdot \frac{|R_i - R_j|}{R_i + R_j} \quad [\%]$$

where R_i is the rain rate (in mm/h) in the i-th pixel.

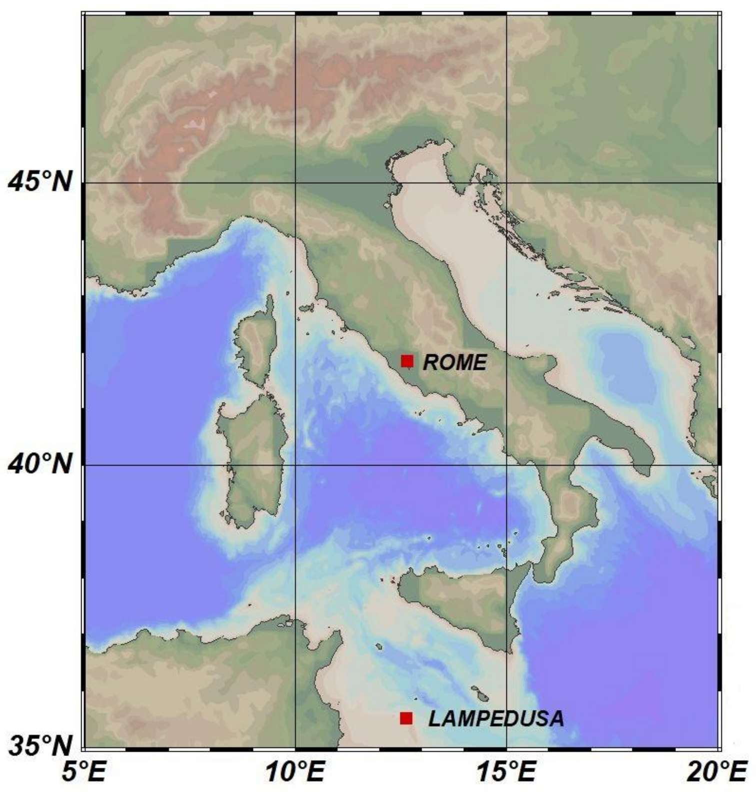
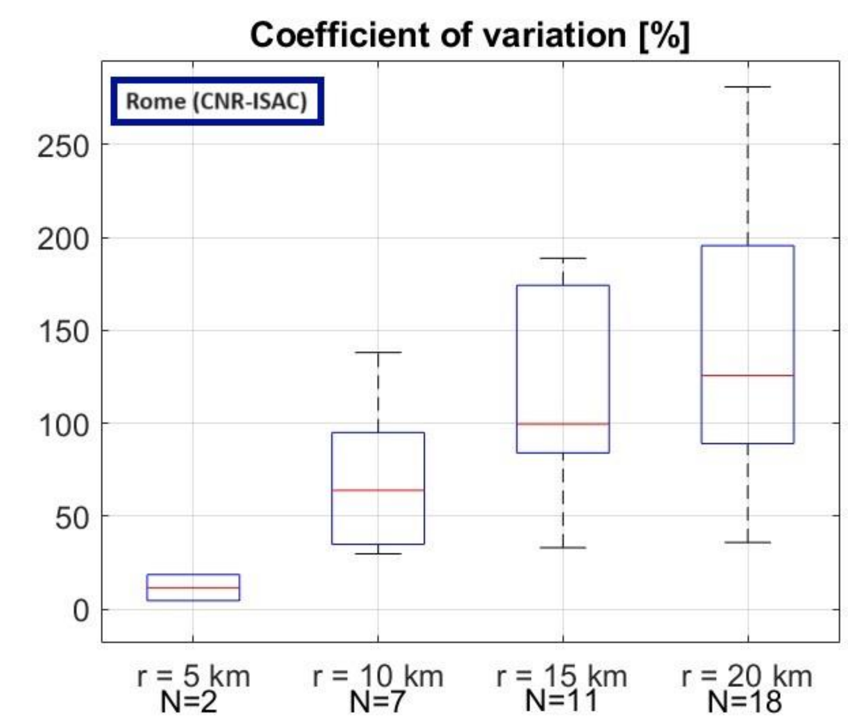


Fig. 1: Location of the validation sites.

III – GPM precipitation data analysis



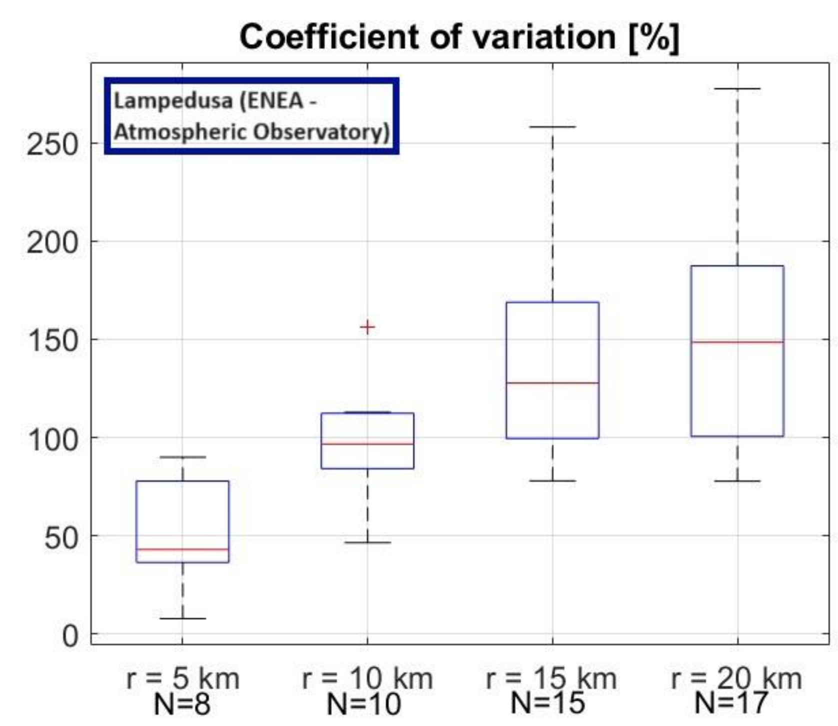
The variability of precipitation DPR measurements is analyzed by means of *CV*.

The results are presented using boxplots: the plot on the left refers to the Rome site (CNR-ISAC, 41.8402°N 12.647°E), while the plot on the right is related to the Lampedusa site (Atmospheric Observatory, 35.518201°N 12.630482°E).

CV is expressed as a percentage, and each boxplot describes the statistics of the coefficient for radius *r*. The number of samples *N* is indicated in the x-axis.

N is always very low because of available low number of overpasses during precipitation the non-continuity over time of satellite precipitation measurements. Nevertheless, an increasing trend with *r* of *CV* is evident, more pronounced in Lampedusa, likely because of a high number of convective events sampled.

To obtain a more accurate representativeness analysis, it was necessary to use DPC radar data where available, since large sample size are necessary for the analysis



IV – Analysis of precipitation data from the Italian National Weather Radar Network

The higher resolution of weather radar data enables a more detailed analysis. For each radius, a statistical analysis is performed on the total cumulative precipitation of the samples. Only samples that exceed the 75th percentile (equal to ~5 mm) are analyzed.

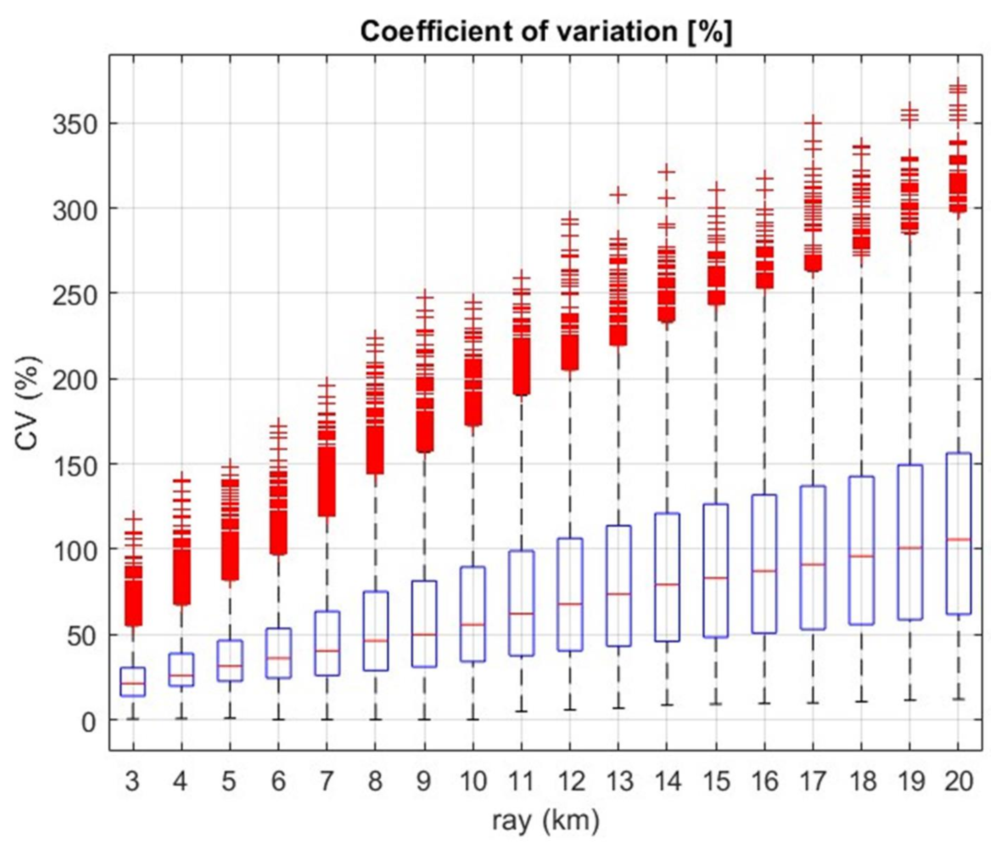


Fig. 2: Coefficient of variation (in %): each boxplot shows the statistics of CV values for the reference radius (x-axis).

The *CV* at varying distances is calculated for each sample. A statistical analysis of *CV* values for radii from 3 to 20 km reveals a clear increasing trend of the medians (Fig. 2).

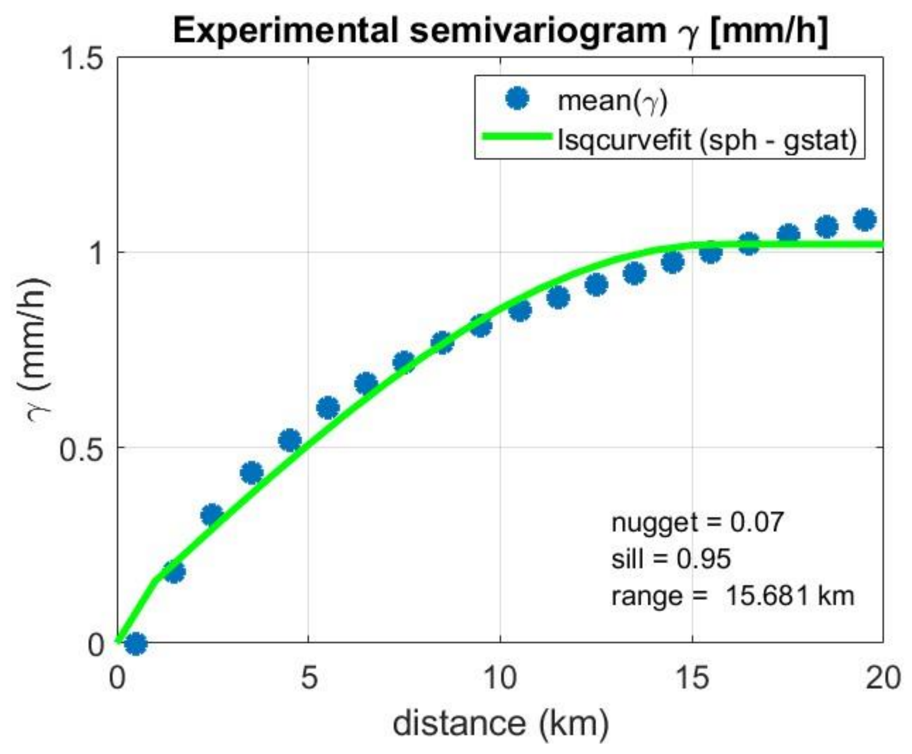


Fig. 3: Average experimental semivariogram γ at varying distances (x-axis). Blue dots represents the mean values of γ; green line is the fitted curve.

The experimental semivariogram provides the spatial dependence of precipitation data at different distances. Fig. 3 shows the average experimental semivariogram value for each radius, and the corresponding fitted curve, whose three parameters have a specific mean and correspond to nugget, sill and range of the variogram.

The range, equal to **15.7 km**, is of particular interest in our analysis, representing the threshold beyond which the data are no longer spatially correlated. For distances greater than the range, the comparison between two measurements is not relevant.

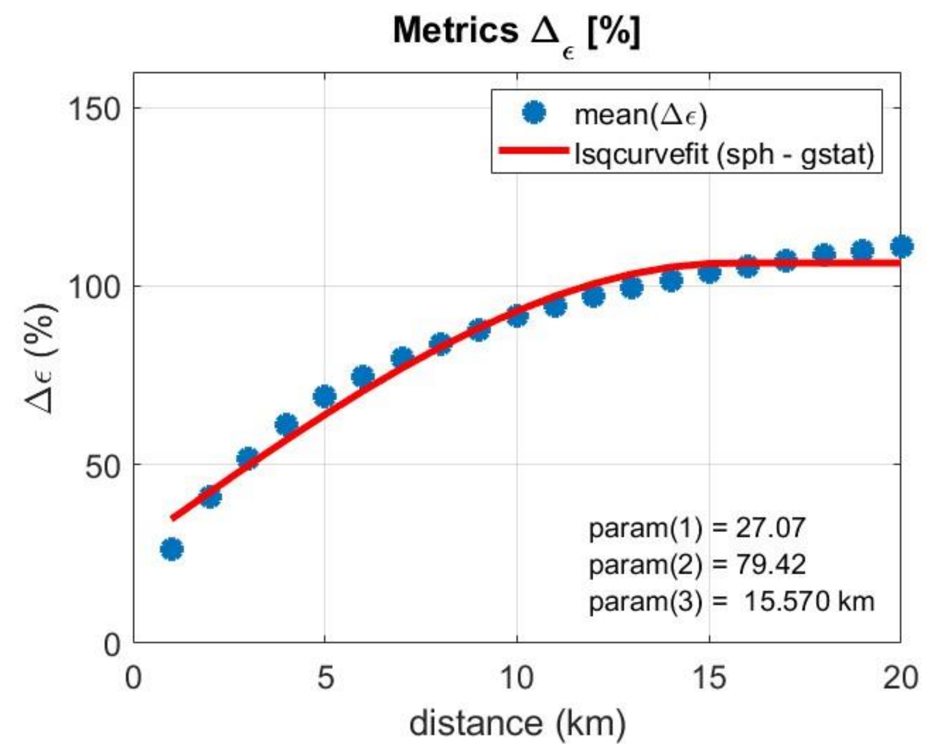


Fig. 4: Average values of the metrics Δε at varying distances (x-axis). Blue dots represents the mean values of Δε; red line is the fitted curve.

Fig. 4 represents the average value of Δε for each radius, with the fitted curve providing three parameters. In this case, even if the fit is performed with the same function used in the previous analysis, the 3 parameters have a different meaning compared to those related to Fig. 3.

The third parameter, equal to **15.6 km**, indicates that data stabilizes for radii larger than ~15 km. This metric provides an estimate of the uncertainty on the comparison between measurements at a given distance: for example, at a distance of 5 km the estimated uncertainty is equal to 69%.

V - Conclusions

- Obtaining significant correlative precipitation data for validating satellite profiles is not easy due to the spatial variability of precipitation fields.
- Precipitation variability was evaluated with 2D rainfall field provided by GPM-DPR over Rome and Lampedusa sites with a 5x5km resolution and by the DPC SRI product with a spatial resolution of 1x1 km and a temporal resolution of 5 minutes.
- The spatial variability as a function of the distance from the validation sites is quite pronounced. The one obtained from DPR is higher, likely due to the higher variability related to the measurement error of DPR.
- For mid-latitude validation sites like those in Rome and Lampedusa, the chances of collecting overpass data in precipitation are not high. For Rome ISAC-CNR site, 30 EarthCARE overpasses are available per year, of which 1/5 during a rainy day. In addition, due to the uncertainty related to the orbit's dead-band, the distance from the validation site to the ground track of the satellite can reach to 30 km.
- The analysis shows that the correlation length of precipitation fields is small, compared to uncertainty of the orbit. Therefore, a careful selection of the few cases of overpasses, say, within 10-15 km, must be performed to select significant data.

VI. Acknowledgments

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VII. References

[1] Tokay, A., L. P. D'Adderio, F. Porcù, D. B. Wolff, and W. A. Petersen, 2017: A Field Study of Footprint-Scale Variability of Raindrop Size Distribution. J. Hydrometeor., 18, 3165–3179, https://doi.org/10.1175/JHM-D-17-0003.1.

[2] Riciniello, A. Representativity of photometric measurements of aerosol properties for a set of Mediterranean sites.Master thesis, Sapienza Università di Roma, 2023.