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Optimizing Wet Antenna Attenuation Models for Improved Rainfall Estimation Using Commercial Microwave Links

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1 ABSTRACT

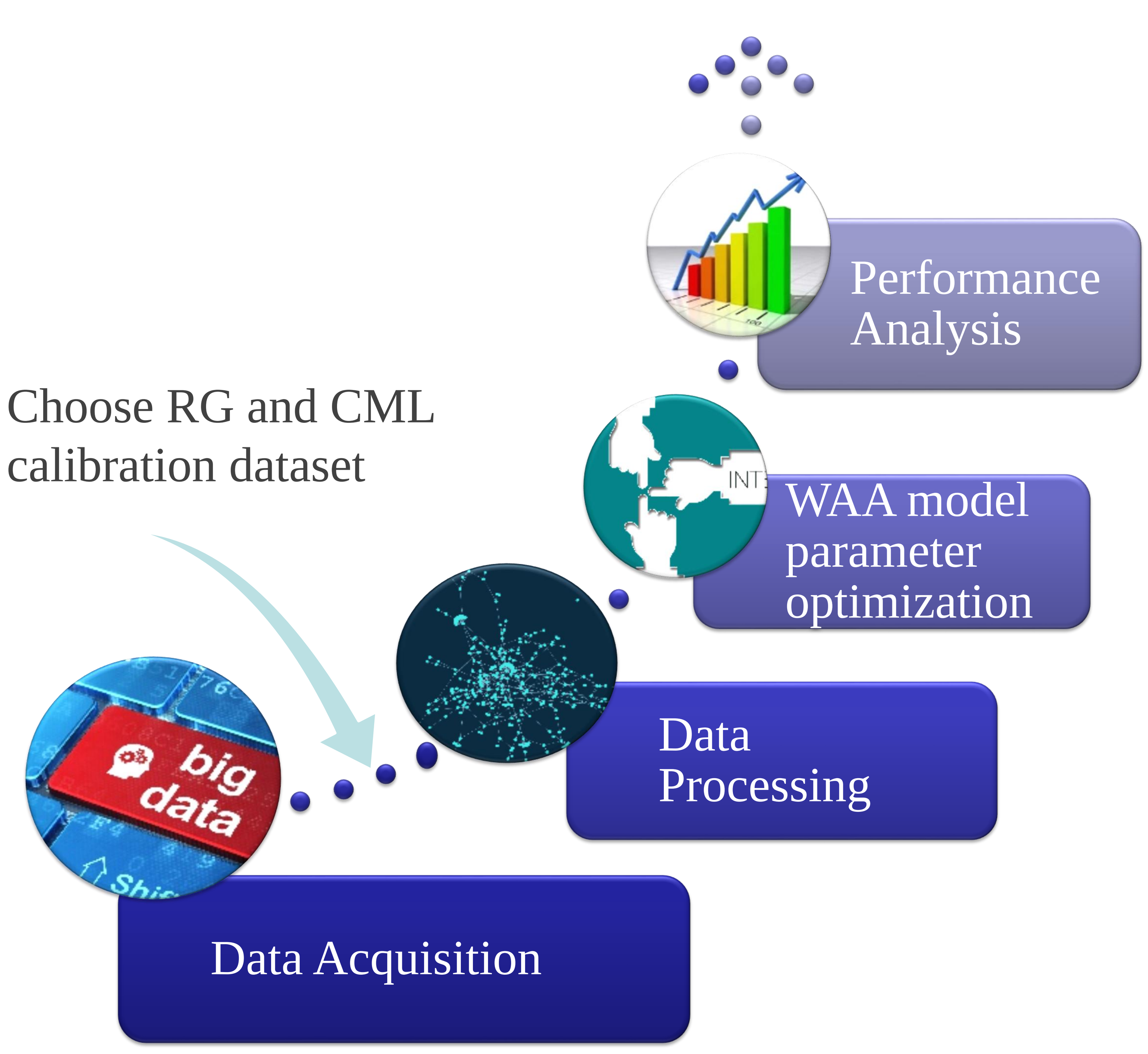
Accurate **rainfall estimation** from **Commercial Microwave Links (CMLs)** is hindered by **Wet-Antenna Attenuation (WAA),** ending-up in large **overestimation** of rainfall intensity. This study:

- Developed a **CML calibration framework** through **rain gauge (RG) data,** incorporating **time-integration** of data. Applied **effective distance** and **link-length** methods to optimize **WAA model parameters.** Evaluate performance using **KPIs** and conducted **sensitivity analysis.**
- Applied framework with measured data in the Seveso River basin, Northern Italy.
- Evaluated several **WAA models,** demonstrating better performance of **locally calibrated Valtr-Fencl-Bares (VFBm)**.
- **VFBm** reduced **bias by 90%** and **normalized RMSE by 70%** compared to uncorrected CML rainfall data.
- **WAA** confirms to be dependent on **rainfall intensity.**

2 RESEARCH QUESTION

- Does the **calibration of the VFBm model** influences the **accuracy of rainfall estimates** in **higher and lower frequency bands**?
- How do different **WAA models** impact the **accuracy of hourly rainfall accumulation estimates** from CMLs compared to RG?

3 METHODOLOGY



4 RESULTS

i Study area

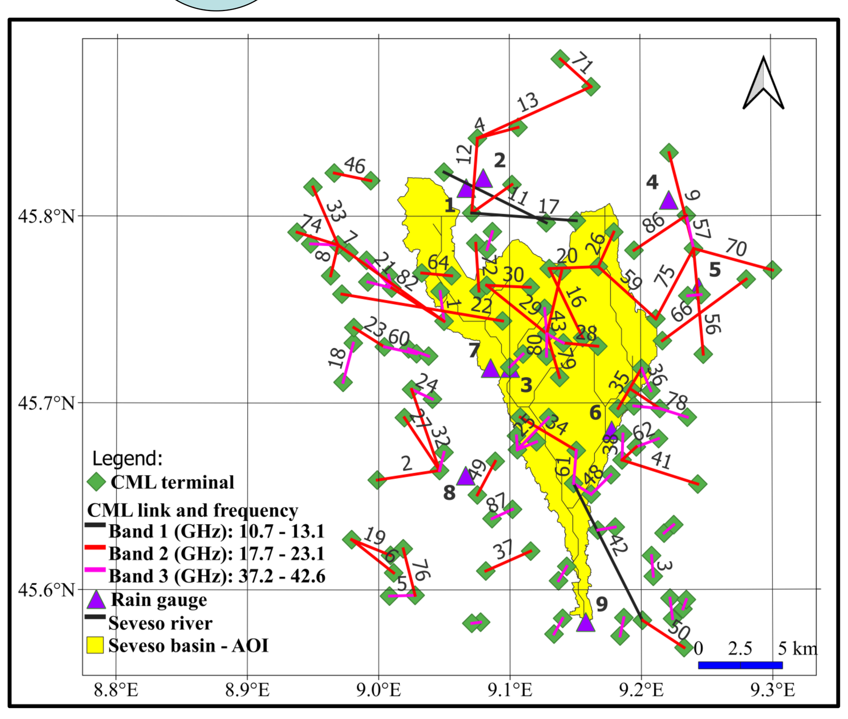


Fig: Catchment area of Seveso basin (Northern Italy) – CMLs and frequency bands

$A_r = A - A_b - A_w \rightarrow A_r = L(\kappa R^{\alpha})$

A_r - rainfall attenuation (dB), A - total path attenuation (dB), A_b - baseline level (dB), A_w - WAA (dB).
L - path length, κ and α – coefficient (ITU), R - rainfall intensity

ii Optimization of WAA model

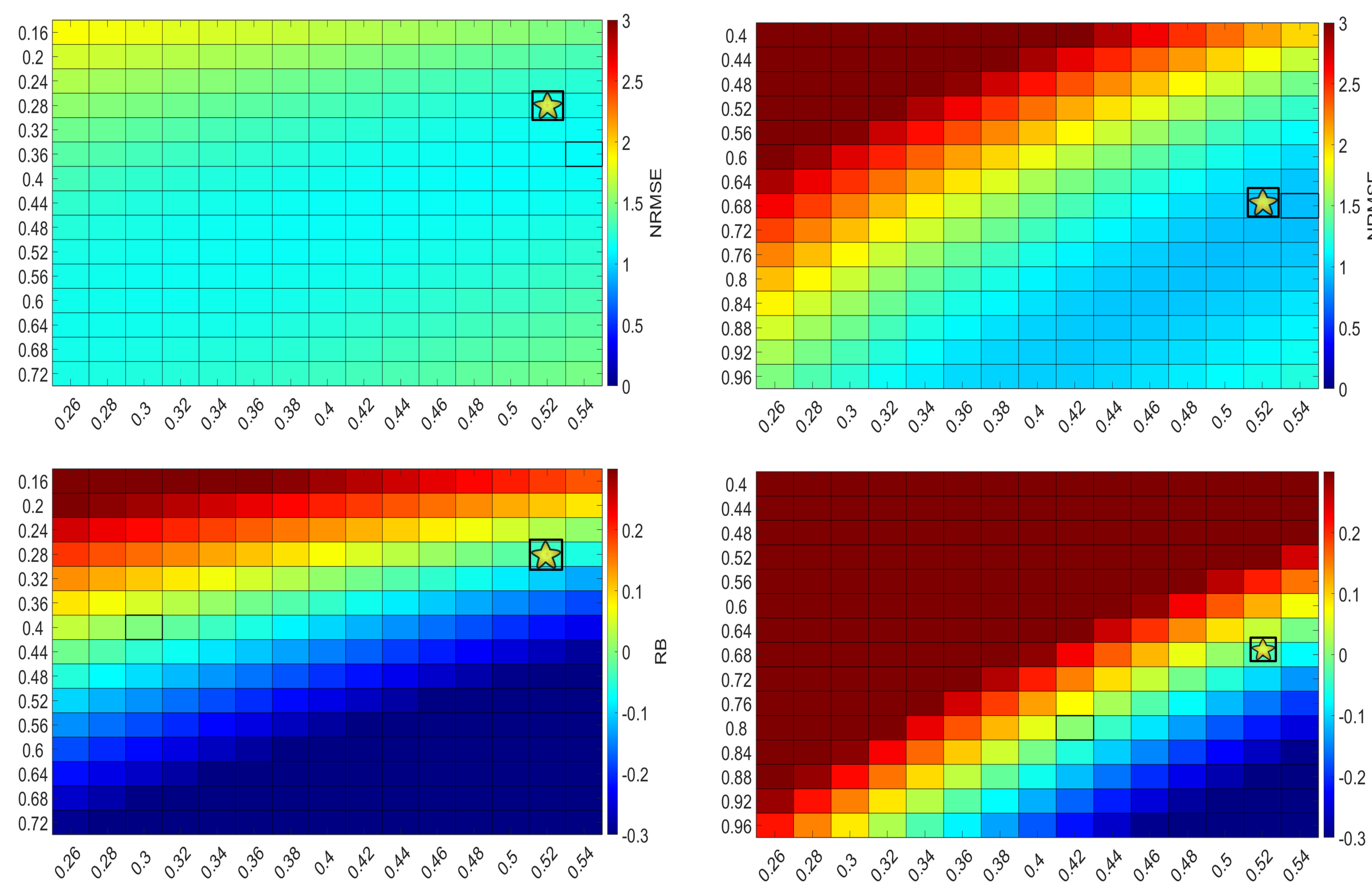


Fig: Calibration outcome of VFBm model for frequency band 17.7 – 23.1 (left) and 37.2 – 42.6 GHz (right), based on two different KPIs: Normalized Root Mean Square Error (NRMSE) (top) and Relative Bias (RB) (bottom).

Table: Overview of WAA models

No. Aq	Model	Analytical expression	Parameters	Links and antennas
1.	Schleiss, Rieckermann and Berne	$A_{w,i} = \begin{cases} min\left(A_i, W, W_{i-1} + (W - W_{i-1})\frac{3T}{\tau_w}\right), \\ if\ i\ wet \\ min(A_i, W), if\ i\ dry \end{cases}$	τw=15 min, W=2.3 dB (38 GHz)	1.85 km link; 30 cm antennas
2.	Valtr, Fencl and Bareš (VFB)	$A_w = k'R^{\alpha'}$	k'=0.68, α'=0.34 (32 GHz)	820 m and 611 m links; 30 cm antennas with a radome
3.	Valtr, Fencl and Bareš modified (VFBm)	$A_w = k'R^{\alpha'}$	k'=0.28, α'=0.52 (17.7-23.1 GHz) k'=0.68 α'=0.52 (37.2-42.6 GHz)	Calibration over 24 links in two different bandwidths

iii Rainfall estimation performance

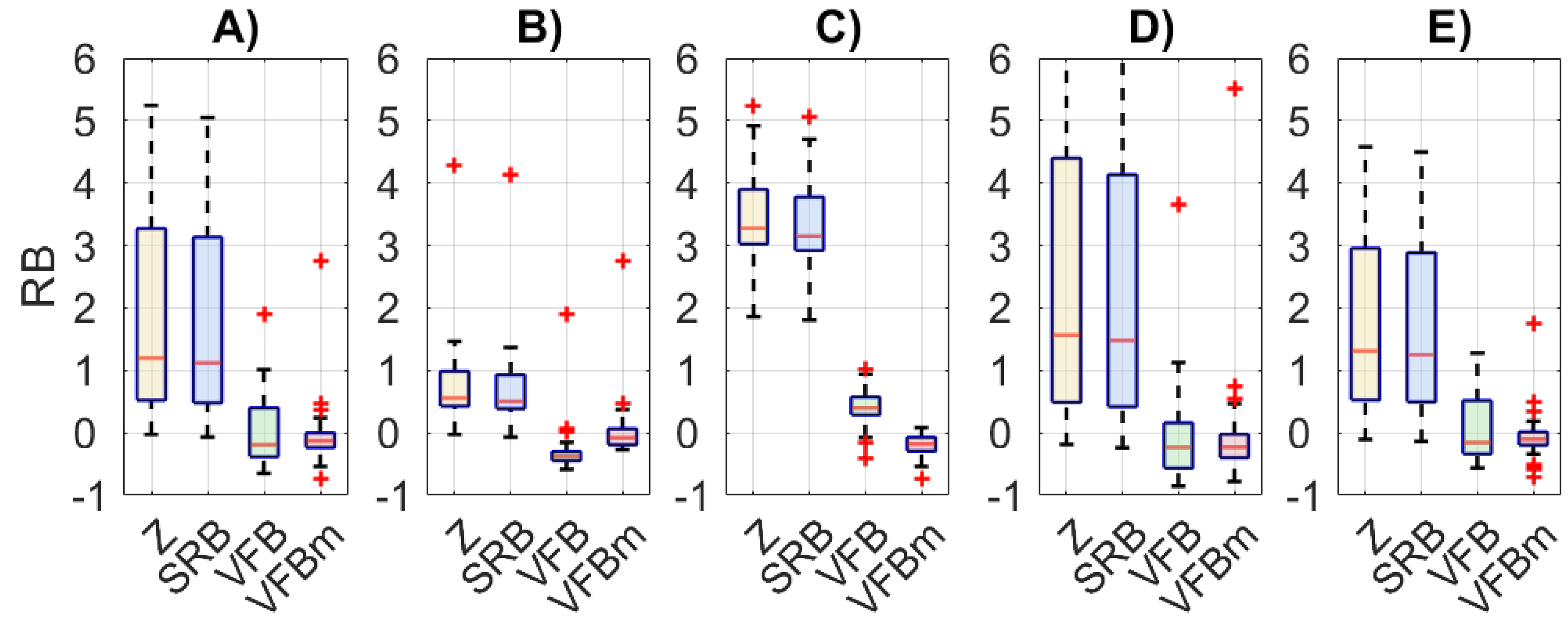


Fig: Hourly rainfall accumulation: CML vs RG estimates (RB – Relative Bias).A) All 87 CMLs, B–C) Frequency bands 17.7–23.1 & 37.2–42.6 GHz, D) Weak rain (0.2–2.5 mm), E) Heavy rain (>2.5 mm).

6 CONCLUSIONS

- **WAA impact is frequency-dependent,** stronger in the 37–43 GHz band than in 17–23 GHz.
- **VFBm improves accuracy** of rainfall estimates, reducing Relative Bias (RB) compared to the original VFB model.
- Performance shows a **dependence** on **distance to RG**, and **misclassification** of **weak rain event** due to quantization.