Added value of Personal Weather Stations for Precipitation Estimates in the Lazio Region, Italy

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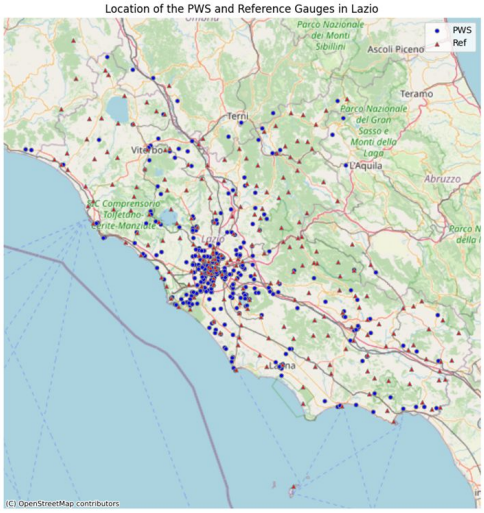
Introduction

In the Lazio region, a dense network of 230 trustworthy rain gauges (HydroNet) with a high temporal resolution, as well as data from more than 339 Netatmo Personal Weather Stations (PWS) are available. Employing data from this data-rich location, we demonstrate the benefit of PWS in addition to professional rain gauges. Since the PWS do not meet professional standards in terms of installation and maintenance, a quality control (QC) of the data is required. For this purpose, we apply the latest QC filters and bias corrections developed in the OpenSense COST Action. After the QC, the PWS data are evaluated by comparison with co-located professional rain gauges.

Study Area and Dataset

The Lazio region, located in central Italy along the mid-Tyrrhenian coast, covers an area of 17,232 km², stretching from the Apennines to the Tyrrhenian Sea. Its territory is physically diverse, with a predominance of hilly (54%) and mountainous areas (26%), while plains (20%) are mainly concentrated near the coastline. The region features a varied climate: mild and temperate along the coast and continental over the Apennines. The Regional Functional Center of the Civil Protection manages the Lazio rain gauges network, which consists in 230 stations with different recording times, varying between 1 and 30 minutes (Morbidelli et al., 2025).

Location of the PWS and Reference Gauges in Lazio

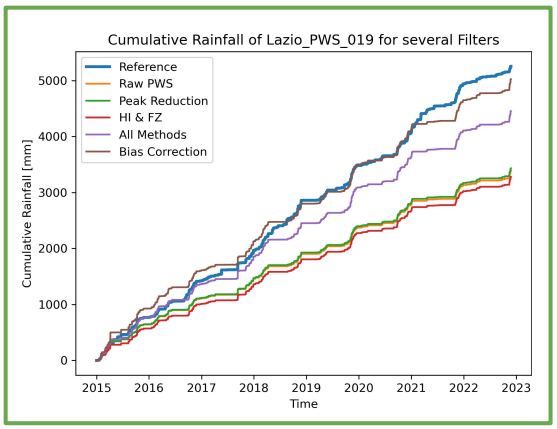


Methods

To showcase the importance and benefits of quality control for PWS, we select four co-located pairs of HydroNet gauges and PWS which are within 500 m distance. Further criteria for this selection is the length of the PWS data and the passing of the **Indicator Correlation Filter**, i.e. they fit into the spatial correlation structure of the reference stations (HydroNet). The other available PWS QC methods (c.f. El Hachem et al. 2023) are applied successively to assess in the impact of each of those filters. The newly developed **Peak Removal Filter** detects and corrects spikes from Netatmo PWS rain data which are caused by interruptions between the rain module and the base station. Further filters that we apply are the **Faulty Zeroes (FZ)** and **High Influx (HI)** filters as well as bias correction based on quantile mapping.

HydroNet-PWS Pairs used for the Analysis

PWS	Reference	Distance [m]	NaNs PWS [%]	Start of PWS data
Lazio_PWS_019	HydroNet_036	362	4.61	2014-12-31
Lazio_PWS_036	HydroNet_114	189	18.89	2015-12-25
Lazio_PWS_115	HydroNet_225	113	6.05	2018-08-26
Lazio_PWS_080	HydroNet_147	419	15.53	2019-05-08



Statistics and Metrics after Successive Filter Application

	Ref	PWS raw	PWS peak rem	PWS HI	PWS FZ	PWS FZ HI	PWS FZ HI REF	PWS bias corr	PWS all methods
Valid data [h]	63650	63650	65177	63642	54016	54008	53970	63650	55308
Valid data [years]	7.27	7.27	7.44	7.27	6.17	6.17	6.16	7.27	6.31
Prec. Sum [mm]	5254.80	3392.39	3432.87	3264.02	3392.39	3264.02	3280.48	5024.57	4454.25
Max [mm]	48.80	27.98	27.98	27.98	27.98	27.98	27.98	47.62	47.62
Min [mm]	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0
99% [mm]	2.40	1.41	1.41	1.41	1.72	1.72	1.72	2.18	2.18
P_0	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
Pearson Corr	0.99	0.58	0.71	0.73	0.76	0.79	0.80	0.71	0.80
Ind Corr	1.00	0.68	0.70	0.70	0.76	0.76	0.76	0.68	0.77

Main Takeaways from Filter Application

- Thorough QC and individual bias corrections are essential to obtain reliable data from PWS as it allows for an extrapolation in the upper tail of the cdf
- Bias correction should be applied after the other filters
- Infilling of short gaps and removing peaks increases the number of valid data significantly and improves the correlation metrics
- FZ filter should be applied with caution as it flags many time stamps thus reduces the number of valid and data increases the 99% percentile
- Individual PWS occasionally miss (extreme) rainfall events

Outlook and Future Work

- In subsequent work we will interpolate the pre-processed PWS data to create rainfall maps (combinations with and without official gauges, official gauges only) using both conventional and copula-based interpolation frameworks. We can then assess the added value of PWS in capturing the spatial variability of rainfall (extremes) and on precipitation interpolation, e.g. for hydrological modelling
- A systematic benchmark study on the effects and impacts of single pypwsqc filter modules (and different combinations) is planned
- Development of a new event based filter which checks for plausible data for each time step from generally trustworthy PWS

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Literature:
El Hachem, A., Seidel, J., O'Hara, T., Villalobos Herrera, R., Overeem, A., Uijlenhoet, R., Bárdossy, A., and de Vos, L.W (2024), Technical note: A guide to using three open-source quality control algorithms for rainfall data from personal weather stations, Hydrol. Earth Syst. Sci., 28, 4715–4731.

Morbidelli, R., Flammini, A., Echeta, O., Albano, R., Anzolin, G., Zumr, D., ... & Saltalippi, C. (2025). A reassessment of the history of the temporal resolution of rainfall data at the global scale. Journal of Hydrology, 654, 132841.