



Improving data reliability in air quality monitoring from static and mobile sensor platforms and networks using the FILTER framework

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The growing adoption of low-cost sensors (LCSs) has significantly enhanced environmental monitoring by enabling widespread, community-driven data collection, particularly in regions requiring dense monitoring, and in regions with limited or no reference instrumentation. Increased public awareness and demand for dense environmental monitoring have resulted in extensive air quality and meteorological datasets from diverse sources. However, the integration of such datasets into regulatory frameworks and large-scale environmental monitoring remains challenging due to persistent issues related to data quality, standardization, and interoperability.

To address these challenges, the FILTER (Framework for Improving Low-cost Technology Effectiveness and Reliability) approach developed by Hassani et al. (2025) provides a suite of algorithms to harmonize, quality-check, flag, and perform in-situ corrections on crowdsourced PM_{2.5} LCS datasets. While FILTER was initially designed and validated for static PM_{2.5} sensors, it has since been extended to address data quality challenges associated with the dynamics of mobile and wearable sensing.

Across both static and mobile LCS platforms, FILTER employs a unified processing pipeline that generates measurement-level quality flags based on multiple statistical tests, to quantify the reliability of each observation. Quality control (QC) includes statistical tests to: (a) assess physical measurement consistency (range validity test), (b) detect flatline behavior (constant value test), and (c) identify abnormal patterns (spatiotemporal outlier detection test) using both historical trends and spatial comparisons with neighboring LCSs. Beyond these mandatory QC steps, more advanced statistical procedures incorporate relative (spatial correlation test) and absolute (spatial similarity test) comparisons with nearby LCSs, higher-quality instruments, and reference monitoring stations. For mobile and wearable sensing, FILTER has been specifically adapted to support pairwise comparisons between mobile sensors and comparisons with higher-accuracy nodes, accounting for operation under dynamic environmental and operational conditions. In this context, statistical comparisons are evaluated during rendezvous events, that is, periods in which the mobile sensor and a higher-accuracy node provide temporally coincident

measurements. The modified framework retains the core principles of transparency, scalability, and sensor independence, while introducing additional steps to address motion-related artifacts, intermittent time series, and location-specific uncertainties.

FILTER is developed in the open-source R environment. Its modular and hierarchical design allows flexible adaptation of quality control and correction workflows based on data availability, the spatiotemporal characteristics of LCS networks, and application-specific requirements. By improving data reliability and usability, FILTER enables crowdsourced LCS datasets to serve as a reliable complement to official monitoring networks for air quality management, urban- and regional-scale modeling, and policymaking.

References

Hassani, A., Salamalikis, V., Schneider, P., Stebel, K., and Castell, N.: A scalable framework for harmonizing, standardization, and correcting crowd-sourced low-cost sensor PM_{2.5} data across Europe, *J. Environ. Manage.*, 380, 125100, 2025.