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SHORT ABSTRACT

Abstract title: Assessing the spatial representativeness of urban traffic monitoring sites using real-world measurements, modeling, and data fusion approaches

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Abstract

Urbanization is rapidly increasing worldwide, fostering economic growth while placing pressure on urban infrastructure and ecosystems. In dense metropolitan areas, high traffic, industrial activity, and energy demand increase air pollution, particularly nitrogen dioxide (NO_2), health risks, and contribute to environmental degradation. Despite regulatory efforts, urban air quality remains a challenge, emphasizing the need for improved monitoring strategies.

A key concept in air quality management is the Spatial Representativeness Area (SRA) of monitoring stations. The SRA defines the area over which measurements from a station are representative; however, the lack of a standardized method to determine SRAs undermines consistency across studies and regulations.

This study addresses this gap through a case study centered on Barcelona's Eixample urban traffic monitoring station. An experimental campaign used 40 NO_2 Palmes-type passive diffusion tubes, with dosimeters deployed across traffic-influenced and urban background sites. Simultaneously, the CALIOPE-Urban air quality modeling system was operated at high spatial resolution to simulate NO_2 distributions, incorporating street and regional scale processes. Three approaches were applied to determine SRAs: monitored data, modeled data, and a data fusion approach based on Universal Kriging, integrating both data sources. For each methodology, SRAs were delineated by incrementally expanding a circular buffer around the monitoring station. In the context of monitored and modeled data, expansion continued until concentrations within the buffer deviated

significantly from the station's mean value, based on method-specific thresholds associated with observational or modeling uncertainty. Additionally, the data fusion method considered uncertainty from passive dosimeter observations and the data fusion results. Results revealed varying SRA extensions across methods, highlighting the influence of measurement and modeling approaches on representativeness estimates. Notably, the fusion approach provided a range of spatial representativeness (rather than a fixed area), marking a methodological advancement by explicitly integrating uncertainty into the determination process.

This study provides a novel, reproducible framework to define SRAs using observed and modeled data, addressing a current methodological void. The inclusion of uncertainty in spatial delineation represents a significant step toward more robust air quality assessment practices. These findings are especially relevant for harmonizing atmospheric dispersion modeling methodologies across Europe, supporting consistent, science-based implementation of regulatory policies.