High-Resolution Retrieval of Local Road Emissions from Coarse Satellite Images Using CFD Modeling

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Accurately quantifying local road emissions is crucial for understanding urban air quality and its health impacts. This study presents a novel approach for retrieving high-resolution emissions data, achieving up to 1-meter resolution, from relatively coarse resolution satellite images (500 meters). The methodology integrates Computational Fluid Dynamics (CFD) to simulate wind fields and pollution dispersal from selected road segments in complex urban conditions.

The model is based on several key assumptions: emission rates remain constant along each road segment, pollution dynamics are treated as a passive scalar without considering chemical transformations, and the pollution field within the domain is defined solely by the selected road segments and boundary conditions. The CFD simulation covers a domain of 1km by 1km with a vertical extent of 800 meters, achieving a resolution of 1 meter near buildings to accurately capture fine-scale variations in the pollution field, different surface types are using in this model: buildings, water, vegetations and roads.

For each road segment, we calculate the Aerosol Optical Depth (AOD) from the pollution field. Given that the pollution patterns are linear with respect to the velocity field, we can scale the pollution field according to emission values, allowing for flexible adaptation to varying emission rates. Our approach considers the 25 largest road segments, constructing a basis set from their respective AOD patterns. By using a linear combination of these AOD patterns, we develop a regression model where the weights correspond to the emission values for each road segment.

To solve this regression problem, we employ the Non-Negative Least Squares (NNLS) method, ensuring physically plausible, non-negative emission values. This technique provides a robust and scalable framework for transforming coarse satellite imagery into high-resolution emission maps, significantly enhancing the spatial granularity and accuracy of urban air quality assessments. Our approach represents a significant advancement in environmental monitoring, offering valuable insights for urban planners and policymakers aiming to mitigate pollution and improve air quality.

Keywords: Urban scale modelling, CFD, remote sensing