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Correlation analysis of noise and ultrafine particle counts in a street canyon

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ABSTRACT

Ultrafine particles (UFP, diameter < 100 nm) are very likely to negatively affect human health, as underlined by some epidemiological studies. Unfortunately, further investigation and monitoring are hindered by the high cost involved in measuring these UFP. Therefore we investigated the possibility to correlate UFP counts with data coming from low-cost sensors, most notably noise sensors. Analyses are based on an experiment where UFP counts, noise levels, traffic counts, nitrogen oxide (NO, NO_2 and their combination NO_x) concentrations, and meteorological data were collected simultaneously in a street canyon with a traffic intensity of 3200 vehicles/day, over a 3-week period during summer. Previous reports that NO_x concentrations could be used as a proxy to UFP monitoring were verified in our setup. Traffic intensity or noise level data were found to correlate with UFP to a lesser degree than NO_x did. This can be explained by the important influence of meteorological conditions (mainly wind and humidity), influencing UFP dynamics. Although correlations remain moderate, sound levels are more correlated to UFP in the 20–30 nm range. The particles in this size range have indeed rather short atmospheric residence times, and are thus more closely short-term traffic-related. Finally, the UFP estimates were significantly improved by grouping data with similar relative humidity and wind conditions. By doing this, we were able to devise noise indicators that correlate moderately with total particle counts, reaching a Spearman correlation of $R = 0.62$. Prediction with noise indicators is even comparable to the more-expensive-to-measure NO_x for the smallest UFP, showing the potential of using microphones to estimate UFP counts.

1. Introduction

Urban environments are characterized by busy motorized traffic leading to high noise levels and high concentrations of airborne pollutants. The (combined) adverse effects of both of these environmental stressors on human health have been the subject of numerous studies (see Den Boer and Schroten, 2007 and WHO Working Group, 2003 for a comprehensive overview). Exposure to those pollutants can be reduced through formulation of effective urban planning (King et al., 2009; McNabola et al., 2009) or traffic strategies (Can et al., 2010; De Coensel et al., 2010). Monitoring sensor networks with a sufficient spatial and temporal resolution are needed to get an accurate estimate of personal exposure to these pollutants, or assess the outcomes of reduction initiatives. This high resolution can be reached with a dense sensor grid (Richards et al., 2006). Interpolation techniques (De Kluijver and Stoter, 2003; Ionescu et al., 2000; Janssen et al., 2008) and classification methods (Beaulant and Perron, 2008) are often used to improve spatial resolution. However, those methods all require deploying a substantial number of sensors, which is impossible for some pollutants such as UFP, due to the high cost of the measurement device. This is unfortunate in light of the potential harmful effects (Nel, 2005; Nel et al., 2006) and the highly dynamic character of UFP (Morawska et al., 2008).

This research is part of a project dealing with the proposed use of a non-homogeneous sensor network for pollution monitoring. This network could (i) use sensors of different quality and cost for each stressor, and (ii) be based on the juxtaposition of a limited number of high-quality and expensive sensors (UFP and particulate matter PM) with a larger number of moderate-cost sensors (gaseous pollutants such as NO_x; their price being more than one order of magnitude lower than the mentioned expensive sensors but still prohibitively high to allow wide-scale deployment) and low-cost sensors (microphones and traffic counters such as pneumatic loops; their price being more than two orders of magnitude lower than the mentioned expensive sensors). Ongoing research, testing the accuracy of low-cost microphones (Van Renterghem et al., 2010), shows that some sensors with a price orders of magnitude less expensive than reference equipment, are sufficiently

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