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Uncertainty in mapping urban air quality using crowdsourcing techniques

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Small and low-cost sensors measuring various air pollutants have become available in recent years owing to advances in sensor technology. Such sensors have significant potential for improving high-resolution mapping of air quality in the urban environment as they can be deployed in comparatively large numbers and therefore are able to provide information at unprecedented spatial detail.

However, such sensor devices are subject to significant and currently little understood uncertainties that affect their usability. Not only do these devices exhibit random errors and biases of occasionally substantial magnitudes, but these errors may also shift over time. In addition, there often tends to be significant inter-sensor variability even when supposedly identical sensors from the same manufacturer are used. We need to quantify accurately these uncertainties to make proper use of the information they provide. Furthermore, when making use of the data and producing derived products such as maps, the measurement uncertainties that propagate throughout the analysis need to be clearly communicated to the scientific and non-scientific users of the map products.

Based on recent experiences within the EU-funded projects CITI-SENSE and hackAIR we discuss the uncertainties along the entire processing chain when using crowdsourcing techniques for mapping urban air quality. Starting with the uncertainties exhibited by the sensors themselves, we present ways of quantifying the error characteristics of a network of low-cost microsensors and show suitable statistical metrics for summarizing them. Subsequently, we briefly present a data-fusion-based method for mapping air quality in the urban environment and illustrate how we propagate the uncertainties of the individual sensors throughout the mapping system, resulting in detailed maps that document the pixel-level uncertainty for each concentration field. Finally, we present methods for communicating the resulting spatial uncertainty estimates associated with the urban-scale air quality maps to both scientific audiences and the public.