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Evaluation of mobile micro-sensing devices for GPS-based personal exposure monitoring of heat and particulate matter – a matter of context

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The application of mobile micro-sensing devices (MSDs) for human health and personal exposure monitoring (PEM) is an emerging topic of interest in urban air quality research. In the context of climate change, urban population growth and related anthropogenic activities, an increase is expected for the intensity of citizens' exposure to heat and particulate matter (PM). Therefore more focus on the small-scale perspective of spatio-temporal distribution of air quality parameters is important to complement fixed-monitoring site data. Mobile sensors for PEM are useful for both, the investigation of the local distribution of air quality and the personal exposure profiles of individuals moving within their activity spaces. An evaluation of MSDs' accuracy is crucial, before their sophisticated application in measurement campaigns. To detect variations of exposure at small scales, it is even more important to consider the accuracy of Global Positioning System (GPS) devices within different urban structure types (USTs). We present an assessment of the performance of GPS-based MSDs under indoor laboratory conditions and outdoor testing within different USTs. The aim was to evaluate the accuracy of several GPS devices and MSDs for heat and PM 2.5 in relation to reliable standard sensing devices as part of a PhD-project. The performance parameters are summary measures (mean value, standard deviation), correlation (Pearson r), difference measures (mean bias error, mean absolute error, index of agreement) and Bland-Altman plots. The MSDs have been tested in a climate chamber under constant temperature and relative humidity. For temperature MSDs reaction time was tested because of its relevance to detect temperature variations during mobile measurements. For interpretation of the results we considered the MSDs design and technology (e.g. passive vs. active ventilation). GPS-devices have been tested within low/high dense urban residential areas and low/high dense urban green areas and have been compared according to their deviation from the original test route and according to their technology (GPS, A-GPS, GSM, WLAN).
In result the performance of the MSDs varies spatially and temporally. Variations mainly depend on the USTs, meteorological conditions, device design and technology. However, the sensors' variation for GPS (3-7m) temperature (1-1.3°C) and PM (800-1100 particles/cu ft) is quite stable over the whole range of value records. Difference measures can be used to consider and correct for mean errors. Furthermore we show that smartphone based GPS-tracking in combination with connected MSDs are a reliable easy-to-use method for PEM.
In conclusion our evaluation underpins the applicability of MSDs in combination with GPS for PEM. We observed that especially relative changes in the environmental conditions can be well detected by the devices. Nevertheless, data quality of MSDs remains a relevant concern that needs more investigation especially for applications in citizen science. Eventually the usefulness of mobile MSDs mainly needs to be evaluated depending on the context of application.