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Assessing the importance of transportation activity data for urban emission inventories

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ABSTRACT

The aim of this research is the implementation of a GPS-based modelling approach for improving the characterization of vehicle speed spatial variation within urban areas, and a comparison of the resulting emissions with a widely used approach to emission inventory compiling. The ultimate goal of this study is to evaluate and understand the importance of activity data for improving the road transport emission inventory in urban areas. For this purpose, three numerical tools, namely, (i) the microsimulation traffic model (VISSIM); (ii) the mesoscopic emissions model (TREM); and (iii) the air quality model (URBAIR), were linked and applied to a medium-sized European city (Aveiro, Portugal). As an alternative, traffic emissions based on a widely used approach are calculated by assuming a vehicle speed value according to driving mode. The detailed GPS-based modelling approach results in lower total road traffic emissions for the urban area (7.9, 5.4, 4.6 and 3.2% of the total PM10, NO_x, CO and VOC daily emissions, respectively). Moreover, an important variation of emissions was observed for all pollutants when analysing the magnitude of the 5th and 95th percentile emission values for the entire urban area, ranging from −15 to 49% for CO, −14 to 31% for VOC, −19 to 46% for NO_x and −22 to 52% for PM10. The proposed GPS-based approach reveals the benefits of addressing the spatial and temporal variability of the vehicle speed within urban areas in comparison with vehicle speed data aggregated by a driving mode, demonstrating its usefulness in quantifying and reducing the uncertainty of road transport inventories.

1. Introduction

Air pollution, particularly that resulting from the transport sector, has emerged as a major problem in urban areas, with direct consequences for the health of urban citizens (WHO, 2013, 2014). Despite emissions of main air pollutants having decreased in Europe in recent decades, a large proportion of the urban population is still exposed to air pollution concentrations exceeding European air quality standards, and road transport is one of the main contributors to this problem (EEA, 2012).

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To protect public health, the European Union (EU) has implemented a legislation framework to regulate ambient air quality. Currently, the limit values for several pollutants are defined by the Air Quality Directive 2008/50/EC (EC, 2008), thereby introducing a significant commitment from European member states to improve air quality. Under this directive, action plans had to be established by member states, with the aim of controlling air quality. Furthermore, there has been an improvement in fuel quality and emission reduction technologies, which has contributed to reduce the air pollution loads. However, urban areas continue to experience problems that are inherent to large population clusters, resulting in the continuous growth of private transport, with negative consequences for air quality and human health (Borrego et al., 2003; Tchepel and Dias, 2011; Dias et al., 2012, 2016).

Within this context, the complexity in characterizing the urban environment requires simulation tools for assessing air quality levels, in order to provide quantitative information to support the analysis and evaluation of various policies and emission abatement measures (Denby et al., 2011). Numerical modelling provides a methodology for supplying decision makers with important information regarding source-receptor relations (Borrego et al., 2006). Based on modelling predictions, several scenarios for transportation planning can be analysed and a preferable development scenario can be selected, taking into account the air pollution problems associated with traffic. This type of application requires the estimation of atmospheric emissions induced by road traffic and evaluation of air pollutant concentration. The emission data uncertainty is an important contributor to the total uncertainties of the air pollution and human exposure model predictions, and in this regard, reliable inventories that describe the sources of such emissions thoroughly are of considerable importance (Tchepel et al., 2012; Coelho et al., 2014).

At urban scale, emission inventories generally require a fine spatial and temporal resolution to establish the necessary links between measures, plans and emission reductions, which cannot be achieved with the desired quality by means of downscaling methods of top-down inventories. This implies a need for methods that relate emissions to transport patterns and relevant activity data (FAIRMODE, 2010a; Borge et al., 2014).

The average-speed approach is extensively used for the quantification of on-road vehicle emissions, and particularly for compiling emission inventories (EC-METI, 2009; Toffolo et al., 2013; Boulter et al., 2007, 2012). Emission models based on this approach can incorporate a wide range of vehicle and technology categories. In this type of model, emissions are quantified as a function of average speed, which may be implemented as a continuous function or in a discrete form by attributing a "typical" average speed to predefined driving modes (for example, urban, rural, and highway) (Ntziachristos and Samaras, 2012; Smith et al., 2015; Grote et al. 2016). The latter is the approach widely used by most European countries for reporting emissions from road transport to be included in annual national inventories (for example, APA, 2015; CITEPA, 2016).

Emission factors are commonly recognised as the main source of the uncertainties in emission inventories (Wang et al., 2008; Kouridis et al., 2010; EMEP-EEA, 2016). However, it is also crucial to understand how activity data will contribute to the overall uncertainties. Therefore, one of the research questions here is: How spatial and temporal variability of the activity data could affect the quality of emission inventories, particularly in complex urban areas? This question is relevant not only for bottom-up emission estimates but also for the studies based on top-down disaggregation methodologies.

In this regard, for the analysis of the high spatial and temporal variability of transport-related air pollution within the urban environment, it is necessary to characterize the transport activity to quantify the corresponding emissions and air pollutants levels. For this purpose, a system based on transportation modelling linked to emissions and dispersion modelling is considered as one of the most suitable approaches for providing detailed information regarding traffic flow for each road segment and the related pollution, and is an essential tool for the development of atmospheric emission abatement measures (Borrego et al., 2006; Dias et al., 2016). Moreover, the combination of numerical modelling with available resources such as Global Positioning System (GPS) could potentially be used to better understand the contribution of emissions from road transport in urban areas (Dias and Tchepel, 2014). The collection of time-location information using GPS technology provides continuous vehicle tracking with high data resolution in time and in space, allowing for improvement in the precision of the related emission estimations.

The research described in this paper aims to evaluate and understand the importance of activity data for improving the road transport emission inventory at urban scale by applying a GPS-based modelling approach focused on obtaining a reliable estimation of vehicle speed data and its spatial distribution, and comparing the resulting emissions with a widely used approach, based on the average vehicle speed according to driving mode. To assess the emission data reliability, the performance of the proposed approach is evaluated based on air quality data from a monitoring station. An example application of this methodology in the city of Aveiro (Portugal) for a typical working day is presented.

2. Methodology

In order to achieve the defined objectives, three modelling tools: (i) microsimulation traffic model (VISSIM); (ii) mesoscopic emissions model (TREM); and (iii) air quality model (URBAIR), were linked and used to estimate the atmospheric pollution induced by road traffic with high spatial and temporal resolution (Fig. 1). First, data were related to road configuration, and vehicle dynamics collected by GPS data-logger equipped vehicles were used to validate the vehicle traffic dynamics estimated by VISSIM. The outputs of this model were used as inputs to the TREM model to quantify the pollutant amounts emitted from road sources. Finally, the URBAIR model was applied to evaluate the urban air quality and compared with the air quality monitoring data (Fig. 1). The following sections present the major details of each of these steps.

It should be highlighted that, in this study, the emissions are derived for each link of the entire road network (1 m road segments), thereby combining the advantages of the average emission-based model and the detailed transport activity data provided by a microscopic model. This detail allows for capturing of the spatial pattern of emissions, which is often lost in other studies combining traffic modelling data and dispersion modelling. A further important difference is that the modelling approach covers all 24 h of a

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