18th International Conference on Environmental Science and Technology

Athens, Greece, 30 August to 2 September 2023

Multi-scale high-resolution atmospheric emission inventory for the transport sector

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Abstract
This study aims to develop a multi-scale atmospheric emission inventory for the transport sector with high spatial and temporal resolution using Portugal as a case study. For that, a combination of the traditional method of emissions calculation with an innovative way to gather and process data (BigAir approach) was implemented. The accuracy of the developed inventory was evaluated by applying a multi-scale air pollution system, with two sets of data: i) BigAir and ii) EMEP emission inventories. The scalability and replicability nature of the BigAir approach allows it to be used by the scientific community in other regions of the world.

Keywords: Big data, critical air pollutants, road transport; railways; aviation; air quality modelling

1. Introduction

Atmospheric pollution is the single largest environmental risk to human health, and it is responsible for 7 million premature deaths worldwide every year (WHO 2021). Since 2008, the European Commission's Air Quality Directive (2008/50/EC) defined that the Member States should assess and forecast air quality (AQ) as well as quantify human exposure for public information and health protection. Transport is one of the major emission sources causing numerous exceedances of critical air pollutants and one of the sectors that most contribute to AQ modelling uncertainties. To reduce these uncertainties, this paper develops a multi-scale atmospheric emission inventory for the transport sector with high spatial and temporal resolution using Portugal as a case study. The accuracy of the developed inventory was evaluated by applying a multi-scale AQ modelling system composed of a meteorological model (WRF-ARW), a chemical transport model (CAMx), and an urban Gaussian model (URBAIR), with two sets of data: i) BigAir emissions inventory and ii) European Monitoring and Evaluation Programme (EMEP) emissions inventory.

2. Methodology

This section describes the proposed methodology to estimate the transport emissions (Section 2.1.1) as well as the approach considered to improve the spatial distribution of the European emission inventory (Section 2.1.2) and the air quality modelling system (Section 2.2) used to evaluate the tested emission inventories (BigAir and EMEP).

2.1 Atmospheric emissions

2.1.1 BigAir emission inventory

The annual railway emissions were quantified using the annual fuel consumption of diesel fuel provided by the Portuguese energy balance and emission factors from the EMEP guidebook. The hourly timetables by train station (obtained from the Portuguese railway company) and railway length from the OpenStreetMap database were used to distribute the emissions temporally and spatially in Portugal.

The landing and take-off cycle approach was used to estimate the civil aviation emissions. The daily movements by aircraft type for 24 airports provided by the ANAC dataset were used, while due to a lack of country-specific data, the hourly temporal profiles provided in the TNO dataset for the aviation sector were considered. For military aviation, the annual consumption of jet fuel provided by the Portuguese energy balance, emission factors from the EMEP guidebook and land use datasets (to identify land military activities) were considered to estimate the atmospheric emissions. To obtain the hourly emissions, the daily movements from ANAC at the airports with military activity and the hourly temporal profiles provided in the TNO dataset for the aviation sector were used.

Road transport emissions were calculated using, as main input data, road traffic volume, road length, road types, road pavement, meteorology (from Section 2.2), vehicle categories and classes. Road traffic counts from Portuguese and OpenTransportMap datasets were considered. For the road networks without information about road traffic volume, a numerical algorithm was applied where the independent variables were: i) road traffic counts; ii) population by subsection; and iii) fuel consumption by municipality. For the vehicle categories and classes, data by municipality and a dataset provided by the Portuguese Environment Agency were considered.

2.1.2 EMEP inventory

The EMEP inventory with a horizontal resolution of 0.1 × 0.1◦ for the year 2020 was improved by applying the approach developed by Ferreira et al. (2020) and used to provide gridded atmospheric emissions to the AQ modelling system (Section 2.2).

2.2 Air quality modelling system

A high-resolution multi-scale air pollution system composed of the WRF-ARW, the CAMx, and the URBAIR models (Lopes et al. 2023) was used to evaluate the accuracy of the BigAir and EMEP emission inventories.

3. Results and discussion

Figure 1 a) shows the annual spatial distribution of PM emissions (ton) for the Lisbon airport with a horizontal spatial distribution of 500 × 500 m^2, while Figure 1 b) presents the monthly emission profiles computed by the BigAir approach at the Lisbon airport and the CAMS temporal profile dataset. The annual emissions of particulate matter (PM) were about 3 tons at the Lisbon airport for the year 2020. The BigAir quantified that the highest values were recorded in January (profile=2.23) while for CAMS, the maximum PM emissions were estimated in August (profile=1.24) during the summer vacations. The lowest values were registered in April (profile=0.19) in the BigAir approach when the Portuguese state of emergency caused by the COVID pandemic was in effect (between March 19 and May 3, 2020) (Decree-Law no 10-A/2020, 2020; Decree-Law no 20/2020, 2020).

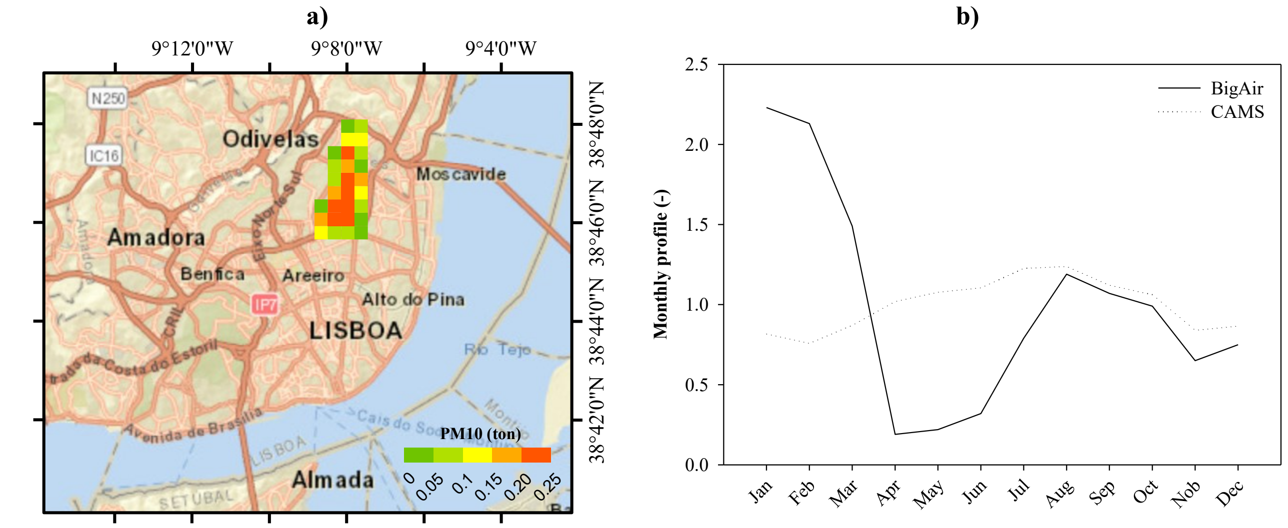

Figure 1: Spatial distribution of the PM annual emissions for aviation activity obtained from the BigAir approach (a) and monthly PM emissions profile (BigAir and CAMS) for the aviation sector in 2020 at the Lisbon airport.

4. Final remarks

The improvements in the spatial and temporal distribution obtained in this study contribute to reducing the uncertainties of AQ modelling results, identifying new research challenges in the atmospheric pollution field, and providing important information to society about its emission contribution. In addition, the scalability and replicability nature of the BigAir approach allows it to be used by the scientific community in other regions of the world.

Acknowledgements

This work was financially supported by the project "BigAir - Big data to improve atmospheric emission inventories", PTDC/EAM-AMB/2606/2020, funded by national funds through FCT - Foundation for Science and Technology. We acknowledge financial support to CESAM by FCT/MCTES (UIDP/50017/2020+UIDB/50017/2020+ LA/P/0094/2020), through national funds. Thanks are due to FCT/MCTES for the financial support to the PhD grant of D. Graça (2022.11105.BD), the contract grants of Joana Ferreira (2020.00622.CEECIND) and Hélder Relvas (2021.00185.CEECIND).

References

Ferreira J, Lopes D, Rafael S, et al (2020) Modelling air quality levels of regulated metals: limitations and challenges. Environ Sci Pollut Res 27:33916–33928. https://doi.org/https://doi.org/10.1007/s11356-020-09645-9

Lopes D, Ferreira J, Rafael S, et al (2023) High-resolution multi-scale air pollution system: Evaluation of modelling performance and emission control strategies. J Environ Sci 137:65–81. https://doi.org/10.1016/J.JES.2023.02.046

WHO (World Health Organization) (2021) New WHO Global Air Quality Guidelines aim to save millions of lives from air pollution. https://www.who.int/news/item/22-09-2021-new-who-global-air-quality-guidelines-aim-to-save-millions-of-lives-from-air-pollution. Accessed 9 Feb 2022