Dear referee,

Thank you very much for the valuable comments to our paper and suggestions for article improvements. The manuscript has been modified accordingly.

Below are the answers and modification on the manuscript. In the following: "RefC" is the comment from Referee, "AuthR" is the author's response and "AuthCM" represents the author's changes to the manuscript. Page and line number refer to the page and line number in the version submitted for discussion.

Specific comments

Introduction

Comment 1.

RefC: Expand the explanation of the limitations of alternative models, such as dispersion models. For example, discuss the dependence of dispersion models on detailed meteorological data and high computational capacity, contrasting this with the simplicity and efficiency of LUR.

AuthR: Modified according to the reviewer's note,see changes to manuscript.

AuthCM: Page 2, lines 49-51: "(b) linear regression is one of the most used fine-scale spatial interpolation methods because it is fast, easy to implement, and does not require high computing power, and (c) a LUR model does not require detailed information on atmospheric conditions as input data ..." was changed to "(b) linear regression is one of the most used fine-scale spatial interpolation methods because it is fast, easy to implement (Hoek et al, 2008; Jerrett et al, 2005), and does not require high computing power such as computational fluid dynamics based on large-Eddy simulation or Reynolds-averaged Navier–Stokes approaches (Lin et al, 2023, 2024), and (c) a LUR model does not require detailed information on atmospheric conditions and an emission inventory as input data. LUR model usually requires measurement data and land-use predictor variables (e.g. CORINE dataset) ...."

Comment 2.

RefC: Develop a specific section addressing the short-term risks associated with high concentrations of PM10 and NO2. Include information about cardiovascular, respiratory, and even immune system impacts.

AuthR: We added several sentences related to the short-term human health risks associated with high PM and NO_2 concentrations.

AuthCM: Page 2, lines 21-23: "These compounds are often associated with the onset of multiple health issues including cardiovascular diseases, asthma or lung cancer" was changed to "Numerous epidemiological studies related short- and long-term PM_{10} and NO_2 exposure with mortality and morbidity (). Short-term exposure to high concentrations of pollutants can be related to both minor discomfort, such as irritation of the eyes, respiratory tract, or skin, and serious conditions, such as asthma, pneumonia, bronchitis, chronic obstructive pulmonary disease and heart problems (Liu et al, 2022; Hasegawa et al, 2023). Furthermore, years of continuous exposure to PM were shown to be associated with both newborn mortality and cardiovascular disorders. A $PM_{2.5}$ concentration increase with 10 $\mu g/m^3$ was associated with a increase of 0.67% – 1.04% (Hamanaka and Gökhan 2018) in all-cause mortality, 0.52% in cardiovascular hospital admissions and 1.74% increase in respiratory admissions (Hasegawa et sl 2023). While, a PM_{10} concentration increase with 10 $\mu g/m^3$ was associated with a 43% increase of fatal coronary heart disease (Hamanaka and Gökhan 2018) and 39.31% of deaths from cardiovascular diseases from short-term exposure (Seihei et al, 2024). A smaller impact is foreseen in the case of short-term exposure to NO_2 concentration, when an 10 ppb increase of concentration was associated with 0.19% increase in all-cause mortality in US (Hamanaka and Gökhan 2018).

Comment 3.

RefC: Are there comparative studies with other methods in cities similar to Bucharest that could enrich the justification presented?

AuthR: Unfortunately, there are no recent studies based on LUR methods or other methods of assessing air quality in metropolitan areas that can be compared with the metropolitan area of Bucharest, from the point of view of street network, traffic, urban and industrial development. In fact, this was one of the reasons why Bucharest was selected as a pilot station in the European RI-URBANS project. The mixed-effect LUR approach was already mentioned for several cities.

AuthCM: none

Methodology

Comment 1.

RefC: Add detailed maps of the study area, highlighting industrial, residential, and commercial zones. Include the routes of mobile measurements and collection points to contextualize the spatial distribution.

AuthR: Modified according to the reviewer's note.

AuthCM: A map with diverse land use types present in the Bucharest metropolitan area and the routes from the measurement campaign has been added as Figure 1.

Comment 2. Part A

RefC: Explain the criteria for buffer size selection and the reasons for using varying sizes.

AuthR: Buffer analysis is a common technique in GIS. The sizes of the buffers used in this study are those established within the European Study of Cohorts for Air Pollution Effects (ESCAPE) for the development of LUR models. Variable buffer sizes are applied to create buffers around raster datasets used for analyzing spatial relationships between continuous surfaces, such as identifying areas of land use that are a certain distance from a street segment.

AuthCM: Page 7, line 207: added text "The sizes of the buffers are those established within ESCAPE project for the development of LUR models. These buffer sizes are used to determine the spatial proximity of different features by defining a distance zone around the features."

Comment 2. Part B

RefC: Justify the use of the moving average filter, considering its role in removing outliers and enhancing model accuracy.

AuthR: The models are obtained by fitting the LUR model structures to the observed input-output data. If the data obtained from the measurements contain "outliers" or "outlier data points", they can negatively influence the model results. The moving average is the most common tool used to enhance the accuracy of the model by smoothing out data fluctuations caused by random variations or noise. By calculating the average of a set of time-series data, moving averages can reveal underlying trends and patterns that would be difficult to see otherwise.

AuthCM: none

Comment 3.

RefC: Include a comparative table presenting the advantages and disadvantages of alternative methodologies, such as satellite-based models versus hybrid models like LUR/mixed-effects.

AuthR: Of course, there are many methodologies used for air quality. In our article, we mention the methodologies close to our approach.

AuthCM: none

Comment 4.

RefC: Were sensitivity tests conducted to evaluate the impacts of different combinations of predictive variables?

AuthR: Assessing the impact of different combinations of predictive variables is the subject of another article and was not included in this study. In this paper, only the models for which the highest values of R^2 were obtained are presented and discussed. (lines 210-211: "Further, only the results and performances of the LUR models for which the highest adjusted R^2 value was obtained are discussed")

AuthCM: none

Comment 5.

RefC: How did varying buffer sizes influence the results, and was cross-validation performed to determine the optimal parameters?

AuthR: The results of the learning process were influenced by the variation of the size of the buffers by obtaining different values for the statistical parameters R^2, variance inflation factor (VIF) and p_value, the parameters that were used to select the predictor variables used in the LUR models. After applying the selection criterion of the best models (Section 3.1.2 "Predictor variable selection"), a cross-validation was performed for all selected models. The models that obtained the highest R^2 score were considered to have the optimal parameters.

AuthCM: none

3 Results and discussions

Comment 1.

RefC: Relocate the methodological descriptions from sections 3.1, 3.1.1, 3.1.2, and 3.2 to the methodology section, facilitating a more focused discussion of the results.

AuthR: Due to the complexity of the process of cross-validation of the model with observational data, we would prefer that the description of this process and the results obtained be presented in section 3 "Results and discussions".

AuthCM: The methodological descriptions of Sections 3.1, 3.1.1, 3.1.2 were relocated to the methodology section.

Comment 2.

RefC: It would be beneficial to explain in detail why the model underestimates PM10 levels in urban areas. Including maps illustrating the spatial distribution of pollutants in different environments would enhance the section on environmental types.

AuthR: The 2018 CORINE land cover data used in the model is currently the latest iteration. For this reason, the model could underestimate the level of PM10 in urban areas, as it does not fully cover the changes made

in the last 6 years in the metropolitan area of Bucharest. Nevertheless, the relative differences are around 10%. However, the results obtained from the model agree with the measured data. We considered that the maps presented in figures 2 and 4 are relevant to illustrate the spatial distribution of pollutants in different environments.

AuthCM: A map with diverse land use types present in the Bucharest metropolitan area and the routes from the measurement campaign has been added as Figure 1.

Page 14, line 194: Added: "which can be also influenced by the low number of available fixed stations in each environment"

Comment 3.

RefC: What were the main technical challenges in modeling industrial and high-traffic areas?

AuthR: The lack of data, especially traffic data, were the main technical challenges.

AuthCM: none

Comment 4.

RefC: Add graphs showing the differences between predictions and measured values, highlighting seasonal variations.

AuthR: We consider that Figure 2 and Figure 3 from the submitted manuscript are relevant both to emphasize the differences between the modeled data and the data measured at the fixed stations as well as the seasonal variation.

AuthCM: none

Conclusions

Comment 1.

RefC: Detail how citizen involvement could improve data collection, including examples of using bicycles or pedestrians to access restricted areas.

AuthR: OK, see changes to manuscript.

AuthCM: Page 17, line 355: added text "Data sets systematically collected by citizens during daily (repeated) activities or walks could provide improved estimates of spatial variability for these areas (Snyder et al., 2013; Hankey and Marshall, 2015; Van den Bossche et al., 2016 and 2018). The citizen involvement increases the pollutants data collection on areas restricted for cars or bicycles and enable the possibility to study the sinks on green or water areas, but are based only on low cost sensors.

Comment 2.

RefC: Discuss how the methods could be adjusted for cities with similar urban characteristics, detailing the data requirements and necessary adjustments.

AuthR: The usually required input data in LUR are measurement data and land-use predictor variables. Depending on the purpose for which the model is used, data population density (available from national or European statistics catalogues) and traffic intensity variables (available from the national statistics, or modeled) can also be used as input data. Measured data can be obtained from the national air quality monitoring network, if there are enough stations with a distribution to cover the entire area of interest or, as in the case of

the study presented in this manuscript, from the campaigns. The LUR models must be fitted to the measurements specific to the area of interest to obtain the regression coefficients used to estimate the concentrations.

AuthCM: Page 18, line 366: added text "...in other cities as well, using the series of predictor variable identified in this study as necessary. This is feasible ..."