RC1: 'Comment on essd-2025-63', Anonymous Referee #1, 20 May 2025

The scope of this paper is the monitoring of CO2 emissions of European cities from the atmospheric concentrations. Indeed, the emission from the cities increases the atmospheric concentrations so that concentration measurements can be used to infer the emissions. There are a number of challenges however linked to the emission-concentration relationship that depends on the variable atmospheric transport, the heterogeneity of the emission or the other (than the city emissions) fluxes that impact the CO2 concentrations. The challenges are different among cities and this paper attempts to classify the European cities according to these challenges. They have defined a number of indicators to quantify the various challenges and make a statistical analysis based on this criteria to identify the cities that are the most suitable for CO2 monitoring experiments.

The paper is interesting and can be of interest for the growing community that attempts to estimate city emissions either from surface network measurements of from remote sensing imagery. One could certainly criticize the definition of the challenge indicators but the choice of the authors appear reasonable.

Note that some challenge apply mostly to remote sensing applications (such as the cloud cover) whereas other are more applicable to the definition of use of a surface network (such as the wind direction). All indicators are made available so that one can make its own classification.

We thank the reviewer for their assessment of our manuscript. Below, we address each of the points raised in blue. Please note that the line numbers in the reviewer's comments refer to the original version of the paper, while our responses pertain to the revised version.

Minor comments to be considered by the authors:

Line 38 : Cities account for approximately : "account for" is not clear enough. Is it scope 1, scope 2 or scope 3 ? Only scope 1 emissions could be measured from the atmospheric concentrations

We agree with the reviewer that this needs to be clarified and have updated the text to be more specific:

Line 42: "In 2020, cities accounted for approximately 67-72% of global CO_2-equivalent emissions based on consumption-based accounting (Lwasa et al., 2022)"

Consumption-based accounting not only includes Scope 1 (direct) emissions, but also Scope 2 and Scope 3 emissions. However, in this introduction, our aim is to highlight the general importance of cities.

Line 52 : (such as kgCO2/vehicle), : It would make more sense to have kkCO2/km

We agree with the reviewer: it is indeed not emission per vehicle, but emission per vehicle kilometre (vkm) that is used when talking about emission factors for road transport in the context of the emission inventory we use. We have updated the text:

Line 55: “Most cities that engage in emission monitoring use “bottom-up” approaches that usually do not include direct observations: activity data (such as traffic counts) are combined with emission factors (such as $kgCO_2$/vehicle km (vkm)), and the sophistication of its implementation varies.”

The emission inventory we use reports quantities in kilograms, which is why we keep this unit.

Line 83 : in Indianapolis the enhancement is only about 3 ppm. Is it on average, or max ?

We have updated the text, as we agree with the reviewer that clarification was needed.

Line 88: “For example, in Indianapolis the enhancement at the downwind site was only about three ppm in October 2012 (averaged over 17-22UTC), according to Lauvaux et al. (2016).”

Line 148 : “about 50 out of 365 plumes per year could” . Better to say that, out of the 365 days in a year, only 50 appear suitable to observe the CO2 plume from space"

We thank the reviewer for the suggestion which we have implemented.

Line 154: “For example, in a synthetic study for Berlin, Kuhlmann et al. (2019) found that out of the 365 days in 2012, only 50 appeared suitable to observe the CO_2 plume from space due to unfavourable meteorological conditions.”

Line 149 : Furthermore, the collected samples were higher… Not clear. What is higher ? Emissions or CO2 plume ?

Emissions were higher, and we see that this was not clear in the text. We have now clarified it:

Line 156: “Furthermore, the emissions during the sample collection were 18% higher than the annual total for Berlin, requiring temporal profiles to correct for this sampling bias.”

Line 153. might be monitored from ». "might be monitored" lacks detail. It depends on the accuracy requirement

We agree with the reviewer and have updated the text to be more specific.

Line 159: “Wang et al. (2020) suggested that emissions from a city or a power plant larger than 7.33 $MtCO_2$ yr^{-1} (2 MtC yr^{-1}) could potentially be constrained between 8:30 and 11:30 using the CO2M instrument, which has a planned launch in 2026. The threshold corresponds to a posterior uncertainty smaller than 20% for more than 10 times within a year.”

Line 449 : make eddy covariance measurements ». I did not understood that this paper analyzes the possibility to make such measurements

The focus of the paper is indeed the atmospheric monitoring of CO_2, and we have updated the text to provide a more relevant example to illustrate the connection between monitoring challenges and the heterogeneity of biogenic activity.

Original: “One implication is that this potentially makes it hard to find good locations to make eddy covariance measurements with limited influence of the urban biosphere.”

Line 463: “One implication is that signals from emissions are mixed with signals from biogenic activity, making it difficult to isolate them.“

Line 458 : What emissions from airport are considered ? Is it mostly that of the building or that of the plane take off ? For those, the temporal profile of the emissions may be quite challenging

The building emissions are a different category, and it is rather the emissions associated with take-off and landing that are considered. They are centred on the location of the airport and treated as point-source emitters. In the paper, we state: “Airports cannot be represented with take-off and landing information in the TNO emission inventory and are therefore rather turned into point sources which keep their exact location.” (line 473).

Point-source emitters, in general, are indeed challenging, partly because of their temporal profiles. Here is a relevant section of the paper:

Line 624: “The challenge for models to accurately represent nearby point source emissions is also well-established (e.g. Gaudet et al., 2017; Maier et al., 2022; Brunner et al., 2019). This challenge is compounded by large emission quantities stemming from these sources, which generally do not have point-source-specific temporal profiles. However, hourly emissions are sometimes available, such as for many power plants throughout Europe, but most models cannot include them.“

There is, for example, the metric “Share of point source emissions” (see Sect. 2.2.2) as part of the modelling challenge, which airports contribute to.