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Atmospheric Measurement Techniques
Discussions
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Interactive comment on "Detectability of CO_2 emission plumes of cities and power plants with the Copernicus Anthropogenic CO_2 Monitoring (CO2M) mission" *by* Gerrit Kuhlmann et al.

Anonymous Referee #2

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To the authors of the manuscript,

This study assessed the utility of future space instruments to detect CO2 plumes from cities and power plants. The study examined different instruments (CO2, NO2 and CO) with different noise levels under different constellation scenarios for the CO2M. The study is based on a high resolution Nature run achieved by the COSMO model (described in Brunner et al. 2019) that allowed the authors to consider realistic concentration fields and the cloud cover information. A key part of this study is a plume detection algorithm the authors developed. This study examined the plume detection capability of different instruments, assuming the use of the plume detection algorithm.

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Discussion paper

The use of co-emitted species for assessing anthropogenic CO_2 emissions was studied previously in Reuter et al. (2014). But, as pointed out by the referee #1, the SCIAMACHY's large footprint wasn't ideal for observing CO_2 concentration enhancements due to localized sources. In my opinion, assessing the utility of current/future improved instruments and/or combinations of these instruments from CO_2 monitoring perspective is important. I believe this study has important implications for the planning of future carbon observing missions. These missions will improve our understanding of anthropogenic CO_2 emissions.

Before I recommend this manuscript for publication, I would like to raise a few points for discussion, which I listed below. I also included line-by-line comments. I hope my review comments prove helpful to improve this manuscript. I look forward to receiving the authors' response.

Sincerely,

Anonymous referee

Points of discussion:

1. How to quantify the emissions?

Clearly, plume detection is an important first step to quantify emissions from localized sources, but it is not the ultimate goal of satellite carbon missions such as CO2M. In my opinion, it would be helpful for AMT readers if the authors could detail the entire carbon emission quantification process for emission verification support. I am aware that the authors stated that they plan to describe their inverse emission estimation method in another publication. However, I think including some text describing how the detected plume information/data will be used in the inverse estimation is necessary in this manuscript for several reasons. First, as I mentioned earlier, I think it is necessary for the AMT readers to understand the entire picture of the carbon emission estimation. By doing so, the authors should be able to better highlight the significance of this work.

Second, the way carbon emission estimates are obtained (in other words, how the data collected with the plume detection is used) should define good plume detection (which is only loosely defined in this study). I thought the lack of text regarding the entire emission estimation process made it very difficult to define what is useful.

2. What is useful?

Relating to the comment above, the authors should try to define the evaluation criteria more clearly and make it more relevant to carbon emission estimation. In the manuscript, for example, the number of pixels detected was used as a measure. Even if the same number of pixels are detected, the usefulness of the collected information is not necessarily the same in terms of emission estimation.

3. Weak relevance to emission monitoring.

I believe CO2M will be useful for emission monitoring by the planned improvements over previous missions, but I am not quite sure how exactly CO2M will contribute to improving understanding of carbon emissions. This is related to discussion points #1 and #2 that I discussed above. For example, would it be possible for this CO2M (assuming the detection and inverse methods work perfectly) to distinguish underreported power plants?

4. Limitations of the plume detection algorithms?

It seems that the proposed plume detection algorithm requires accurate locations of coal-fired power plants (is this correct?). The source location information is required for the step 4, where the plume is related to the source of interest. This study used the TNO emission inventory that includes reported power plant information for Europe (which I assume is reasonably accurate for this application). But what if this plume detection algorithm is implemented globally? For some parts of the world (where emission uncertainty is thought to be high due to poor data availability), it is often challenging to collect accurate/reliable emission information, such as point source information and city inventories (this is a part of our motivation to provide an emission verification support, right?). It is thus not easy to build a good inventory with the reported point source emissions like the TNO emission inventory. Can we use this algorithm to detect missing power plants? This is a huge limitation when the monitoring is implemented globally.

5. Overestimation of the success rate due to some simplifications done in this study.

As the authors acknowledged, there are some simplifications made in this study (e.g. aerosols, clouds, emission temporal variation). I understand the necessity of simplicity in the interest of time. However, at the very least, the author should discuss the impact of the simplifications on the results (e.g. successful rate of detection).

Line-by-line comments:

P1, L1: Probably better to add the motivation for detecting plumes? While this may be clear to some AMT readers who are aware of the research concerning space-based CO2 monitoring, it may not be apparent to other readers.

P1, L8: Spell out

P2, L7: We need emission inventories (which are the basic tool for emission monitoring) first before science-based monitoring systems like COM2 (I think). Independent from what? Monitoring system is a little too much for them, although that is something that the scientific community can assist with.

P2, L11: Curious to hear how to directly approach to emissions at the national level. Unlike cities and power plants, it seems to be difficult to do so.

P2, L17: The detection is not the end of the emission estimation problem, but just a start. . .

P4, L11: I assume there are mismatches in surface emission configurations among models (which are probably not important in this study)

P5, P3: Data source for Berlin inventory? How are they constructed? Basic specification?

P8, L14: Adding some info about the CarbonSat mission concept and others would be helpful for the readers who are not familiar with the space-based CO_2 monitoring.

P12, L4: So this algorithm requires the source location as a prior information. Correct?

P14, L20: 100 cloud free observations - This might be good enough to cover the source areas spatially, but might not be enough to estimate CO_2 emissions.

P27, L12: But this paper still describes what this detectability means in the emission monitoring via inverse modeling. . . the authors at least show the relevance. . .

P27, L22: "useful" - I do think this will be useful, but the authors should try to be a little bit clearer in defining what is useful and why it is useful as this is a scientific paper.

P29, L2- but NO_2 and CO_2 are not exactly the same although they are co-emitted, right?

P29, L8 – and accurate database of NO_x power plants,

P30-L22 huge - this sounds a little bit subjective to me.

P30, L25 weaker – Maybe the authors could be more quantitative?

References

Bovensmann et al. (2010) AMT Nassar et al. (2017) GRL

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