Discussion: Segmentation of XCO_2 images with deep learning: application to synthetic plumes from cities and power plants

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In the following, the referees comments are in italics and in blue.

Report 2

We would like to thank the anonymous Referee 2 for her/his technical comments and suggestions on improving the manuscript.

Segmentation of XCO2 images with deep learning: application to synthetic plumes from cities and power plants" by Dumont Le Brazidec et al. describes a new method for segmentation of CO2 plumes in satellite imagery that could improve methods for quantifying CO2 emissions from anthropogenic sources. The authors develop and train a convolutional neural network (CNN) for XCO2 plume segmentation from satellite observations that outperforms the more common thresholding approaches, when demonstrated on modelled plumes with random noise and non-uniform backgrounds. The manuscript applies atmospheric models to address a relevant scientific question that has implications for the Copernicus CO2M mission and monitoring, verification and support (MVS) efforts to support climate policy. The CNN approach developed is novel and represents a substantial advance for the field. In general, the method is described well and the manuscript overall is well-written, well-structured and well-presented.

Specific Points

- *Line 1: It would be best if expanded text matched acronym: "CO2 Monitoring Verification and Support" system and "CO2MVS" system.*

  This is true. It has been corrected. Thank you.

- *Line 2: "Amount of CO2" should be replaced with "Distribution of CO2"*

  We made the correction.

- *Line 35: It is my understanding that 2 of 3 satellites CO2M are scheduled for launch in 2026, with the 3rd to follow by a year or more. (The authors should confirm whether this is correct and if not, revise with the most up to date information).*

  As far as we know, there is no certainty about the dates. We have therefore replaced "by 2026" with "from 2026".

- *Line 113: including only January, March and August barely the minimum for representing "seasonal variability" with 3 of 4 seasons. A more thorough effort could have been made here.*

  This is the case for the Paris dataset. However, we use a full year for the SMARTCARB dataset which represents most of our data (Berlin, and 3 other power plants presented in this manuscript).

- *Line 120: Some basic information about CO2M observing characteristics would be useful for the reader, at minimum, the nominal image pixel size (2x2 km2) and swath width warrant mentioning. Furthermore, it is unclear whether the 0.7 ppm Gaussian random noise is applied at the model resolution of 1.1x1.1 km2 or the CO2M imagining pixel size, which was never mentioned. 0.7 ppm noise at 1.1x1.1 km2 is equivalent to a lower noise level at 2x2 km2.*

  Details on the swath and resolution of CO2M have been added in the introduction section (from https://www.eoportal.org/satellite-missions/co2m).

This manuscript is mainly motivated by the sole real mission now planned for launch with very large swath (i.e CO2M). But its focus is on CO2 images in general. We have included clarifications in the introduction to prevent any potential confusion. For our analysis, we used images of approximately 1km resolution, which differs from the CO2M resolution. This resolution is the native resolution of the SMARTCARB dataset. Consequently, we applied Gaussian random noise of 0.7 ppm at the model resolution.

– *For improved readability, capitalization of "WBCE", "NWBCE" and "DDEQ" acronyms is strongly recommended throughout the entire manuscript.*

  WBCE and NWBCE have been capitalised in the manuscript. ddeq has been kept in lower case for consistency with other manuscripts and the python page.

– *It might be difficult to reproduce these results from only the brief description about how the plumes were modified to generate the training dataset.*

  We have added the following paragraph (end of section 3.2) to specify how the plumes are modified to generate the training dataset: "In practice, during the training phase, the plumes undergo a two-step transformation process. Firstly, they are transformed using the weight function described in Eq. 3. Subsequently, they undergo further transformation using the data augmentation techniques specified in section 2.2. The resulting transformed plumes are subjected to the loss function defined in Eq. 4 during training." In addition, we have made available the code used to modify the plumes during the training phase.

– *Figure 13 seems to be the only mention of the magnitude of emission sources in the manuscript. For some perspective the authors should mention either the annual emissions for the sources in the study (Paris, Berlin and power plants). As a suggestion for additional perspective, the authors can cite the recent real world example of quantifying CO2 emissions from Europe's largest power plant using satellite observations (https://doi.org/10.3389/frsen.2022.1028240), consistent with the high end of the blue scale in Figure 13.*

  As Figure 13 is about Berlin, we have added the following sentence before the study of the right histogram: "Plumes that we assess are the consequence of a variety of emission levels. For example, Berlin emissions range from approximately 4 to 35 Mt/yr."

  We have provided in the second section of the manuscript the average emissions (plus the standard deviation) for all sources studied. "emission range variability across different locations and times. In Berlin, the average emissions based on the inventory is 16.8 Mt/yr with a standard deviation (std) of 7.2 Mt/yr. In Jänschwalde, the emissions average is 33.3 Mt/yr with a std of 7.7 Mt/yr, while in Boxberg, the average is 19.0 Mt/yr with a std of 4.4 Mt/yr. The Grand Paris emissions average is 20.7 Mt/yr with a std of 9.5 Mt/yr;"

  We have also cited https://doi.org/10.3389/frsen.2022.1028240 in the conclusion.

Thank you very much for all these very clear and helpful remarks.