Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2019-180-RC1, 2019

Atmospheric Measurement Techniques Discussions

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 #1

Received and published: 19 July 2019

The manuscript describes a method for the detection of CO2 plumes of point and city-scale sources. The authors apply the developed method to simulated satellite data of the envisaged CO2M Copernicus mission in different constellations with 1 to 6 satellites. By the example of Berlin and nearby power plants, they derive the number of expected detectable plumes potentially useful for flux retrievals and assess the benefits of simultaneous or S5 NO2 and CO retrievals. Overall, the manuscript is well structured and illustrated with figures of good quality. The topic of the manuscript is relevant for future emission monitoring activities and fits well in the aims and scopes of AMT. Nevertheless, I have several comments and I would recommend a publication only after a corresponding revision of the manuscript.

1 General comments

The proposed method cannot be applied to real satellite data as it is now, because a key problem is not addressed, namely how to derive the background and its uncertainty. This should be discussed more prominently also in the conclusions and already be mentioned in the abstract.

To me, many points in the description of the algorithm are unclear (see my specific comments).

NO2 can be used in more cloud contaminated scenes compared to CO2. This is one reason why you find more plumes in NO2. When computing the number of successfully found inner-plume soundings with NO2, do you apply the stricter CO2 cloud filter in the last step? This would be very important, because only these soundings could be used for the flux estimation. Please clarify this in the manuscript and if this last filter is not applied, discuss why you think that your results are still meaningful for CO2M. Which effect is dominating the advantages of NO2, less strict cloud filtering or better SNR? How would both compare if CO2 cloud filtering would have been also applied to NO2?

In respect to a potential future application to real data, the pros and cons of plume detection based flux retrieval methods should be compared to inverse modeling approaches in more depth. Some examples: Inverse modeling can be applied also to plumes below the detection limit. Inverse modelling may place the plumes wrongly so that modelled plumes become less correlated with measured plumes resulting in underestimated fluxes. Plume detection depends on plume strength, so that this may introduce an observational bias towards large fluxes, i.e., annual average fluxes will likely be biased high, so that comparisons of reported and measured fluxes are more meaningful on a per-overflight basis. Plume detection methods can be applied to unknown source positions. Etc.

Why do you consider PPV a good measure for performance? As an example: consider a very conservative plume detection algorithm, detecting only soundings which are 20ppm larger than the BG. In this case, TP would admittedly become small, but FP would become zero, so that PPV would become 1. Could the Hanssen-Kuiper Skill Score or True Skill Statistic be a better option?

To my knowledge, the Z-test is appropriate only for samples with more than 30 elements. 5 out of 8 tested smoothing kernels (Fig.4) consist of less elements. Why do you think the z-test is still appropriate in these cases?

What happens at cloud edges and at the edges of the swath? Effectively, the smoothing kernel here has fewer elements. Is this considered?

2 Specific comments

P2L23: Please also cite Reuter et al. 2014 in this context. They analyzed CO2+NO2 measurements from the same sensor (SCIAMACHY) and proposed multi-species measurements for future satellite missions. As signals in SCIAMACHY data are smaller because of the large pixel size, they had to follow a statistical approach. Note that this does not only cover strong localized sources, but all localized sources.

P3L4-L5: I would suggest moving this outlook to the conclusions section.

P3L8-L27: Strictly speaking, everything in these lines does neither belong to "data" nor to methods. Maybe it would fit better in the introduction.

P3L24: The situation is also not that simple for individual point sources, because chemistry changes the NO2 plume which is not the case for the CO2 plume. The following points should be addressed in this context: 1) NO2 decays with time. 2) NO2 and CO2 can be emitted/transported into various altitudes with differences chemical regimes. For example, the high altitude part of the plume may decay faster/slower compared with the low altitude part of the plume. As the wind direction often changes with height, the

satellite observed CO2 plume may have a different (wider) shape as the NO2 plume. 3) NO2 is primarily emitted as NO (which later forms NO2), which can result in different plume shapes especially near the source.

P7L4: sun-synchronous orbits are not circular.

P7L5: "... in case of 3 satellites." Please describe what this means (the satellites will have the same Eq. crossing times...).

P9L30: Cloud coverage is a main driver for data yield of XCO2 satellite products. I guess COSMO diagnoses fractional cloud coverage in its 3D model domain. How do you/COSMO compute the 2D cloud fractional coverage from this (e.g., maximum/minimum overlap assumption) and how realistic are the 2D cloud coverage statistics for this particular model?

P10 Fig3 Caption: "... are marked with "T" for True." Shouldn't be True = blue/red and T = detected by Z-test? If so, consider replacing T by Z.

P11L7: The choice of neighborhood size appears a bit arbitrary. Please discuss, why it makes sense to try neighborhood sizes as selected. For example, I could imagine, that the maximum meaningful neighborhood size is reached once the noise of the smoothed pixels dropped significantly below levels of typical enhancements. On the other hand, the neighborhood should probably never be significantly larger than the typical plume extends.

P11L20,L21: Please describe why the Z-test calculates the SNR (e.g., the variance of the basic population is assumed to be known from the measurement erros, X$_obsisanestimatorfortheexpectationvalue).$

P11Eq1: On P9L4 you stated that systematic errors are not scope of this study. Why considering them in Eq1? Xobs are the smoothed observations (not to be confused with the original observations). This should be corrected also at P11L13. Sigma$_randisonlyapproximatelythesameforallsoundingswithinthesmoothingkernelbutstric$

P11Eq2: Does this imply that there will also be false positives just by chance? How often is this expected to happen?

P11L30: Does this mean sigma$_{s}ys = sigma_{b}ginEq.1?$

P12L1: What is the chosen level for significance?

P12L5: Please explain “Moor neighborhood”.

P12L9: “. . . radius of 5km” In reality, this can result in non-detected NO2 plumes when NO2 is emitted primarily as NO.

P12L21: Can you separate both effects; which one usually dominates? In other words, why is a plume not detected, too low signal or CO2 plume != NO2 plume?

P13Fig.5d: How can you compute X$_{o}bsintotallycloudyregimes?$

P14L14: If the standard deviation of the background was used as threshold, shouldn’t there be about 16

P26 Tab8: What does “large number of false positives” mean. How large is large?

P27L29: Why should the higher emissions and the not-considering of emission profiles by Pillai et al., result in a larger number of usable plumes? To my knowledge, they analyzed each sufficiently cloud free overpass; please check. Isn’t it expected, that you find less usable scenes simply because inverse modeling studies usually assume knowledge of the plume position while you have to search for strong enough signals?

P28L4: . . . and also due to the fact that NO2 is used primarily for plume detection but XCO2 will also be used for flux estimation.

P30L7,L8: Which effect dominates, the higher SNR or the lower sensitivity to clouds (see general comment)?

P30L24,L25: . . .and cleaner sources in terms of NO2 emissions.

P30L26: Please add a discussion that this future plume detection scheme will have to

solve the problem of the unknown BG before it can be applied to real data.

3 Technical corrections

P3L1: can be detected -> is expected to be detected

P3L1: CO2 (or NO2 or CO) -> CO2, NO2, or CO

P7L2: Please add Eq. crossing times to Tab3.

P8L3: “. . . requirements for Sentinel-5”. Please add a reference if possible.

P10 Fig3 Caption: “(a) A large (red) and small (blue) . . .” Have you mixed up large and small?

P11L7: “at a satellite” -> “at a smoothed satellite”

P11L12+L13: “n” -> “ns”

P27L15: “which we describe in another publication” do you mean “which we will describe in another publication”

P27L17: “used our study” -> “used in our study”

P27L29: remove “using”

4 References

M. Reuter, M. Buchwitz, A. Hilboll, A. Richter, O. Schneising, M. Hilker, J. Heymann, H. Bovensmann, J.P. Burrows: Decreasing emissions of NOx relative to CO2 in East Asia inferred from satellite observations. Nature Geoscience, doi:10.1038/ngeo2257, 2014

Interactive comment on Atmos. Meas. Tech. Discuss., doi:10.5194/amt-2019-180, 2019.