Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2020-438-AC1, 2020

Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Quantifying sources of Brazil's CH_4 emissions between 2010 and 2018 from satellite data" *by* Rachel L. Tunnicliffe et al.

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Received and published: 21 August 2020

Please also see attached PDF which contains the same comments with formatting.

We would like to thank the reviewer for their valuable comments and include responses below. Line numbers have been included where appropriate.

Response to Reviewer #1

The authors presented an inverse modeling study of Brazil's methane emissions using observations by GOSAT satellite. Their estimate of anthropogenic emissions matches with Brazil's national inventory, while estimated emissions from wetlands are smaller than those by several other studies. To check the validity of the results and to quantify the impact of uncertainties in the inputs, the authors implemented a number of sen-

sitivity studies. Although the study doesn't use the ground-based observations inside the target region in the inversion, the results are supported by sensitivity tests. Discussions point out a large uncertainty of wetland emissions and the spread of different estimates, which has to be investigated further in the future. Paper is well written and can be accepted after minor revisions reflecting the review comments.

Detailed comment.

1) Line 50-56, Authors try to show that there is a wide range of estimates. To make that point it's better to group together the estimates for same regions/categories. It is not clear how big is the difference between studies when the target area is different. Another study using aircraft observations by Beck at al. (2013) could also be mentioned.

The discussion around previous results has now been rearranged to focus on total emissions rather than mixing both total and wetland emissions to allow these numbers to be more easily contrasted while considering the different regions that encompass this work. Reference to Beck et al. 2013, which combined modelling with aircraft measurements over the Amazon, has also been added when discussing these results.

The text has now been updated as follows: [Lines 50-59] Current top-down estimates of CH4 emissions from Brazil, the Amazon and tropical South America vary depending on the method, source of data and area considered. In the synthesis of Saunois et al. 2016, across the Tropical South America region, emission estimates derived using different datasets and top-down methods span the large range of 63 - 119 Tg yr-1 (23 - 69 Tg yr-1 from wetlands) for 2012. Across the Amazon basin, estimates of total emissions derived from aircraft measurements are between $\sim$16 – 72 Tg yr-1 derived for May, 2009 (Beck et al. 2013) and 31 – 43 Tg yr-1 for 2010 - 2013 (Wilson et al. 2016; Pangala et al. 2017). A recent study that performed a regional analysis using satellite data by Janardanan et al. 2020 found Brazil's emissions alone, on average, to be 56.2 Tg yr-1 (39.8 +/- 12.4 Tg yr-1 from wetlands) across 2011-2017. In addition, many previous studies have estimated emissions globally using satellite data (e.g., Bergamaschi et al. 2009; Feng et al. 2017). The wide range of estimates indicate that large uncertainties exist and these uncertainties are exacerbated when estimating emissions over smaller scales such as the Amazon basin or when quantifying individual sources.

2) Line 53-54 Janardanan et al (2019) used global inversion, not regional. The correct publication year is 2020, not 2019.

Thank you for spotting this error. All references to Janardanan et al. 2019 have been updated to Janardanan et al. 2020 [Lines 59, 360, 363, 367]

The text has now been updated as follows: [Line 362] Janardanan et al. 2020 estimated Brazil's CH_4 emissions using a coupled global Eulerian–Lagrangian model from 2011 - 2017 using GOSAT and surface data and find total emissions to be 56.2 Tg yr-1 compared with 33.3 +/- 3.7 Tg yr-1 derived in this study.

3) Line 270-275 The discussion implies that there is a bias in boundary conditions (taken from global models). Is there any bias between those global models and data at RPB?

The offset parameter used in the inversion does not represent a bias between Ragged Point and the global model used to produce the boundary conditions but represents any biases between the Ragged Point and GOSAT data used in the inversion as well as any biases in how the atmospheric transport model is able to simulate the two datasets (one surface, one column).

In fact, the CAMS inversion product assimilated surface sites including Ragged Point, and thus by design, there is consistency between Ragged Point data and the CAMS global mole fraction product. However, we include offsets to the global mole fraction field in our regional inversion to account for any variations that might occur outside of the assimilated data points in CAMS.

4) Line 290-295 Figures 8 and A5 show the observation and model time series, while it

is difficult to understand the sign of mean mismatch between observed and simulated concentrations. It would be useful to add monthly mean data to make differences easier to see.

For clarity, figures 8 and A5 have been updated to include the monthly means of both the modelled and measured mole fractions. In addition, the histogram already included gives a summary of the size and direction of the offset between the modelled and measured data. These two updated figures have been attached.

5) Line 355 The reasons for different models to give diverting results could be low number of GOSAT observations in wet season over the western Amazon basin. The full physics algorithm retrievals are likely to produce less data than proxy retrievals in partly cloudy conditions.

We have added a statement regarding estimates derived from different retrieval algorithms, which can impact both the retrieved mole fractions as well as the different numbers of data points.

The text has now been updated as follows: [Line 364-369] The difference between our results can be attributed to the natural wetland emissions estimates for which Janardanan et al. 2020 derive 39.8+/-12.4 Tg yr-1 compared to 13.1 +/- 1.9 Tg yr-1 presented here. Anthropogenic estimates (excluding biomass burning) are similar at 16.5 Tg yr-1 compared with our estimate of 18.8 +/- 2.6 Tg yr-1. One factor in this difference could be the differing GOSAT retrieval products used which were derived using different algorithms (CO_2 proxy vs full physics retrievals). Another reason for the discrepancy could stem from Janardanan et al. 2020 not allowing for an offset parameter between the surface/aircraft and satellite data within their inversion.

6) Line 359 Most global inversions add a latitude-dependent offset to XCH_4 in a way proposed by Bergamaschi et al (2009). So, it is better to note that offset is added differently here.

The GOSAT product we are using has already had a global bias correction applied (7.7 nmol mol-1) based on the global average difference with TCCON. The offset that we are describing in reference to the Janardanan et al. 2020 is due to any additional regional differences between the datasets as well as in their representation by the NAME model. The text has been updated to reflect the inclusion of the latitudinal correction in other inversions [Line 357] and text around the comparison with Janardanan et al. 2020 has been modified to clarify this [Line 367].

The text has now been updated as follows: Line [356-361] The GOSAT product used here has been previously corrected by 7.7 nmol mol-1 as a global average offset to independent ground based measurements from the Total Carbon Column Observing Network (TCCON) (Wunch et al. 2011). However, large regional variations can still exist (Dils et al. 2014). The offset estimated in an inversion is due to biases between the different datasets as well as their representation by the atmospheric transport model. Other inversion studies have imposed latitude-dependent bias corrections to the GOSAT data (e.g. Bergamaschi et al. 2009, Turner et al. 2015). Line [366-368] – see correction (5) for this updated text

7) Line 365-370 High tropical wetland emissions are needed in global models to fit the observations. When there are observations downwind of Amazon basin such as aircraft data used by Wilson et al. (2016), discarding those estimates as improbable needs to be done with some caution.

It is not our intention to suggest disregarding the estimates produced using aircraft data but simply to consider how best to reconcile the difference in our results with past results. When describing these results as inconsistent [Line 292-293] this is done in relation to the ATTO tall tower data and its representation by the NAME/FLEXPART models.

The text has now been updated as follows: Line [381-383] Future work should perform a detailed comparison between aircraft-derived estimates and those derived from

satellites, investigating the inversion setup and the degree of constraint by the datasets to understand the reasons for this discrepancy. Line [374-375]: However, these higher estimates, as shown in Fig. 8d, when simulated with NAME, are less consistent when compared with CH4 mole fractions measured at the ATTO tower.

References âĂć Beck, V., Gerbig, C., Koch, T., Bela, M. M., Longo, K. M., Freitas, S. R., Ka-plan, J. O., Prigent, C., Bergamaschi, P., and Heimann, M.: WRF-Chem simula-tions in the Amazon region during wet and dry season transitions: evaluation of methane models and wetland inundation maps, Atmos. Chem. Phys., 13, 7961–7982,https://doi.org/10.5194/acp-13-7961-2013, 2013. Reference to Beck et al. 2013 has been added (see point 1)

Please also note the supplement to this comment:
https://acp.copernicus.org/preprints/acp-2020-438/acp-2020-438-AC1-supplement.pdf

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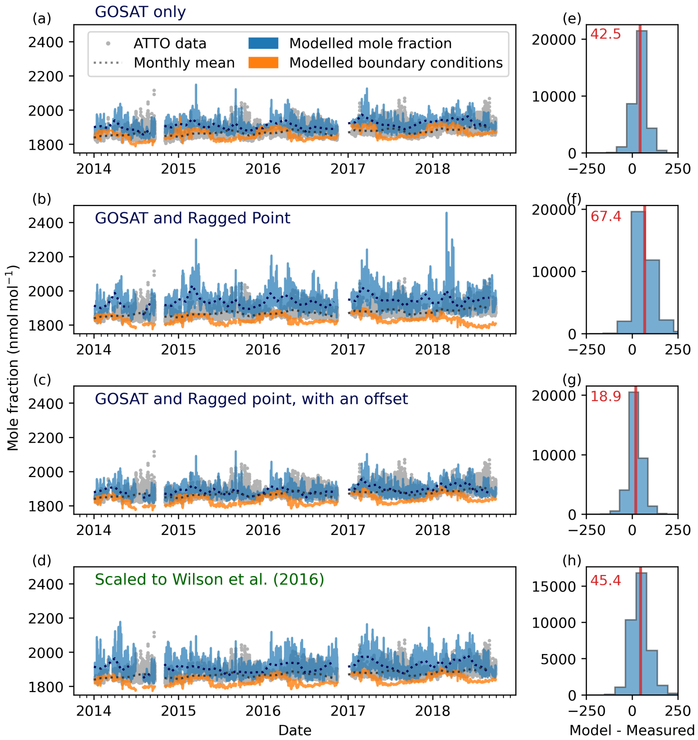
(a)
GOSAT only
ATTO data
Monthly mean
Modelled mole fraction
Modelled boundary conditions
(b)
GOSAT and Ragged Point
(c)
GOSAT and Ragged point, with an offset
(d)
Scaled to Wilson et al. (2016)
Mole fraction (nmol mol^{-1})
Date
(e)
42.5
(f)
67.4
(g)
18.9
(h)
45.4
Model - Measured

Fig. 1.

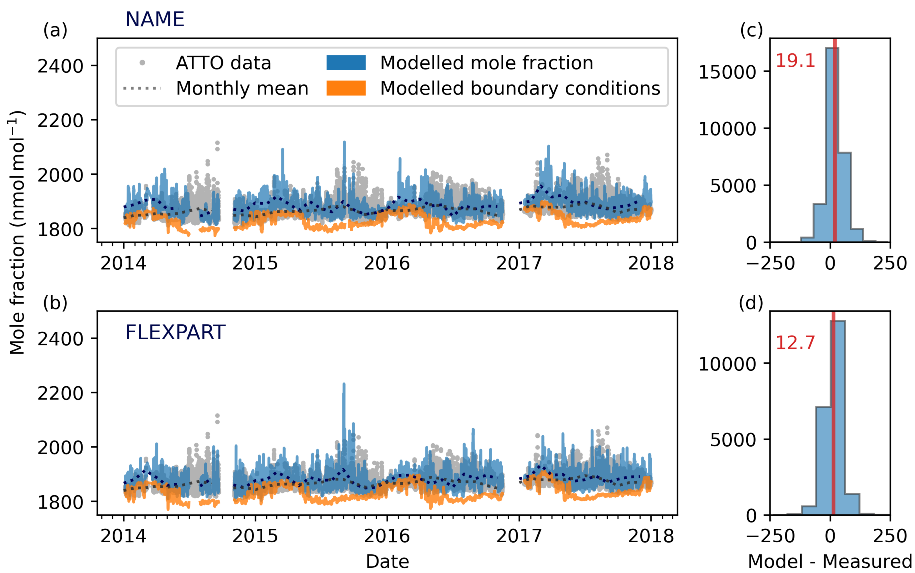
(a)
NAME
ATTO data
Monthly mean
Modelled mole fraction
Modelled boundary conditions
(b)
FLEXPART
Mole fraction (nmol mol^{-1})
Date
(c)
19.1
(d)
12.7
Model - Measured

Fig. 2.