Interactive comment on "The role of termite CH_4 emissions on ecosystem scale: a case study in the Amazon rain forest" *by* Hella van Asperen et al.

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Response to Anonymous Referee 3

Interactive comment on "The role of termite CH_4 emissions on ecosystem scale: a case study in the Amazon rain forest" by Hella van Asperen et al.

This study presented a global interesting issue of termite CH_4/CO_2 emission in an Amazonian tropical rainforest. As a case study, this in-situ measurement of termite mound emissions provided information about termite CH_4/CO_2 production under natural conditions, it will contribution some knowledge to Biogeosciences. However,

the field experiment was not well designed, and the limited data was not well analyzed. I would like to encourage the authors to revise the manuscript following my comments.

Thank you for your time spent on reviewing our submission! We are grateful for your suggestions, which we have used to improve the manuscript. Below you will find a point to point response to each of your raised concerns and, if applicable, the corrected and improved manuscript text.

In addition we would like to point out that:

- we have uploaded a revised text of §4.1 (First paragraph of discussion), which is shown at the end of this review;

- we have uploaded a revised Figure 2, which is shown at the end of this review (Previous Figure 4 is Figure 2 in revised manusript);

- we have uploaded a revised Figure 4, which is shown at the end of this review (Previous Figure 5 is Figure 4 in revised manusript);

- we have uploaded 4 additional figures, belonging to point 7 and 8 of this review, which are shown at the end of this review;

- the given values in the text might have changed due to an improved termite weight determination.

General comments

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1. "The blank measurements (collar with only soil and litter) showed an average

CH$_4$ emission of 1.15 nmol collar^{-1} s^{-1}" (L175) means the forest soil was a VERY LARGE CH$_4$ SOURCE (4.6 nmol m^{-2} s^{-1} or 23.2 CH$_4$ ha^{-1} y^{-1}). It was a FUNDAMENTAL PROBLEM! Actually, the "blank" soil should be CH$_4$ sink. Even "1.15 nmol collar^{-1} s^{-1}" was "-1.15 nmol collar^{-1} s^{-1}", the soil CH$_4$ sink of "-23.2 kg CH$_4$ ha^{-1} y^{-1}" was an unbelievable large value.

Though the reviewer correctly points out that most tropical forest soils are methane sinks, soil methane emissions in tropical ecosystems are common, especially when anaerobic conditions occur. Therefore, we disagree that this points to a fundamental problem.

In the revised manuscript we will substitute our blank collar measurement by a set of additional measurements from the surrounding area. These measurements show that the methane fluxes from the valley soil are spatially heterogeneous, but in general low. It is important to note that this heterogeneity has no impact on the given CH$_4$ emission estimates from the termite mounds, since the emissions measured from the mounds are on average a factor 627 higher than the average background soil CH$_4$ emission.

Below we will:

- provide additional information (measurements and literature) which show that soil valley CH$_4$ fluxes are heterogeneous but of low magnitude in comparison to the measured mound fluxes;

- compare the soil and mound fluxes by providing an improved Figure 4;

- provide text for the revised manuscript.

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Additional soil valley flux measurements

Most tropical forest soils are methane sinks (Dutaur and Verchot, 2007, Kiese et al. 2003). Nevertheless, soil methane emission in tropical ecosystems can still be observed (Carmo et al. 2006), especially when anaerobic conditions occur, such as which can be found in the valley (Sihi et al. 2020, Moura et al. 2012). This is also observed by our set of additional measurements:

 Additional measurements: valley soil chamber flux measurements (small chamber set up as described in §2.5), 10 soil collars, 3 repetitions, ~500 m from manuscript termite mounds, 5-50 m from igarapé (stream), measured in same week as termite mounds (March 2020), soil CH$_4$ fluxes ranged between -0.12 to 2.89 nmol m^{-2} s^{-1}, (median=-0.02, average=0.15, sd=0.55).

Our additional measurements show that valley soil fluxes are heterogeneous, and in general negative (median=-0.02), but that locations with relative high emissions (hotspots) can be found. Our mound adjacent soil fluxes were in general higher (0.3-8.9 nmol CH$_4$ m^{-2} s^{-1}, 16 soil collars), showing that mound adjacent soils are deviating from the average valley soil, likely due to the nearby presence of an active termite mound.

The magnitude of the *original* blank collar fluxes (3.9-5.4 nmol CH$_4$ m^{-2} s^{-1}) is quite similar to the magnitude of mound adjacent fluxes (0.3-8.9 nmol CH$_4$ m^{-2} s^{-1}). While the blank collar was not directly located next to a mound (~5 m of mound nr. 15), the comparison with the different datasets points at the presence of a local CH$_4$ hotspot (Subke et al. 2018), thereby not being representative as a control collar. For the revised manuscript we will use the 10 additional soil collar measurements as our 'blank collar' reference point.

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The aim of the blank 'control' measurement was to show the large difference between a 'normal' valley CH_4 emission (per area), and an emission (per area) when a termite mound is present. Considering the average mound emission of 25.2 nmol mound^{-1} s^{-1}, and the average valley soil emission of 0.03 nmol collar^{-1} s^{-1} (0.15 nmol m^{-2} s^{-1}), an average collar area emits a factor 630 more CH_4 when a termite mound is present. Including these complementary measurements will strengthen our message that termite mounds are hotspots in comparison to their surroundings.

We have included these additional measurements for comparison, by adapting Figure 4 (now renumbered as Figure 2, see end of this review), and by including these measurements at the following places in the manuscript:

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In Methods, §2.5: Valley and mound adjacent soil fluxes
Every mound adjacent soil flux measurement was 4 minutes, and the set of 4 collar measurements was performed once per mound, with exception of mound nr. 19. For mound nr. 13 and nr. 14, the measurements were performed on the 2nd measurement day, for mound nr. 15 and nr. 16, the measurements were done on the 3rd measurement day. Mound adjacent soil fluxes will be expressed per collar area (0.25 m^2), to be better comparable to mound emissions. The same chamber set up was used in a sub study at a close by transect ($\sim$ 500 m from termite mounds) where, among others, valley soil fluxes were measured (10 collars, 3 repetitions). Measured soil fluxes from the valley will be shown for comparison.

In Results, §3.1: Mound CH_4 and CO_2 emissions
Headspace concentrations increased strongly during chamber closure, and chamber concentrations reached up to 5750 nmol CH_4 mol^{-1} and 1950 μmol CO_2 mol^{-1}. Mound CH_4 emissions ranged between 17.0 and 34.8 nmol mound^{-1} s^{-1} (Fig. 1), with an average emission of 25.2 nmol mound^{-1} s^{-1}. Additional valley measurements showed heterogeneous soil CH_4 fluxes with small uptake and emission taking place alongside, ranging between -0.1 and 2.9 nmol m^{-2} s^{-1} (med=-0.02, avg=0.15, sd=0.54). Mound adjacent CH_4 soil fluxes, measured at 20 and 45 cm from the mound, ranged between 0.4 and

8.9 nmol CH_4 m^{-2} s^{-1} (avg=2.14, sd=2.00), and were on average enhanced in comparison to valley soils (Fig. 2). Soil valley CO_2 fluxes were found to range between 0.9 and 3.7 μmol m^{-2} s^{-1} (avg=2.14, sd=0.74) (Fig. 2). Mound adjacent soil CO_2 fluxes showed an average emission of 4.84 μmol CO_2 m^{-2} s^{-1} (range=2.0-10.1, sd=2.01), thereby being enhanced with respect to the surrounding soils (Fig. 2). Mound CO_2 emissions, corrected for the average valley soil respiration, were ranging between 1.1 and 13.0 μmol mound^{-1} s^{-1}, with an average emission of 8.14 μmol mound^{-1} s^{-1} (Fig 1).

In Discussion, §4.3:
Valley soil CH_4 and CO_2 fluxes were similar to what was found by earlier studies (Souza (2005), Moura (2012), Chambers et al. (2004), Zanchi et al. (2012). On average, mound adjacent soil CH_4 and CO_2 fluxes were enhanced with respect to valley soils, although differences were small, and no clear emission pattern with 'distance to mound' was observed. While mound adjacent soil fluxes are possibly enhanced, we preferred to avoid overestimation, and decided to treat termite mounds as very local hot spots, with measured fluxes only representative for the collar area of 0.25 m^2. On average, CH_4 and CO_2 fluxes per collar area were found to be a factor $\sim$630 and $\sim$16 higher when an active termite mound was present.

References:
- Carmo, Janaina Braga do, et al. "A source of methane from upland forests in the Brazilian Amazon." Geophysical Research Letters 33.4 (2006).
- Chambers, Jeffrey Q., et al. "Respiration from a tropical forest ecosystem: partitioning of sources and low carbon use efficiency." Ecological Applications 14.sp4 (2004): 72-88.
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- Kiese, Ralf, et al. "Seasonal variability of N_2O emissions and CH_4 uptake by tropical rainforest soils of Queensland, Australia." Global Biogeochemical Cycles 17.2 (2003).
-Moura, V. S. d.: Investigação da variação espacial dos fluxos de metano no solo em floresta de terra firme na Amazônia Central, MSc thesis INPA/UEA, 2012.
- Sihi, Debjani, et al. "Representing methane emissions from wet tropical forest soils using microbial functional groups constrained by soil diffusivity." Biogeosciences Discussions (2020): 1-28.
- Souza, Juliana Silva de. "Dinâmica espacial e temporal do fluxo de CO_2 do solo em floresta de terra firme na Amazônia Central." (2005).
- Subke, Jens-Arne, et al. "Rhizosphere activity and atmospheric methane concentrations drive variations of methane fluxes in a temperate forest soil." Soil Biology and Biochemistry 116 (2018): 323-332.
- Zanchi, Fabrício B., et al. "Soil CO_2 exchange in seven pristine Amazonian rain forest sites in relation to soil temperature." Agricultural and Forest Meteorology 192 (2014): 96-107.

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2. An early study in a Southeast Asian tropical forest showed that the populations of termites was 3,000 – 4,000 m^{-2}, 60% of which being wood-feeding termites and 30% being either litter-feeding or humus-feeding species (Chiba, 1978). This population density was supported by many recent studies showed in this manuscript (L356-358). Why this study did not include the major termite species (wood-feeding)?

When designing this field study, we decided to focus only on 1 species, so that effects of interspecies variability could be excluded. In addition, since mound emission was one of the focus points, our preference was to look for an epigeal nest (mound) building species.

Wood-feeding termite species are most likely **not** the major termite species in the Amazon rainforest. The distribution of feeding groups within an assemblage varies around the globe, so while wood-feeding termites might be the major termite species in a Southeast Asian tropical forest (Chiba, 1978), this can be different in other tropical forests.

Jones and Eggleton (2011), compiling data of global biogeography of termites, states that soil-wood interface feeders, such as *N. Brasiliensis*, composes the most diverse and dominant group in Neotropical rainforests (page 491). In addition, the species *N. Brasiliensis* is one of the most common species in our region, and one of the most abundant among mound-builder species (Dambros et al 2016, Pequeno et al. 2013).

In the revised manuscript, we have added the following lines to the Introduction:

Revised text in Introduction: In addition, for the Amazon, it is expected that most termites are soil-feeding (Jones and Eggleton, 2011), a group which are expected to be the strongest emitters of CH_4 (Bignell and Eggleton, 2000; Brauman et al., 1992).

Revised text in Introduction: In this paper, we are presenting a case study performed in a tropical rain forest in the Amazon, where we measured the emission of CH_4 and other gases of epigeal (aboveground) termite nests of the species *Neocapritermes Brasiliensis*, a soil-feeding species abundant in the Amazon (Constantino, 1992; Pequeno et al., 2013), and one of the most common species in the region (Dambros et al. 2016).

References:
- Dambros, Cristian S., et al. "Association of ant predators and edaphic conditions with termite diversity in an Amazonian rain forest." Biotropica 48.2 (2016): 237-245
- Jones, D. T., and P. Eggleton. "Global biogeography of termites: a compilation of sources. In 'Biology of Termites: A Modern Synthesis'.(Eds DE Bignell, Y. Roisin and N. Lo.) pp. 477–498." (2011).

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3. Large variations in both CH_4 and CO_2 emissions (Figure 1; L221-222, L240) among the mounds suggest that the five applicates (mounds) was not enough to represent the ecosystem level CH_4 and CO_2 emissions. From your statement (2.6: sub sample), I would guess that your CH_4/CO_2 flux measurements were conducted for all the 19 mounds but not only 5 mounds (Figure 1). If my guess is correct, the authors should explain (in the Method) the reasons for not including the data from other mounds, for example, the other mounds were not active mounds.

From the reviewers comment, we realize that confusion might arise about the amount of mounds sampled. Below we will:

- clarify that we measured fluxes of 5, and not 19, termite mounds;

- clarify how many mound *sub*samples have been measured;

- report additional subsample measurements which confirm the termite emission factor, and present a new Figure 5, which will show these additional measurements;

- provide the improved manuscript text for §2.6, and for other parts of the manuscript.

Our mound selection procedure for the 5 mounds was as follows:

- Firstly, we searched for mounds, which were suitable for flux chamber measurements (sufficient space for collar installation, not attached to tree). We found 20 suitable and active mounds, and we sampled each mound and determined the species at the *Laboratory of Systematics and Ecology of Soil Invertebrates* at INPA. Table 1 in the manuscript gives an overview of the found species per mound.

- When further selecting individual mounds of these 20 mounds, we only choose mounds of the same species, so that effects of interspecies variation could be excluded.

- For practical reasons, we choose a set of mounds which were closely located to each other.

- With these criteria in mind, we selected the mounds from which fluxes would be measured, which were mounds nr. 13, nr. 14, nr. 15, nr. 16 and nr. 19.

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The choice of limiting our flux measurements to 5 mounds was based on practical considerations (hours of daylight, days in the field, distance to cover), which were especially time constrained due to our additional bag sampling measurements (Appendix A). For a possible follow up study, we would leave this element out.

Moreover, the authors should explain why the sub sample experiment was only conducted for one mound (L161: "only one sub sample was found suitable from the all 19 mounds").

The sentence copied by the reviewer is different than the sentence stated at line 161, which was:

'From the sample from mound 19, only one suitable sub sample was found'

To clarify: for each of the 5 selected mounds, we sampled one solid (not crumbling) piece, of which we took 3 subsamples, of which we measured emissions and counted termites. In principle, this would lead to 15 subsamples. Nevertheless, due to practical problems at mound 19, we only managed to separate 1 suitable subsample, wherefore the total amount of subsamples was 13, as shown in the original Figure 5 of the manuscript.

In the last few months, we have performed additional measurements:

- Additional measurement 1 (AM1): performed in October 2020 (dry season), with 15 subsamples of the same mounds (mounds nr. 13, nr. 14, nr. 15, nr. 16 and nr. 19). A termite emission factor of 0.0002976 (se=$1.32*10^{-5}$) CH_4 per termite per second was found.

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- Additional measurements 2 (AM2): performed in December 2020 (transition dry/wet season), with 5 subsamples, taken from a new mound of the same species. A termite emission factor of 0.0003043 (se=$1.41*10^{-5}$) CH_4 per termite per second was found.

For the revised manuscript, we have added these CH_4 termite emission measurements to the text and to Figure 5, to show the reader the consistency of the termite emission factor between mounds and seasons. Nevertheless, since we prefer to combine only measurements obtained during the same field campaign week, the manuscript estimates and derivations are based on the original determined termite emission factor of 0.0002985 nmol termite^{-1} s^{-1}.

We have improved Figure 5 (in revised manuscript, renumbered as Fig. 4), which we uploaded, and which can be found at the end of this review. In the text, we have made the following changes:

Revised text caption Table 1: Termite mounds: location, dimensions, and observed species. Termite mound volumes were estimated by Eq. (1), and mound surfaces were estimated by mathematically considering the lower part of the mound as a column, and the upper part as half a sphere. In mound nr. 1, two different termite species were found. The five mounds indicated in bold (mound nr. 13, nr. 14, nr. 15, nr. 16 and nr. 19) were the mounds selected for flux measurements.

Revised text in §2.6: At mound nr. 13, nr. 14, nr. 15, nr. 16 and nr. 19, after the last mound flux measurement, a mound sample was taken of approximately 1 L volume. From this, three small sub samples were taken (volume not determined).

Revised text in §2.6: To verify whether the termite emission factor was stable between seasons and mounds, additional measurements were performed. In October 2020 (dry season), the same type of measurements were performed on 15 subsamples of the same termite mounds, and in December 2020 (transition dry-wet season), 5 subsamples of a different mound of the same species were analysed.

Revised text in §3.2: CH_4 and CO_2 emissions of 13 mound sub samples were measured. For each sub sample, the measured gas production was plotted over the counted termites (Fig. 4). The fitted line has a forced intercept at y=0. For CH_4, an emission of 0.0002985 nmol termite^{-1} s^{-1} was found (se=$1.77*10^{-5}$), fitted with an R^2 of 0.95 (n=13). The set of additional measurements resulted in similar termite emission factors namely 0.0002976 nmol termite^{-1} s^{-1} (se=$1.32*10^{-5}$) and 0.0003043 nmol termite^{-1} s^{-1} (se=$1.41*10^{-5}$), for respectively the measurements of October and December 2020. Given estimates in this paper are based on the originally determined termite emission factor of 0.0002985 nmol termite^{-1} s^{-1}. For CO_2, an emission of 0.1316 nmol termite^{-1} s^{-1} was found (se=$2.59*10^{-2}$), with an R^2 of 0.68 (n=13). Excluding the out liers (32, 14.9 nmol s^{-1} and 313, 80.9 nmol s^{-1}) gives an R^2 of 0.88 (n=11), with a CO_2 emission of 0.074 nmol termite^{-1} s^{-1} (se=$8.5*10^{-3}$).

Revised text in §4.3: Furthermore, exploratory dry season measurements of the same mounds showed emissions of the same magnitude (not shown), and additional dry season mound subsample measurements revealed very consistent termite CH_4 emission factors (Fig. 4). We therefore do not expect that mound CH_4 emissions are only of importance in the valleys, or only present in the wet season.

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4. In tropical forest, the termite mounds have different size and different shapes, and many are already not active mounds. This study only selected the relatively small size of termite mound (Table 1), thus it is not surprised that the authors gave the conclusion of weak correlation between CH_4 emission and mound size (3.1; Fig. 3).

For this study, we only measured active termite mounds; but during our search in the first phase of the research, no abandoned epigeal mounds were found, and only 1 abandoned tree nest was found.

Furthermore, we also point out to the readers that termite mounds appear in many

different sizes and shapes (§4.1). Because we are aware that different species build different type of nests, we only searched for a *species-specific* correlation between mound size and mound emission.

It is common that a certain species-specific correlation is found between mound size and mound population (Lepage and Darlington, 2000, Pequeno et al. 2013), wherefore it is also reasonable to expect a relationship between mound size and mound emission. Nevertheless, as Pequeno et al. (2013) pointed out, mounds from the species *N. Brasiliensis* have been shown to **not** present a strong correlation between mound size and mound population. Therefore, it is not surprising that we also did not find a strong relationship between mound size and mound emission.

To shorten the manuscript, we have decided to remove the original Figure 3, and only report our findings in the text. The discussion on variation in termite mounds and shapes, and on correlation between emisssion and mound size, can be found in the Discussion in §4.1 and §4.2:

Revised text in §4.1: There is a large variety in type of termite mounds (shape and size are dependent on species, ecosystem, climate (Noirot and Darlington, 2000)), explaining the wide range of reported termite mound CH_4 emissions (Table 2, middle and lower part).

Revised text in §4.2: Interestingly, Pequeno et al. (2013) concluded that mound volume is a weak indicator for population size for nests of the species *N. brasiliensis*, as also indicated by the weak correlation we found between mound volume and mound CH_4 emissions .

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5. This in-situ measurement could not be able to partition the contribution of

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mound soil (CO$_2$ source but CH$_4$ sink) from termite, thus the termite CH$_4$ emission could be underestimated but termite CO$_2$ emission could be overestimated. The results should be calibrated, because the structure and nutrients of the mound-soil are different from the normal soil (blank soil in this study).

Based on in-situ mound measurements as conducted here, it is impossible to partition the contribution of mound material vs termites. This was not done in any comparable studies. As the reviewer correctly points out, for CH_4 this will lead to an underestimation, and for CO_2 to an overestimation of estimated termite emissions. However, studies like ours determine the overall termite-induced emissions and this is the aim of our study.

Below we will:

- evaluate the impact of soil and mound emissions/uptake on our CH_4 and CO_2 termite estimates;

- elaborate on direct and indirect termite CO_2 emissions (termite-induced CO_2 emissions);

- show how we improved this part in the manuscript.

The impact of mound emissions/uptake on our CH$_4$ and CO$_2$ termite estimates

For mound CH$_4$ emission: overestimation is not expected: surrounding valley soils show heterogeneous but in general low magnitude (negative) fluxes, ranging between -0.03 to 0.72 nmol collar^{-1} s^{-1} (median=-0.01, average=0.03, sd=0.55, collar= 0.25 m^{-2}). Considering the average mound emission (25.2 nmol collar^{-1} s^{-1}),

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the contribution of an average soil CH_4 flux to the mound emission would lead to an overestimation of $< 1\%$.

As the reviewer correctly points out, underestimation is more likely, due to the uptake of CH_4 by mound material, as also discussed in the manuscript. To give a lower bound assessment, we have used the *net* mound CH_4 emissions for our ecosystem estimates.

For mound CO_2 emission: we cannot be sure which part of the mound emitted CO_2 derives directly from termites and which part derives from soil and mound respiration. To account for soil respiration, the most attainable approach is to determine the average CO_2 emission of the surrounding soils and subtract this value from the measured mound CO_2 emissions. Values shown in the manuscript are the corrected values.

Mound respiration however is an indirect effect of termite activity, and thereby a termite-*induced* emission. Partitioning direct and indirect termite CO_2 emissions is difficult, and impossible to determine without disturbing the mound. We will therefore clearly state this in the manuscript, and discuss that *direct* termite-emitted CO_2 emissions are presumably lower.

The topic of soil and mound respiration is discussed in the following places of the revised manuscript:

Revised text in §2.3, last sentence: Unless mentioned otherwise, given mound CO_2 emissions are corrected for the estimated contribution of soil respiration, by subtracting the average valley soil CO_2 emission (see §2.5).

Revised text in §3.1: Soil valley CO_2 fluxes were found to range between 0.9 and 3.7 μmol m^{-2} s^{-1} (avg=2.14, sd=0.74) (Fig. 2). Mound adjacent soil CO_2 fluxes showed an average emission of 4.84 μmol CO_2 m^{-2} s^{-1} (range= 2.0 - 10.1, sd=2.01), thereby being enhanced with respect to the surrounding soils (Fig. 2). Mound CO_2 emissions, corrected for the average valley soil respiration, were ranging between 1.1 and 13.0 μmol mound^{-1} s^{-1}, with an average emission of 8.14 μmol mound^{-1} s^{-1}.

Revised text in §4.1: Mound CO_2 emissions and the termite CO_2 emission factor were similar, or a little higher, in comparison to the few values found in literature. Nevertheless, since mound material and termites were measured together, the contribution of *indirect* termite emissions, i.e. mound respiration, cannot be quantified, so that the *direct* termite-produced CO_2 emission is presumably lower.

Revised text in §4.3: Nevertheless, since the 'emission per mound' as well as the 'termite emission factor' are both affected by indirect effects of termite activity (mound respiration), the contribution of *direct* termite-emitted CO_2 into the ecosystem is presumably smaller.

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6. Chamber volume (CV in L145; L159-163, L258-262) is a major parameter for calculation of flux rate (Equation 2). If the exact volume of the sample mound was not known, means CV was not known, based on the calculation using equation 2, the estimated both CH_4 and CO_2 fluxes (Table 2, 3; L218-222, L241-243) would be absolutely under- or over-estimated.

In all our assumptions, we have followed literature (Clough et al. (2019), Kirschke et al. (2013), Krishna and Araujo (1968), Pequeno et al. (2013), Ribeiro (1997), Sanderson (1996)), and have tried to aim for a lower bound appraisal. For example, for mound volume estimation, we have chosen to use the equation given by Pequeno (2013). Furthermore, we considered the mound as a solid body, even if a previous comparable study did not (Martius et al. 1993), thereby possible underestimating our mound emissions by $\sim 30\%$ (see text in §4.1, copied below).

So even if CV is an uncertain parameter, by communicating this clearly to the reader, and by demonstrating that our estimate is lower bound, our message, that termite mounds and termites are important in this ecosystem, remains strong.

Revised text in §4.1: An additional possible underestimation is caused by the estimated corrected chamber volume, as used in Eq. (2). In this study, we considered the mound volume as a solid body. A previous study considered the solid nest volume as 10% of the actual mound volume (Martius et al., 1993), leading to a larger corrected chamber volume, and therefore to larger calculated mound emissions. By use of this approach, average measured emissions would increase by almost 30% to be 32.7 nmol CH_4 mound^{-1} s^{-1} instead of 25.2 nmol CH_4 mound^{-1} s^{-1}.

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7. In my experience, this R^2 > 0.95 (L178 and other places) was non-believable. The chamber was relatively (or very) large (220 L), UGGA internal (pump) flow was only about 350 mL min^{-1}, the chamber air could not be mixed without installing one or two micro fans inside the chamber, because it takes about 630 min to replace the chamber air if only depending on the UGGA internal pump. Particularly, the chamber was about 1 m high, the emitted CH_4 and CO_2 was not be able to be mixed inside the chamber if only depending on both diffusion and UGGA internal pump. Moreover, based on the bag sampling (A1), CH_4 flux could be estimated. The authors are suggested to compare the result with that of mound chamber and sub sample.

Thank you for raising this topic, which we will answer point by point (7.1, 7.2, 7.3):

7.1: Mixing in the chamber, where we explain why we did not install a fan, and how we

ensured mixed chamber air;
7.2: Linearity of headspace concentration increase, where we show that, despite small fluctuations, linear regression (dCO_2/dt, dCH_4/dt and dCH_4/dCO_2) was performed with an R^2 > 0.95;
7.3: FTIR bag measurements, where we elaborate on estimation of mound CH_4 fluxes based on bag measurements.

7.1) Concerning the mixing of the chamber, first a small side note: termite mounds emit CH_4 from its entire surface, thereby presenting a sphere-shaped source of 45-65 cm height _inside_ the chamber head space. Therefore, we do not expect a large difference between CH_4 concentrations at the top and the bottom of the chamber head space.

We were hesitant about installing a small mixing fan. On the one hand, the absence of a mixing fan might lead to an underestimation of the flux (Christiansen et al. 2011). On the other hand, a mixing fan might lead to turbulence in the head space (Janssens et al. (2000), Pumpanen (2004)), which might induce unrepresentatively high CH_4 emissions from the mound.

Since we wanted to avoid overestimation of termite mound CH_4 fluxes, we decided to not install a mixing fan. Instead we installed a 4 inlet vertical sampling tube inside the chamber, a technique to minimize the effects of gas concentration gradients in the head space (Clough et al, 2020). Inside the chamber at fitting height (~30 cm), a T-piece with two 20 cm-long Teflon tubing was positioned vertically, and two small incisions were made, so that head space air was sampled from 4 different heights (approx. at 10, 25, 35 and 50 cm height from the soil). The sampling tube was tested in the lab to verify whether air was sampled from all 4 inlets.

We have added the following lines to the manuscript, and have added the following references to the manuscript.

Revised text in §2.3: Two one-touch fittings (1/4 inch, SMC Pneumatics) were installed on each side of the bucket. On the inside of the bucket, a 4 inlet vertical sampling tube was placed, so that air was sampled from different heights (10, 25, 35 and 50 cm) in the headspace (Clough et al, 2020).

References:
- Christiansen, Jesper Riis, et al. "Assessing the effects of chamber placement, manual sampling and headspace mixing on CH_4 fluxes in a laboratory experiment." Plant and soil 343.1-2 (2011): 171-185.
- Clough, Timothy J., et al. "Global Research Alliance N_2O chamber methodology guidelines: Design considerations." Journal of Environmental Quality 49.5 (2020): 1081-1091.
- Janssens, Ivan A., et al. "Assessing forest soil CO_2 efflux: an in situ comparison of four techniques." Tree physiology 20.1 (2000): 23-32.
- Pumpanen, Jukka, et al. "Comparison of different chamber techniques for measuring soil CO_2 efflux." Agricultural and Forest Meteorology 123.3-4 (2004): 159-176

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7.2) Concerning the linear regressions of dCH_4/dt with $R^2 > 0.95$, first of all, we would like to rectify two details from the manuscript. At line 132, we state that chambers were closed for 25 minutes, but this should have been 20 minutes. In addition, we state that we are correcting for sampling bag dilution (line 147), a decision we later reversed because gradients were only calculated over headspace concentrations after bag filling: this sentence should have been deleted.

In the figure (Review-Figure 7.2a, end of this review) we show the *last* 10 minutes (of total chamber closure) of five headspace chamber increases, measured on one day. As can be seen, even while fluctuations occur, the linear regression line still captures the shape of the line well, and still an $R^2 > 0.95$ can be found.

To further clarify the Review-Figure 7.2a: chamber closures were for 20 minutes, and sample bag filling (Appendix A of manuscript) was done at minute 3, 5 and 8. To determine the actual headspace concentration increase, we used the increment *after* the first 10 minutes, when the chamber was less disturbed by the bag sampling. The fluctuations, clearly visible for mound nr. 14 and nr. 15, take place at the 'beginning' of this second time window. Part of this might be explained by the remaining effect of the bag sampling, but we also expect that our presence close to the flux chamber (when closing and labeling the sampling bags) might have had an effect: in a different experiment, we saw headspace fluctuations, which disappeared when we distanced ourselves from the chamber. This is something we should keep in mind for a possible next experiment.

We realize that this part of the *Material and Methods* needs to be improved, and we have revised the text in §2.4 to:

Revised text in §2.4: Linear regression was used to derive the concentration increase, and given error bars are the propagated standard error of the linear regression slope. Concentration increases were calculated over the last 10 minutes of the chamber closure, to avoid possible effects of the bag filling. Nevertheless, if clear headspace concentration fluctuations were observed in the beginning of this time window, possibly by a remaining effect of the bag filling, the window was shortened by a maximum of 2 minutes (leaving a time window of 8 minutes). All calculated dC/dt increases showed a $R^2 > 0.95$.

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Concerning the linear regressions of dCH_4/dCO_2 with $R^2 > 0.95$, at line 178 we stated:

The CH_4 and CO_2 concentration increases inside the closed flux chamber were

strongly correlated ($R^2 > 0.95$ for each chamber closure).

This statement is true: during all chamber closures, fluctuations in CH_4 and CO_2 concentrations were strongly correlated, with $R^2 > 0.95$.

As also discussed in §4.1, both gases are showing a strong correlation, AND showing fluctuations of the same magnitude and at the same moment. We therefore assume that these fluctuations are caused by an external factor, like wind or human disturbance, sucking/pushing out high-concentration air from the chamber. This can also be seen in the figure below (Review-Figure 7.2b), where some fluctuations seem to happen when bag filling is performed. Nevertheless, it can also be seen that the gradient recovers after each fluctuation. In addition, if chamber air is diluted, the gradient will be underestimated, thereby not weakening the message of our paper.

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7.3) Concerning the FTIR bag measurements, bag samples were aimed to be sampled at 2, 5 and 8 minutes after chamber closure ($\Delta t=3$ min). Nevertheless, during the field campaign, variation in Δt occurred, such as due to changing pump performance (due to varying battery voltage), or due to timing inconsistencies. Since Δt between bag samples is not known with certainty, a flux based on the bag samples *alone* cannot be given. As described in the manuscript, we have used the Los Gatos fluxes to deduct the FTIR fluxes.

Revised text in A2: To calculate the fluxes of N_2O and CO, FTIR-measured bag concentrations of N_2O, CO and CO_2 were used. For each chamber closure, the dN_2O/dt, dCO/dt and dCO_2/dt were calculated so that the ratios dN_2O/dCO_2 and dCO/dCO_2 could be derived. To calculate the fluxes of N_2O and CO, the ratios were combined with the in-situ measured mound CO_2 flux, as measured by the Los Gatos instrument. This approach was chosen because the intended 3 min bag sampling interval was not always

accomplished, so that a fixed Δt could not be assumed with certainty.

For the reviewers interest, here below (Review-Figure 7.3) we show one example of bag concentrations, measured by the FTIR, in comparison to Los Gatos concentrations. During this measurement, sampling with 3 minutes interval was close to accomplished, so that Δt approximated 3 min.

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8. Data was too limited; I strongly encourage the authors to show the data measured in the dry season (L348-350) and compare it with that of wet season showed in this manuscript.

The measurements in the dry season were performed as an *exploratory* measurement, to see whether the mounds were still active, and fluxes were similar as in the wet season. Nevertheless, due to time limitations, measurements were only performed once. For this reason, we do not show them in the manuscript.

For the reviewers interest, we can show the additional measurements from October 2020 here in the review (Review-Figure 8, dark red bars). Measurements from mound nr. 13, nr. 15 and nr. 16 were in the same range as measured in March 2020, while fluxes from mound nr. 14 and nr. 19 were deviating. Considering the long time period which passed ($\sim$6 months), the change could be due to increased/decreased population size and/or activity, or (in case of mound nr. 14) a collar which was not well installed. Since it was outside the scope of the presented research, we have not structurally looked into the reasons for the difference, and prefer not to speculate too much. Nevertheless, these measurements confirm that the mounds are also active in the dry season, and remain hotspots in the ecosystem.

Additional 'dry season' measurements of mound *sub* samples, used to determine the termite emission factor, were performed in two sets. For the revised manuscript, the new figure and revised text can be found at point 3 of this review.

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9. Overall, using the limited data to scale up it to ecosystem (4.3) and global (4.4) levels would no doubt create large uncertainty. The authors are suggested to cancel or at least shorten these two issues.

For our upscaling to ecosystem level (§4.3): while this estimate is based on limited data, it is important to note that up scaling was only done for our *local* ecosystems CH_4 budget.

In addition, our fieldsite is situated in a geographical unique region: due to the nearby-presence of the institute INPA (which has been doing Amazon research since the 50's), many termite and ecosystem studies have been performed closeby (see bulletpoints below). Therefore, assumptions (mound density numbers, termite abundance) and comparisons (available ecosystem CO_2 and CH_4 fluxes) can be stated with more certainty than anywhere else in the Amazon. So, because of this strong complementary local dataset, we can estimate and evaluate the role of termites for our *local* CH_4 budget

Local studies:
-5 local studies (< 50 km) reported mound density numbers (Queiroz, (2004), Oliveira et al., (2016), Dambros et al., (2016), (de Souza and Brown, (1994), Ackerman et al., (2007);
-1 local study (< 50 km) studied the weight and mound-population dynamics of the same termite species (Pequeno 2013);
- Several studies focussing on ecosystem CO_2 and CH_4 were performed at the exact same fieldsite (Chambers et al.,

(2004), Moura. (2012), de Souza (2005), Zanchi et al. (2014), Querino et al. (2011).

For our upscaling to global levels, we have followed the method and assumptions as described by Kirschke et al. (2013). To clarify, we only have substituted the 'termite emission factor' value, all the other upscaling has been adapted from Kirscke et al. (2013). In addition, it is important to make the link to the global levels, which informs the reader about the important role of model parameters (termite density and termite emission factors), thereby clearly showing that this is an uncertain part of the CH_4 budget.

As suggested by Reviewer 2, the text on the global estimate has been extended and improved:

Termites contribution to tropical South America CH_4 budget (in §4.3)
In current CH_4 budget studies, a termite emission factor of 2.8 μg CH_4 $g_{termite}^{-1}$ h^{-1} is used for '*Tropical ecosystems and Mediterranean shrub lands* (Kirschke et al., 2013; Saunois et al., 2020), which is mainly based on field studies in Africa and Australia (Brümmer et al., 2009a; Jamali et al., 2011a, b; Macdonald et al., 1998; MacDonald et al., 1999). The only termite emission factor measured for the Amazon rain forest is by Martius et al. (1993) (3.0 μg $g_{termite}^{-1}$ h^{-1}) for a wood-feeding termite species, which are expected to emit less CH_4 than soil-feeding termites (Bignell and Eggleton, 2000; Brauman et al., 1992). As a 'back-of-the-envelope' calculation, based on (Kirschke et al., 2013): 36% of global termite emission (11 Tg) is expected to come from the region of 'tropical South America' (0.36*11=3.96 Tg). Substituting the emission factor of 2.8 with the newly found 5.6 μg CH_4 $g_{termite}^{-1}$ h^{-1} would increase this regions estimate to 7.92 Tg, and the global estimate to 14.96 Tg.

Our study points out that termite emissions are still an uncertain source in the CH_4 budget, and are especially poorly quantified for the Amazon rain forest. Measurement of CH_4 emissions from different termite species, preferably covering species of different feeding or nesting habits, in combination with more precise termite distribution and abundance data, would allow more precise estimates and a better understanding of the role of termites in the CH_4 budget.

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Minor Comments:

L10 (L211, L284): Reads are easily be confused by the colony size and population, also the colony size of 50-120 thousands individuals and 54.6-116.6*10^3 termites per mound should be unified.
Thank you for this point. We have improved this, and have now tried to use words for large numbers (as advised by the guidelines of Biogeosciences). We have unified this in the revised manuscript.

L120: Change "mound 15" to "mound #15".
We have made all mound numbering consistent by adding 'nr' every time a specific mound is mentioned, and we have used '#' when discussing a measurement repetition (For example, measurement #1, #2, and #3 of mound nr. 13.)

L120: Only one control (blank) made this result (also see above) weaker.
We have revised this part of the manuscript, as demonstrated at point 1 in this review.

L130: The distance between the UGGA and chamber was 2 m.
This tubing was of 2 meter length, but the distance was usually a little less. Two meter length was chosen to have some flexibility about where to place the UGGA.

L131: It is about 350 mL/min (from LGR).
We have corrected this.

L150-157 (§2.5): Soil flux chamber had no mixing fan would have the same problem with the mound chamber (see above)
For the small flux chamber, the volume is only 4.7 L, wherefore the circular LGR flow of 0.35 L/min induces basic chamber mixing. In addition, as found by different studies, a fan might induce unnatural turbulence, leading to an overestimation of the flux (Janssens et al. 2000, Pumpanen et al. 2004). Since we wanted to avoid overestimation of our fluxes, and since our CO_2 fluxes (without a fan), measured in different places in the ecosystem, are quite close to earlier studies (Chamber et al. 2004, Souza 2005, Zanchi et al. 2014), we decided to not install a small fan inside this chamber.

References
- Chambers, Jeffrey Q., et al. "Respiration from a tropical forest ecosystem: partitioning of sources and low carbon use efficiency." Ecological Applications 14.sp4 (2004): 72-88.
- Janssens, Ivan A., et al. "Assessing forest soil CO_2 efflux: an in situ comparison of four techniques." Tree physiology 20.1 (2000): 23-32.
- Pumpanen, Jukka, et al. "Comparison of different chamber techniques for measuring soil CO_2 efflux." Agricultural and Forest Meteorology 123.3-4 (2004): 159-176.
- Souza, Juliana Silva de. "Dinâmica espacial e temporal do fluxo de CO_2 do solo em floresta de terra firme na Amazônia Central." (2005).
- Zanchi, Fabrício B., et al. "Soil CO_2 exchange in seven pristine Amazonian rain forest sites in relation to soil temperature." Agricultural and Forest Meteorology 192 (2014): 96-107.

L177: Soil CO_2 emission of 0.47 μmol collar^{-1} s^{-1} (1.87 μmol m^{-2} s^{-1}) was too small. The authors are suggested to compare it with other studies in tropical forests.
Tropical soils usually emit more than 1.87 μmol CO_2 m^{-2} s^{-1}, although wet soils with anaerobic properties, such as our local valley soils, have been shown to emit lower magnitudes (Souza, 2004).

We have extended and improved our soil CO_2 emission estimate by reporting valley

soil CO_2 emissions from 10 soil collars (3 repetitions), which gave an average valley emission of 2.15 μmol m^{-2} s^{-1} (sd=0.74), which is similar to what was found by Chamber et al. (2004), and Zanchi et al. (2014).

The revised manuscript text concerning these additional measurements can be found at point 5 of this review.

L187-189: Move to the Method, and L189-192 move to the caption of Figure 4.
Thank you for the suggestion, we have corrected this.

L252-257: The statement of "air flow below the soil collar" does not make sense.
We have rephrased the sentence.

Equation 2: not completed; missed chamber pressure and chamber temperature.
Since we are stating dC/dt in 'μmol m^{-3} s^{-1}, and not in 'μmol mol^{-1} s^{-1}, the pressure and chamber temperature term in this equation become redundant. We have chosen for this equation form, since we assume a stable temperature, as stated §2.4.

L311: The statement of "Mound adjacent soil flux measurements showed no enhanced CH$_4$ and CO$_2$ fluxes in comparison to soils in the blank collar" does not consist with the results. For example, adjacent CO$_2$ flux (1.3) was almost three times of blank soil (0.47).
Thank you for pointing this out. The revised manuscript text for this part is given in the beginning of this review (review point 5).

L337: 11 g is the maximum value; the variation range should be listed. Consequentially, the following value of 0.5-1.0 nmol m^{-2} s^{-1} was overestimated.
The biomass value of 11 g m^{-2} has been stated and used as a standard for tropical rainforests in different previous studies (Bignell and Eggleton 2000, Sanderson, 1996, Sugimoto et al. 1998).

In addition, for our *local* ecosystem, the termite biomass estimate of 11 g termite m^{-2} is ***not*** considered a maximum value, and possibly even an underestimation:

A recent paper links the termite biomass to GPP, thereby correcting the termite biomass estimate for less active tropical ecosystems (see figure S6 in Kirsche et al. 2013). Since we are only using the termite biomass estimate for our *local* ecosystem, for which the GPP has been estimated to be 3000 g C m^{-2} year^{-1} (Chambers et al. 2004), based on Figure S6 we deducted that the termite biomass is even higher than 11 g m^{-2}. This is also confirmed by a *local* study, performed in a fieldsite close by, where a termite biomass of 14-17 g m^{-2} was found (Martius, 1998).

While the termite biomass is likely higher than 11 g m^{-2} in our ecosystem, we prefer to stay in sync with previous studies on tropical ecosystems, and will continue with this lower bound appraisal for termite biomass.

References
- Bignell, D. E. and Eggleton, P.: Termites in ecosystems, in: Termites: evolution, sociality, symbioses, ecology, pp. 363–387, Springer, 2000.
- Martius, Christopher. "Occurrence, body mass and biomass of Syntermes spp.(Isoptera: Termitidae) in reserva Ducke, Central Amazonia." Volume 28, Número 3, Pags. 319-319 (1998).
- Sanderson, M.: Biomass of termites and their emissions of methane and carbon dioxide: A global database, Global Biogeochemical Cycles, 10, 543–557, 1996.
- Sugimoto, Atsuko, et al. "Methane oxidation by termite mounds estimated by the carbon isotopic composition of methane." Global Biogeochemical Cycles 12.4 (1998): 595-605.

L415: Check the grammar.

Thank you for pointing this out. We have revised this part to:

Revised text in A1:: For calibration of the instrument, 2 calibration gases were used: Gas 1 with values 381.8 μmol CO_2 mol^{-1}, 2494.9 nmol CH_4 mol^{-1}, 336.6 nmol N_2O mol^{-1}, 431.0 nmol CO mol^{-1}, and -7.95 permil $\sigma^{13}C$ of CO_2, and gas 2 with 501.6 μmol CO_2 mol^{-1}, 2127.0 nmol CH_4 mol^{-1}, 327.8 nmol N_2O mol^{-1}, 256.7 nmol CO mol^{-1}, and -14.41 permil for $\sigma^{13}C$ of CO_2.

A3: Shorten or discuss the scientific meaning of 13CO$_2$ in this study.

We have shortened this part, and moved a part of the information to the figures caption. The new text is as follows:

Revised text in A3: For each chamber measurement, a mound-specific $\sigma^{13}C$ value of the CO_2 flux was determined. Figure A2 shows the Keeling plot intercepts, wherein error bars represent the standard errors of the intercept. In general, the values were more depleted than values found by De Araujo et al. (2008), who found a $\sigma^{13}C$ of -30.1 permil for valley litter during the dry season (August 2004). To investigate whether our values are representative for other mounds or soils in the valley, and to investigate whether an isotopic difference exists between mound and soil emitted CO_2, more measurements would be needed.

Unify the concentration unit of ppm and μmol mol^{-1}.

We have corrected this.

Revised Discussion part §4.1

CH$_4$ and CO$_2$ emissions

Measured mound CH_4 emissions were of similar magnitude to emissions found by previous studies (Table 2). The termite emission factor, determined for the soil-feeding species *N. brasiliensis*, was found to be 0.35 (sd= 0.02) μmol g$_{termite}^{-1}$ h^{-1}, which is similar to values found for other species in literature (Table 2, upper part), but almost two times higher than the average value reported by Martius et al (1993) for a wood-feeding species in the Amazon (0.19 μmol CH_4 g$_{termite}^{-1}$ h^{-1}). Our emission rate is within the reported range of 0.1-0.4 μmol g$_{termite}^{-1}$ h^{-1} for soil feeders (Sugimoto et al. 2000). Mound CO_2 emissions and the termite CO_2 emission factor were similar to a little higher in comparison to the few values found in literature. Nevertheless, since mound material and termites were measured together, the contribution of *indirect* termite emissions, i.e. mound respiration, cannot be quantified, so that the direct termite-produced CO_2 emission is presumably lower.

There is a large variety in type of termite mounds (shape and size are dependent on, among others, species, ecosystem, climate (Noirot and Darlington, 2000)), explaining the wide range of reported termite mound CH_4 emissions (Table 2, middle and lower part). In-situ measurement of termite mounds gives information about the *net* CH_4 emission under natural conditions, but is unable to distinguish sources and sinks inside the mound. One known CH_4 sink in termite mounds is the uptake by methanotrophic bacteria, which are also responsible for the CH_4 uptake in aerobic soils. The presence and magnitude of this process have been discussed and reviewed by different studies (Khalil et al., 1990; Macdonald et al., 1998; Nauer et al., 2018; Seiler et al., 1984; Sugimoto et al., 1998a; Ho et al., 2013; Pester et al., 2007; Reuß et al., 2015). The role of possible mound CH_4 uptake should also be acknowledged for the measurement of individual termite emissions (Table 2, upper part): most literature values, including values from this study, are based on termite incubation in presence of mound material, with ongoing CH_4 uptake, wherefore actual termite CH_4 emission values might be higher.

Small variation in emission magnitudes was observed between measurement days. This can be caused by a variation in colony size (due to foraging activities) or termite activity, driven by fluctuations in temperature or radiation (Jamali et al., 2011a; Ohiagu and Wood, 1976; Sands, 1965; Seiler et al., 1984).. However, as our termite mounds are in a tropical forest with relatively constant temperatures and only indirect daylight, strong diurnal temperature and radiation patterns are not expected. Small variation can also be caused by minimal air transport below the soil collar, through the porous upper soil layer;

during preliminary tests *without* a collar, we observed that even a light forest breeze can cause chamber headspace variations. In case our set up was subject to minor air transport below the collar, the given mound estimates will be slightly underestimated with respect to the actual mound fluxes. Another possible underestimation is caused by the estimated corrected chamber volume, as used in Eq. (2). In this study, we considered the mound volume as a solid body. A previous study considered the solid nest volume as 10% of the actual mound volume (Martius et al. 1993), leading to a larger corrected chamber volume, and therefore to larger calculated mound emissions. By use of this approach, average calculated emissions would increase by almost 30% to be 32.7 nmol CH_4 mound^{-1} s^{-1} instead of 25.2 nmol CH_4 mound^{-1} s^{-1}.

The mound emission CH_4/CO_2 ratio was found to be relatively constant over 4 of the 5 mounds, with an average ratio of 2.8*10^{-3}. While values in literature indicate a wide range of reported CH_4/CO_2 ratios (Table 2), both Seiler et al. (1984) as Jamali et al. (2013) found little variation between mounds of the same species, and concluded that the CH_4/CO_2 emission ratio is species-specific. Our overall variation of a factor of ~4 for the CH_4/CO_2 ratio of mound emissions of the same species is of the same magnitude as what was observed in earlier studies (Seiler et al., 1984; Jamali et al., 2013).

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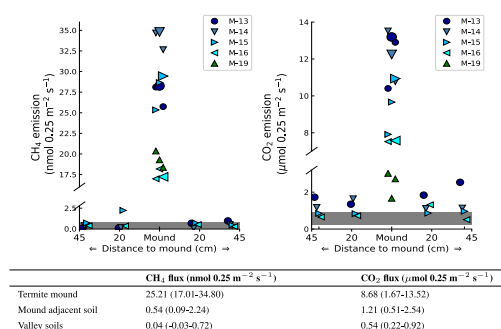|	CH_4 flux (nmol 0.25 m^{-2} s^{-1})	CO_2 flux (μmol 0.25 m^{-2} s^{-1})
Termite mound	25.21 (17.01-34.80)	8.68 (1.67-13.52)
Mound adjacent soil	0.54 (0.09-2.24)	1.21 (0.51-2.54)
Valley soils	0.04 (-0.03-0.72)	0.54 (0.22-0.92)

Figure 2. Measured mound emissions and mound-adjacent soil fluxes for CH_4 (left) and CO_2 (right) for mound nr. 13, nr. 14, nr. 15 and nr.16 expressed in nmol 0.25 m^{-2} s^{-1} for CH_4 and μmol 0.25 m^{-2} s^{-1} for CO_2 (collar area is 0.25 m^2). Note that for CO_2 here the net mound emissions per collar area, not corrected for soil respiration, are shown and stated. The centrally-placed markers are the measured mound emissions (also for mound nr. 19); the larger marker indicates the day-specific mound emission when mound adjacent soil fluxes were measured. The grey bar indicates the range of additionally measured soil valley fluxes. The range and average flux for each group of measurements are given in the table. On average measured mound CH_4 and CO_2 fluxes were a factor 630 and 16 higher in comparison to the surrounding soil valley fluxes.
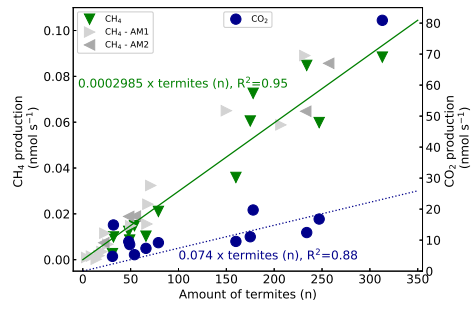
Fig. 1. Revised Figure 2 (previously Figure 4)

Figure 4. CH$_4$ production (left axis, green triangles) and CO$_2$ production (right axis, blue circles), measured in the closed small flux chamber, over counted termites. The lines (green solid for CH$_4$, blue dashed for CO$_2$) represent a linear regression fit with forced intercept at y=0. For CH$_4$, a production of 0.0002985 nmol termite^{-1} s^{-1} (se=1.77*10^{-5}, R^2=0.95) was found, and for CO$_2$, a production of 0.1316 nmol termite^{-1} s^{-1} (se=2.59*10^{-2}, R^2=0.68) was found. Excluding the outliers (32, 14.9 nmol s^{-1} & 313, 80.9 nmol s^{-1}) gives an R^2 of 0.88 (n=11), with a CO$_2$ emission of 0.074 nmol termite^{-1} s^{-1} (se=8.5*10^{-3}). For comparison, two sets of additional subsample CH$_4$ emission measurements are shown. The first additional measurements (AM1, light grey triangles) resulted in a termite emission factor of 0.0002976 nmol termite^{-1} s^{-1}(se=1.32*10^{-5}); one point (599 termites, 0.165 nmol s^{-1}) is not shown in this figure. The second set (AM2, dark grey triangles) gave a termite emission factor of 0.0003043 nmol termite^{-1} s^{-1} (se=1.41*10^{-5})

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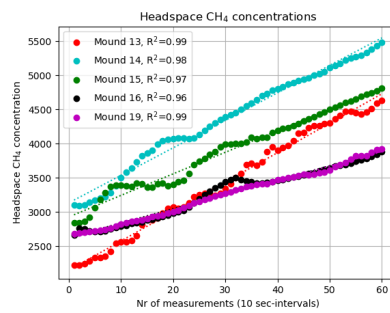**Fig. 2.** Revised Figure 4 (previously Figure 5)

C33

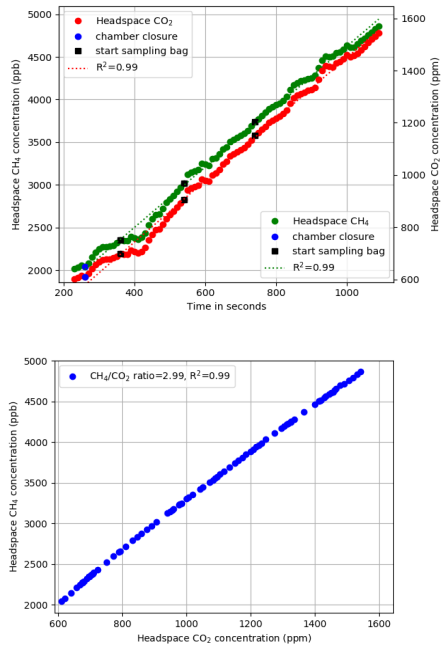**Fig. 3.** Review Figure 'Review-Figure 7.2a'

C34

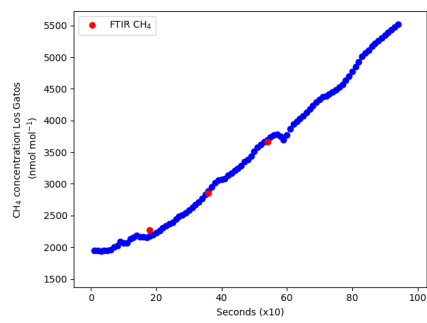**Fig. 4.** Review Figure 'Review-Figure 7.2b'
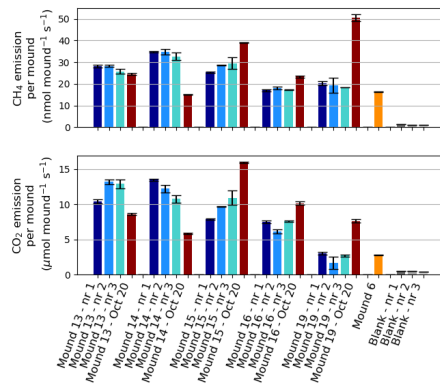
C35

Fig. 5. Review Figure 'Review-Figure 7.3'

C36

Fig. 6. Review Figure 'Review-Figure 8

C37