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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Variability and quasi-decadal changes in the methane budget over the period 2000–2012" *by* Marielle Saunois et al.

Anonymous Referee #2

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This is a timely, thoughtful, thorough, and important work form the scientific community involved in the Global Carbon Project. This effort focuses on the sub-decadal variability in an effort to the apparent, vexing shifts in the atmospheric growth rate of methane (CH4). It takes a measured approach to attributing the cause of CH4 variability in terms of natural (although perhaps perturbed by climate change) and direct anthropogenic sources. It also nicely consolidates the top-down inversions and the bottom-up emission inventories. It does not deal with the possible changes in atmospheric sinks (OH), although the evidence for large variability in the sink are proposed in some recent papers, but remain entirely obscure. This paper takes a balanced approach and could be published as is, or with some minor revisions suggested below. My apologies for the

delay in reading/reviewing this manuscript.

Request: Can we please all go to continuous line numbering so that it is easy to read sections and refer to them without finding the page number?

P4L18. The refs for OH chemistry models are fine as an overview, but the Holmes et al (2013, you have it later in the paper) is a good example of multi-model assessment of the interannual variability in the OH sink and its possible causes that is not found in the ACCMIP studies.

P5L15. The cryo-ethane history has proven useful in evaluating fossil fuel emissions and inferring ff-CH4 sources (Aydin et al., Nature 2011, 476:198-201, 2011; Nicewonger, et al. GRL 43:214–221, 2015), and these are more relevant here than the LA-basin study of Wennberg.

P6L16-17. I think you mean "the first GCP global methane budget. . ."

P6L22ff. I think that this phrase is close but could be better "as most of the inversions used here assume constant OH concentrations over years, generally only optimizing its mean global concentration against methyl chloroform observations (e.g. Montzka et al. (2011))." What the models assume is not constant OH but rather constant CH4 loss frequency (with respect to OH). These are not the same, since if temperature changes then the constant OH will result in different CH4 loss. Moreover, the methyl chloroform decay records a mean loss frequency and not a mean OH as is frequently used. I suggest we move on to more accurate statements like: " as most of the inversions used here assume constant methane loss to OH over the time period, consistent with the observed decay of methyl chloroform (e.g. Montzka et al. (2011); Holmes et al, 2013)."

P9L11-15. You really need to note that if these models used their own OH & T fields that the CH4 budget would vary by 30% or more. It is because they use an accepted OH-lifetime for methane (e.g., Prather GRL 39:L09803, 2012) that top-down agrees so

closely.

P14L2. typo: constrained to constrain.

P14L8. While I tend to believe the Bruhwiler paper and not trust the cherry-picked satellite data over the US, you might consider referencing these two papers (Turner, Jacob, et al. GRL, 43:2218–2224, 2016; Schneising et al. Earth's Future 2:548–558, 2014).

P14L27. the phase "are assumed not to contribute" is awkward. At first it sound like this paper assumes this, but what you mean is "are assumed in these model studies not to .."?

P15L17. awkward end: "emissions occur partly over the same aereas. . .

P15L18. drop the 'of' to make it a sentence.

p15L23. Now you jump from fluxes (Tg/y) in the above to trends/accelerations (Tg/yr^2). How about using this line to transition to translate this difference in emissions to a trend: " and 2008-2012, i.e., a trend of about +1.7 Tg CH4 yr-2).

P16L2. ?? "change, and this result holds similarly for . . ."

P17L11. typo: "..that the increase in methane emissions between. . ."

P17L18ff. Please revise this sentence and make more, shorter ones. I was totally lost at the "although". " The sectorial partitioning from inversions is in agreement (within the uncertainty) with bottom-up inventories (noting that inversions are not independent from inventories), though the top-down ensemble significantly decreases the methane emission change from fossil fuel production and use compared to the bottom-up inventories, although the estimate of the latter should decrease with the upcoming revised version of the EDGAR inventory (see Sect. 3.2.4)."

P17L31. " the spread of land surface models" Please pick a better word than "spread": these models do not grow like forests. . ..

P18L8. Fix up: " wetland emissions per Meter Square." and put the Poulter ref at the end of the sentence if possible.

P18L16. I think you do not want 'incorrectly' in this sentence, the following clause says it all: "Even though top-down approaches may incorrectly attribute. . ."

P19L5. easier to read as: " ..changes leads, as expected, to unrealistically. . ."

P19L19. put a comma between the two independent clauses: " than constraints, and other. . ."

P19L21-35. Here is maybe where it is worth looking at the firn-air record showing ethane decreases (Aydin & Nicewonger refs above).

P20L3-6. This sentence does not really belong in the "Ethane" discussion? " Besides, the recent bottom-up study of Höglund-Isaksson (2017) shows relatively stable methane emissions from oil and gas after 2007. . .."

P20L17-29. This OH section is bothersome. I think you mean that models assume constant methane loss frequency – OR if they fix the 3D OH distribution, then the interannual temperature variations will drive changes in methane loss. I think they do the former and hence the correct wording would be "assume constant OH-lifetime for methane" or "assume constant methane loss frequency." These cannot just assume a uniform OH-loss because then they miss the seasonal and latitudinal gradients. I also recommend that the authors also look at the trends in methane's OH-lifetime from the Holmes et al 2013 paper. Several models show no trends from 2006 to 2010. If anything all the models show a decreasing methane OH-lifetime from a high in 2004 to a low in 2010, an 'OH' increase of about 3%. Moreover, one model running both with GEOS MERRA vs. GEOS6 shows different trends. The Dalsøren 2016 paper is very interesting, but it is only one model – further, this Oslo CTM3 shows different trends than the same model in the Holmes paper. I am not sure which is the better result, but some caution is due. Interestingly, all the models get the big increase in OH across the

1997-89 ENSO year.

P20L26. "However, decreasing OH concentrations since 2008 would require smaller emission changes to explain the observed atmospheric methane increase, also possibly implying .." This is confusing since both the Dalsoren and Holmes papers show a decrease in lifetime (2% possibly) and hence an increase in OH after 2008.

P21L27-30. Again, please check that the models kept the methane OH-lifetime (effectively the inverse loss frequency) fixed and did not freeze OH concentrations, allowing the rate coefficient to vary with temperature as it should, because then the temperature fluctuations could drive %-level variability. Also I think you have the Dalsoren paper backwards: their Fig 15 (&18) shows a steadily increasing methane loss frequency (1/lifetime, left scale) since the 1997-98 ENSO and up to 2010; the year 2008 is the only reversal of this. Their calculated change in OH does not match the CH4 lifetime, and it is the lifetime that determines the annual loss of CH4.

P21L33. "uncertainties" is odd. I am not sure we know enough to even assess the uncertainty. how about "major disagreements in OH fields simulated by the models."

P22L1. It is the fact that we stopped using MCF and it is decreasing rapidly, that makes is a good surrogate for the methane OH-lifetime. When in use the uncertainty in emissions made it difficult to get better than 10-20% accuracy and variability.

P22L5. I am not sure that this comparison with CO2 is useful or accurate. There are many thorny problems left with the CO2 budget and climate feedbacks. Stop at "understood."

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