**We would like to thank Anonymous Referee #2 for valuable comments. We have worked to amend the manuscript so as to more clearly explain our method. Please see our responses to specific reviewer comments below in blue.**

An efficient representation of tropospheric OH as described here can facilitate multi-decadal simulations that need to represent the long lifetime of methane and its interactions with OH, and might be useful for future studies of paleo or future atmospheres. Below I suggest some additional information to help guide future adopters of this approach, as well as some additional evidence, if available, to strengthen the paper

**General comments.**

If possible, it would be stronger to show in the main text the differences in results using archived, annually-varying OH fields versus the parameterized approach as a demonstration of the utility of the parameterization relative to the currently favored computationally efficient approach. For example, is there a scenario with archived OH that could be compared with Base?

Yes, we did such a scenario using annually-repeating archived OH fields from a full chemistry simulation of the NASA GMI CTM (*Base_GMI* scenario). The OH in this simulation falls within the multi-model mean of MIPs, but is generally on the low side. Consequently, it leads to too high methane as shown in the figure below. We didn't adjust the OH field upward to account for this, such as was done in the TransCom MIP – the climatology of Spivakovsky et al. (2000) was adjusted down by 8%. That is, if we were to compare a simulation using the ECCOH module and one using archived OH, the comparison will be dependent on the archived OH used (i.e., seasonally-repeating vs seasonally-varying, the overall magnitude, etc.). Therefore, we decided not to include the comparison.

To address this concern, we added the underlined text to a paragraph in the Introduction:

"Limitations of using archived, monthly OH fields for studies of methane's and CO's evolution are that feedbacks of the $CH_4$-CO-OH system on methane, CO and OH are not captured as the losses of methane and CO by reaction with OH are assumed to be linearly proportional to the OH fields. For methane, this assumption is not desirable, particularly on multi-decadal time-scales (e.g., Prather, 1996). Chen and Prinn (2006) found that using an archived, annual cycle of OH may mask or bias the interannual changes of methane. For relatively short-lived CO (~1-2 months), this assumption is not valid given the strong feedback between CO and OH (e.g., Duncan and Logan, 2008; Voulgarakis et al., 2015). <u>If a multi-decadal simulation of methane or CO using archived and annually-repeating OH reproduces observations, then there must be some compensating factor, for example a bias in emissions. That is, the simulation reproduces observations, but for the wrong reason. The models in the TranCom MIP adjusted down (by 8%) the archived OH</u>

climatology of Spivakovsky et al. (2000) so that the simulated decline in the global atmospheric methylchloroform (MCF) concentration since 2000 better matched that observed (Patra et al, 2011). Adjusting archived OH to improve a simulation of MCF, methane and/or CO makes the specious assumption that emissions inventories, model dynamics, etc. used in the simulation are correct. If using archived and annually-repeating OH, whether adjusted or not, inverse modeling studies of methane and CO will incorrectly determine a posteriori fluxes as the impact of nonlinear feedback of the $CH_4$-CO-OH system on concentrations will be erroneously folded into the flux estimates. Therefore, there is a need for a computationally-efficient solution to simulate credible temporal and spatial distributions of OH over several decades, while capturing the nonlinear feedbacks of the $CH_4$-CO-OH system."

And we added an introductory paragraph to Section 4.2:

"Any model simulation using annually-repeating and archived OH will not accurately capture regional and interannual variations in the loss rates of methane and CO. A simulation using zonally-averaged archived OH (e.g., Spivakovsky et al., 2000), such as was done in the TransCom MIP, will not capture any regional and interannual variations. For example, Fig. S 7 and Fig. S 12 reproduce Fig. 4a and Fig. 5, respectively, but includes methane from a simulation using archived and annually-repeating OH of the NASA Global Modeling Initiative model (Duncan et al., 2007b; Strahan et al., 2007). The simulated longer methane lifetime (Fig. S 7), using archived OH, leads to an accumulation of methane over the multi-decadal simulation."

And we added the following paragraph to the end of Section 4.3:

"Accurate quantification of the magnitude of the combined nonlinear feedbacks is ultimately dependent on the uncertainties and errors of emissions, such as those discussed in Sect. 3, and independent variables, each of which have their own uncertainties, used in the parameterization of OH. With our sensitivity simulations, we discussed instances when changes to emissions and/or the input to the parameterization of OH improved or worsened the simulated methane and CO. In some instances, simulated methane and/or CO from the least complex *Base* scenario more favorably agreed with observations than the other more complex scenarios, including methane in the most complex *AllVary* scenario (e.g., Table 4, Fig. 4). However, in these instances, better correlation does not necessarily imply that a simpler scenario, such as the *Base* scenario or a scenario that uses archived and annually-repeating OH, is inherently better. The best scenario is one that accurately simulates the complex interactions of the factors that influence the $CH_4$-CO-OH system, which will give confidence in the response of the system to perturbations, such as from large interannual variations in wetland fluxes, biomass burning, ENSO, and volcanic eruptions. The next steps for our research include quantifying the 1) sensitivity of the simulated $CH_4$-CO-OH system to uncertainties in the factors (e.g., water vapor, clouds, trace gases) that control tropospheric OH so as to improve simulated methane and CO with observations, and 2) the influence of potential large atmospheric carbon perturbations in a warming world, such as may occur from permafrost thaw, methane hydrate release, and enhanced biomass burning."

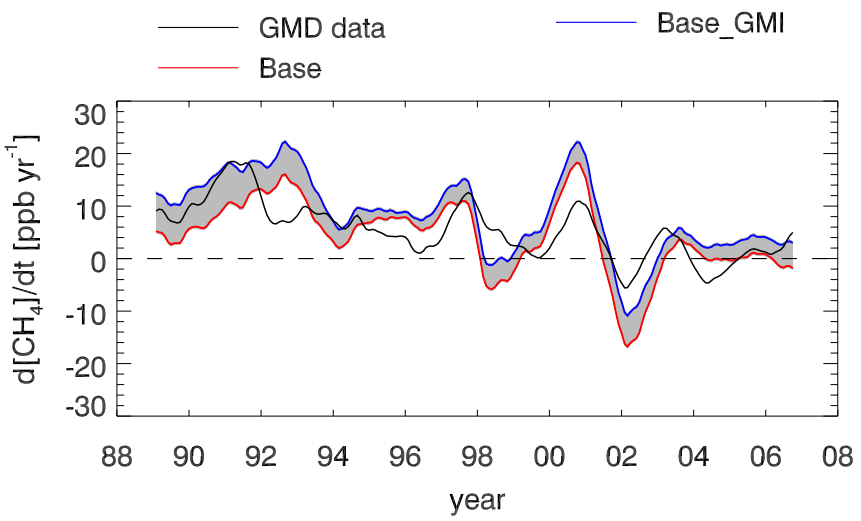


Figure 1: Same as Fig. 4 (Manuscript) but the shaded area is the difference between the *Base_GMI* and *Base* scenarios. *Base_GMI* scenario is similar to the *Base* scenario except that OH is archived 3D fields (i.e., not interactively simulated).

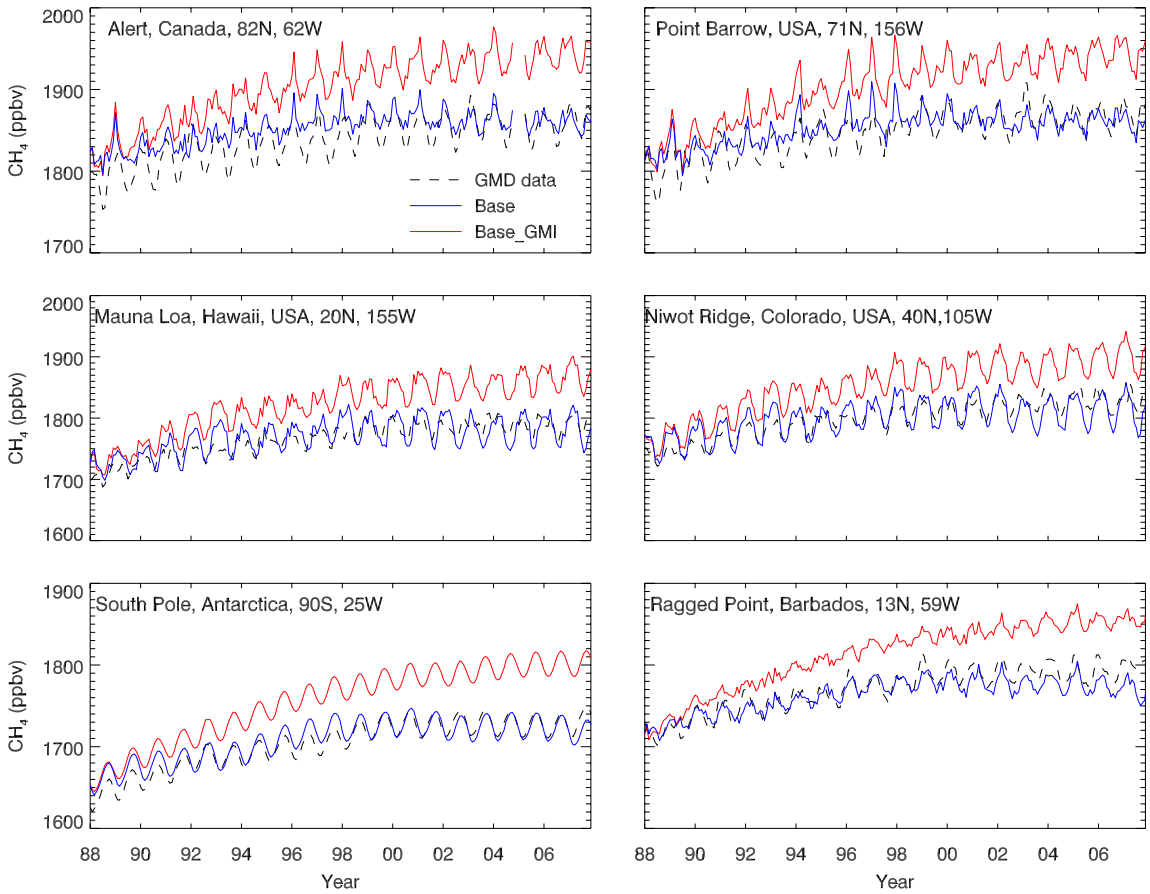


Figure 2: Monthly methane (ppbv) from the *Base* and *Base_GMI* scenarios and observations from six GMD stations. *Base_GMI* scenario is similar to the *Base* scenario except that OH is archived 3D fields (i.e., not interactively simulated).

Comparison with a full chemistry model would also be useful.

That has been done and is discussed in Sect. 3.1, Page 9459, lines 15-27 and in Section S 3 of the Supp. Mat.

Does the parameterization require having a companion full chemistry simulation to provide the driving parameters? If so, then the value here must be that the parameterized version allows for cheaper sensitivity simulations relative to that single full chemistry simulation. If this is correct, it would help to state this more clearly.

To address this suggestion, we added the underlined text to the second paragraph of Section 2.1:

"The parameterization of OH accurately represents OH predicted by a full chemical mechanism as a set of high-order polynomials that describe the functional relationship between the concentration of OH and meteorological variables (i.e., pressure, temperature, cloud albedo), solar irradiance variables (i.e., ozone column, surface albedo, declination angle, latitude) and chemical variables, including CO and methane as well as nitrogen oxides (as a family), ozone, water vapor, and various VOCs. That is, the 24h average OH is calculated interactively in the model and responds to changes in the concentrations of trace gases and meteorology. Input variables to the parameterization of OH may be taken from archived fields from, for instance, an observational climatology or archived fields from a model simulation with a full representation of trace gas and aerosol atmospheric chemistry, and may be annually-repeating or annually-varying. Some variables (e.g., water vapor, clouds) may be taken from the host model as the simulation progresses. Ideally, all input variables should be annually-varying so as to best capture the nonlinear feedbacks of the $CH_4$-CO-OH system. If one chooses to use output from a single computationally-expensive full chemistry model simulation as input to the parameterization of OH, subsequent sensitivity simulations using the ECCOH chemistry module will be far less computationally-expensive relative to that single expensive simulation, which is the primary strength of using the parameterization of OH. In Section 2.2, we discuss the setup of the simulations presented in this study.

Is the factor of 500 a result from this work or is that number based on the 2000 paper (P 9455 L9-11)? It would be useful to provide a brief description of what the parameterization involves, including that it is tailored to regional chemical and meteorological conditions.

The factor of 500 is from the 2000 paper as cited.

To address the reviewer's concern, we modified the following sentence from:

"It was designed to be applicable to preindustrial, present day and possible future conditions (Duncan et al., 2000) and has been used in several studies of CO and OH (Duncan et al., 2007a; Duncan and Logan, 2008; Strode et al., 2015)."

To:

"It is based on the method described by Spivakovsky et al. (1990a), who developed an earlier version of the parameterization of OH used in several studies, including Spivakovsky et al. (1990b) and Prather and Spivakovsky (1990). The parameterization of OH of Duncan et al. (2000) is designed to simulate OH over the range of photochemical environments found throughout the troposphere, including a wide enough range so as to be applicable to preindustrial, present day and possible future conditions (Duncan et al., 2000). It has been implemented into two host atmospheric models and has been used in several studies of the nonlinear feedbacks of CO and OH (Duncan et al., 2007a; Duncan and Logan, 2008; Strode et al., 2015)."

Consider reducing the number of figures in the supplemental material and possibly in the main text.

We deleted Figures S11, S12, S17, S18 - S24 from the Supplemental Material.

**Specific comments follow.**

P9453 L23. How large is this bias from using archived OH?

We added an introductory paragraph to Section 4.2:

"Any model simulation using annually-repeating and archived OH will not accurately capture regional and interannual variations in the loss rates of methane and CO. A simulation using zonally-averaged archived OH (e.g., Spivakovsky et al., 2000), such as was done in the TransCom MIP, will not capture any regional and interannual variations. For example, Fig. S7 and Fig. S12 reproduce Fig. 4a and Fig. 5, respectively, but includes methane from a simulation using archived and annually-repeating OH of the NASA Global Modeling Initiative (GMI) model (Duncan et al., 2007b; Strahan et al., 2007). The simulated longer methane lifetime (Fig. S7), using archived OH, leads to an accumulation of methane over the multi-decadal simulation. In this situation, the archived OH would need to be adjusted higher to improve the simulation of methane as compared to observations."

P9454 L19-22. Does the parameterization avoid this uncertainty somehow? Is it up-dated to include more recent isoprene-$NO_x$-OH relationships?

In this paragraph, we simply make the point that the large uncertainty in OH occurs because there are very few observations of OH and they often disagree with model output that include state-of-the-art chemical mechanisms, including in non-polluted,

forested environments where isoprene is the dominant VOC. That is, there is large uncertainty in current OH chemistry because of incomplete knowledge of OH sources and recycling mechanisms. Therefore, the parameterization of OH is not immune to the uncertainties in OH chemistry. We do not imply this in the paragraph in question.

We added the following sentence to the end of the paragraph in question to address the reviewer's concern:

"Recent updates in isoprene chemistry are not reflected in the parameterization of OH, so OH near the surface in clean, forested environments (e.g., Amazon and Congo basins) is too low relative to current knowledge (e.g., Fuchs et al., 2013). However, the contribution of these regions to global methane and CO loss is small (i.e., < 1%) and the current knowledge of isoprene photochemistry is still highly uncertain (Fuchs et al., 2013). Ultimately, the parameterization of OH reflects uncertainties in the chemistry upon which it is based, as do the photochemical mechanisms in all atmospheric chemistry models (e.g., Stone et al., 2012; Fuchs et al., 2013)."

P9455-9456 Is this the only update from the parameterization described in the 2000 paper?

Yes. Upon comparison of the mechanism used to generate the parameterization with current photochemistry, we found that the quenching reactions of $O^1D$ are by far the most important update, especially as they globally determine the primary production of OH.

Are total ozone columns and stratospheric OH, Cl, and O1D varying interannually?

As mentioned in Tables 1 and 2, ozone columns are annually-repeating in all simulations, except they are annually-varying in the $OH_{input}Vary$ and *AllVary* scenarios. Year-to-year variations in the ozone column are very important in the simulation of tropospheric OH and CO (Duncan et al., 2008).

The stratospheric OH, Cl, and $O^1D$ archived monthly fields are annually-repeating and from an AGCM simulation. Stratospheric loss processes for CO and methane are non-negligible, though their typical year-to-year variations have an unimportant impact on tropospheric OH, CO, and methane.

Are photolysis rates calculated explicitly in ECCOH (P9456 L4)?

No. There are no photochemical rates used as independent variables in the parameterization of OH. The parameterization was designed to be grounded in observations of chemical concentrations, solar irradiance variables and meteorological variables. The independent variables are explicitly listed in the second paragraph of Section 2.1.

P9457 L18. Where does Table 2 describe the input variables?

The input variables are the same in all scenarios as in the *Base* scenario (Table 1), except in the $OH_{input}Vary$ and *AllVary* scenarios – the last two rows of Table 2.

We added to the sentence (underlined text) in question to clarify this:

"These causal factors include annually-varying methane and CO emissions (i.e., Scenarios 2-4 in Table 2; natural methane emissions, and anthropogenic and natural CO emissions, Figs. S1 and S2 in the Supplement) and annually-varying input variables to the parameterization of OH (i.e., Scenario 5 in Table 2)."

P9458 L11-13 seems to require the reader to know what these distributions look like. L18-19 consider showing this comparison.

For clarity, we modified the sentence with the underlined text:

"Despite the challenges concerning OH, we show in this section that the spatial and vertical distributions of simulated global mean OH (Figs. 2 and 3) from the *Base* scenario are reasonable relative to the MCF proxy for OH as well as to simulated OH from other models."

The last sentence of the paragraph is now:

"The seasonal and vertical distributions of the zonal mean OH in the *Base* scenario are quite comparable to the OH climatology of Spivakovsky et al. (2000; see Figure 6 of Spivakovsky et al.), despite the different inputs given to the parameterization of OH in the two studies."

P9459 L3-15 Are these values all for lifetimes with respect to tropospheric OH loss only?

Yes, as also mentioned in the text (P9459, L4).

The method for calculating lifetime of methane/MCF is similar in all mentioned studies, which is by dividing the global atmospheric burden of methane or MCF by its tropospheric OH oxidation flux, except in the study of Naik et al., 2015, where MCF lifetime was calculated by scaling the methane lifetime with the ratio of the rate coefficient of the reactions of methane and MCF with OH integrated from the surface to the tropopause (see Naik et al., 2015 for more details). In Shindell et al., (2006), the lifetime calculation method is not stated explicitly.

P9459 L26. Are these models for the same period as the ECCOH simulations?

For the ACCMIP simulations (Voulgarakis et al., 2013)), the model experiments are the present day (2000 time slice) and future simulations (representative for the

conditions of 2030 and 2050). The mentioned ACCMIP results are for the 2000 time slice. Our simulations are also from 1988-2007, and using the same CO annually-repeating emissions, as mentioned in the text and in Table 1.

For clarity, we updated the last sentence with the underlined text as follows:

"The global, mean tropospheric OH in the *Base* scenario of $10.9 \times 10^5$ molecules $cm^{-3}$ also compares well with that of $11.4 \times 10^5$ molecules $cm^{-3}$ from the ACCMIP simulation (the 2000 time slice) as well as within the range of means from other models (e.g., 6.5 – 13.4 $\times 10^5$ molecules $cm^{-3}$ (Voulgarakis et al., 2013))."

P9460 L3 Table 3 should be Table 4 ?

We removed the incorrect table reference.

L4 "reasonably well" would be stronger if supported by a more objective measure like a correlation coefficient or bias estimate.

Done. $R^2$=0.44 for the base scenario is now included in the text.

L20. What is the evidence for regional high biases in natural emissions; are there isotopic measurements?

The *Base* scenario (based on the CTL TransCom emissions scenario) has annually-varying anthropogenic emissions but annually-repeating natural emissions (Fig. S1). In the $E_{CH4}$*Vary* scenario, (based on the EXTRA TransCom emissions scenario) anthropogenic and natural emissions are annually-varying. The regional high bias improves significantly in the $E_{CH4}$*Vary* scenario, indicating that the reason for the high bias in the *Base* scenario is a high bias in the natural emissions. Saito et al. (2013) mentioned that the CTL and EXTRA emissions differ by more than 100% over some of the regions.

**P9466 L26. How large is the vertical gradient in CH4?**

We added the underlined text to the sentence in question:

"In addition, most loss occurs near the surface despite higher OH in the mid-troposphere (Fig. 2) because of higher methane mole fractions near the surface (e.g., ~3 % over Alaska, and typically higher over surface source regions), the altitude dependence of air density, and the temperature dependence of the loss rate (Fig. 18). Methane's loss rates in the *AllVary* scenario are relatively higher, especially over biomass burning regions (Fig. 17) and have much higher spatial variability than in the Base scenario (Fig. 19)."

P9467 L12-16. Consider adding a statement to explain why this can't be equally well studied with sensitivity simulations using archived offline OH fields.

We incorporated the reviewer's suggestion with the underlined text in the paragraph in question:

"The differences in global abundances of CO and OH between our least complex (*Base*, Table 1) and most complex (*AllVary*, Table 2) scenarios are substantial and their impact on methane's evolution is nontrivial as discussed in Sects. 4.1 and 4.2. Therefore, model studies of methane and/or CO, which use archived fields of OH distributions, will not capture these important nonlinear feedbacks of the $CH_4$-CO-OH system (e.g., Fig. 4). Here, we discuss the contribution of various factors to the observed spatial distributions and temporal evolution of observed methane, CO, and OH to demonstrate the utility of the ECCOH chemistry module for studying the nonlinear $CH_4$-CO-OH system. We provide a brief summary of our conclusions from the scenarios at the end of this section."

P9468 L25-26. Are overhead ozone columns and lightning NOx varying in ECCOH online?

Monthly archived fields of overhead zone column and lightning $NO_x$ are annually-varying in the $OH_{input}Vary$ and *AllVary* scenarios, but annually-repeating in the other scenarios as shown in Table 2.

For clarity, we modified the sentence in question with the underlined text:

"For example, both variations in the overhead ozone column and NO emissions from lightning are known to cause variations in global OH (e.g., Duncan and Logan, 2008; Murray et al., 2013)."

P9469 L11. Are these numbers for the Base or AllVary or both?

*AllVary* scenario. The statement is now rearranged to be clearer:

"Despite large spatial differences in OH, the global, mean MCF lifetime for the *AllVary* scenario, which range from 6.01 (±0.51) to 6.67 (±0.61) years over the simulation period, is not significantly different from that of the *Base* scenario."

P9469 L21. How important is this compared to uncertainty in emissions?

We added the following paragraph (with underlined new text) to the end of Section 4.3 to address this concern:

"Accurate quantification of the magnitude of the combined nonlinear feedbacks is ultimately dependent on the uncertainties and errors of emissions, such as those discussed in Sect. 3, and independent variables, each of which have their own uncertainties, used in the parameterization of OH. With our sensitivity simulations, we discussed instances when changes to emissions and/or the input to the parameterization of OH improved or

worsened the simulated methane and CO. In some instances, simulated methane and/or CO from the least complex *Base* scenario more favorably agreed with observations than the other more complex scenarios, including methane in the most complex *AllVary* scenario (e.g., Table 4, Fig. 4). However, in these instances, better correlation does not necessarily imply that a simpler scenario, such as the *Base* scenario or a scenario that uses archived and annually-repeating OH, is inherently better. The best scenario is one that accurately simulates the complex interactions of the factors that influence the $CH_4$-CO-OH system, which will give confidence in the response of the system to perturbations, such as from large interannual variations in wetland fluxes, biomass burning, ENSO, and volcanic eruptions. The next steps for our research include quantifying the 1) sensitivity of the simulated $CH_4$-CO-OH system to uncertainties in the factors (e.g., water vapor, clouds, trace gases) that control tropospheric OH so as to improve simulated methane and CO with observations, and 2) the influence of potential large atmospheric carbon perturbations in a warming world, such as may occur from permafrost thaw, methane hydrate release, and enhanced biomass burning."

We added the following figures to the Supplemental Material.

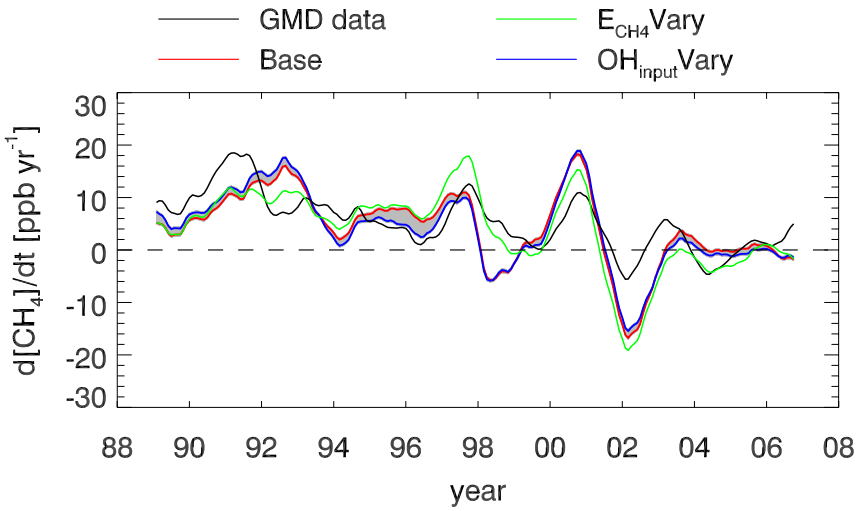


Fig. 1: Atmospheric methane growth rate (ppbv/yr, average of 92 GMD stations) from several scenarios. The shaded area is the difference between the *Base* and $OH_{input}$*Vary* scenarios.

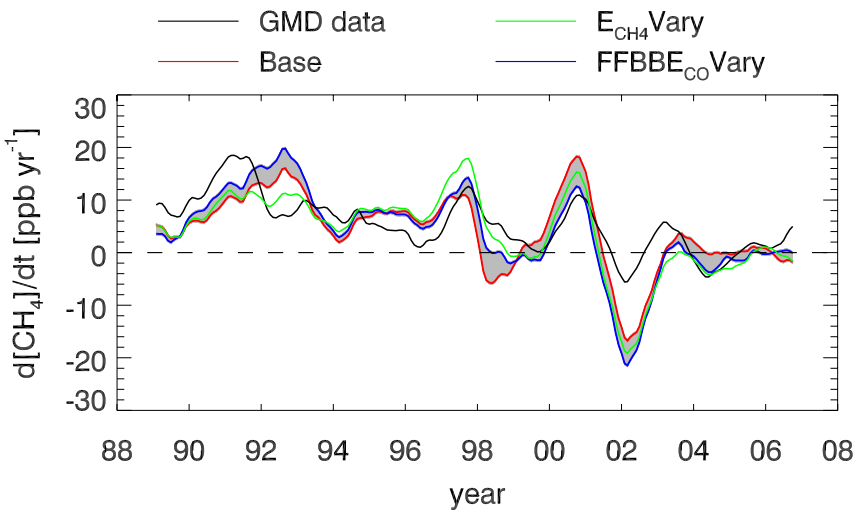


Fig. 2: Atmospheric methane growth rate (ppbv/yr, average of 92 GMD stations) from several scenarios. The shaded area is the difference between the *Base* and *$FFBBE_{CO}Vary$* scenarios.

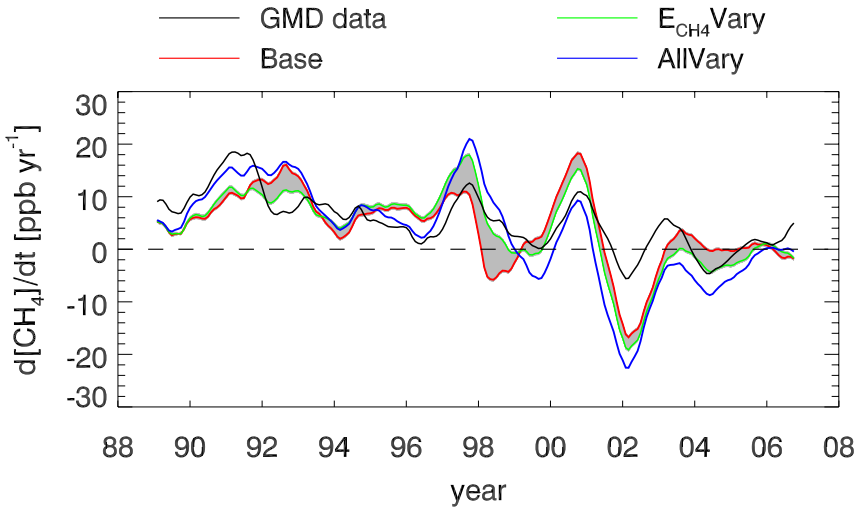


Fig. 3: Atmospheric methane growth rate (ppbv/yr, average of 92 GMD stations) from several scenarios. The shaded area is the difference between the *Base* and *$E_{CH4}Vary$* scenarios.

P9470 L4-6. It would help to point to the evidence supporting this statement.

We added a new sentence (underlined) to the end of the summary:

"Through our simulations, we show the importance of using an interactive $CH_4$-CO-OH system as opposed to using static, archived OH fields, as nonlinear feedbacks on methane, CO, and OH are non-trivial. <u>For example, nonlinear feedbacks modulate the global methane growth rate over our study period (±20 ppbv $yr^{-1}$) by ±4 ppbv $yr^{-1}$ (Figure 4).</u>"

Table 1. The methane tracer is inactive in radiation, but surely there is a methane abundance set in the radiation code?

Yes, greenhouse gases, including methane, are provided as archived fields to the radiation scheme in the current setup.

We modified (underlined) the sentence in question to:

"The methane tracer is radiatively inactive and archived, annually-varying methane fields are used in the radiation code; our aim is reproduce the same meteorology in all simulations so as to more cleanly isolate the impact of the causal factors on methane, CO, and OH trends and variations."

It would be good to clarify that the emissions used here are bottom-up estimates if that is the case. Are the anthropogenic emissions based on EDGAR or have they been optimized through prior inversions?

Methane emissions are based on the TransCom CTL (Base scenario) and EXTRA emission scenarios (Patra et al., 2011). As mentioned in Patra et al. (2011), methane anthropogenic emissions in the CTL scenario are bottom up estimates that are based on EDGAR 3.2, being inter-/extra-polated using 1990, 1995, 2000 emission maps to produce the IAV in emissions (i.e., original EDGAR emissions are only from 1990-1995). EXTRA emissions are optimized to include IAV in biomass burning and wetland emissions. In Table 2, other emissions are explicitly mentioned. CO emissions in the *Base* scenario are gridded emissions that were prepared for the CMIP studies (Lamarque et al., 2013 and Lamarque et al., Atmos. Chem. Phys., 10, 7017–7039, 2010).

To address the referee's comment, we modified (underlined text) the sentence in question:

"Annually-repeating natural (e.g., wetlands, biomass burning) and annually-varying anthropogenic emissions (EDGAR 3.2, TransCom CTL scenario) are described in Patra et al. (2011)."

Table 4. Is there an explanation for why AllVary often performs worse than Base?

To address this concern, we added the following text to the end of Section 4.3:

"Accurate quantification of the magnitude of the combined nonlinear feedbacks is ultimately dependent on the uncertainties and errors of emissions, such as those discussed in Sect. 3, and independent variables, each of which have their own uncertainties, used in the parameterization of OH. With our sensitivity simulations, we discussed instances when changes to emissions and/or the input to the parameterization of OH improved or

worsened the simulated methane and CO. In some instances, simulated methane and/or CO from the least complex *Base* scenario more favorably agreed with observations than the other more complex scenarios, including methane in the most complex *AllVary* scenario (e.g., Table 4, Fig. 4). However, in these instances, better correlation does not necessarily imply that a simpler scenario, such as the *Base* scenario or a scenario that uses archived and annually-repeating OH, is inherently better. The best scenario is one that accurately simulates the complex interactions of the factors that influence the $CH_4$-CO-OH system, which will give confidence in the response of the system to perturbations, such as from large interannual variations in wetland fluxes, biomass burning, ENSO, and volcanic eruptions. The next steps for our research include quantifying the 1) sensitivity of the simulated $CH_4$-CO-OH system to uncertainties in the factors (e.g., water vapor, clouds, trace gases) that control tropospheric OH so as to improve simulated methane and CO with observations, and 2) the influence of potential large atmospheric carbon perturbations in a warming world, such as may occur from permafrost thaw, methane hydrate release, and enhanced biomass burning."

Figure 2. Consider replacing AllVary with a difference plot.

Done.

Figure 4. Please describe how the growth rate is calculated and how to interpret the gray shaded area.

The new figure caption is:

"Figure 4. 12-month running mean atmospheric growth rate of methane (ppbv $yr^{-1}$) for the average of 92 GMD stations and from model output for several scenarios averaged for those station locations. The shaded area is the difference between the *E$_{CH4}$Vary* and *AllVary* scenarios, which indicates the total contribution of nonlinear feedbacks (i.e., from variations of CO emissions and variables input to the parameterization of OH) of the $CH_4$-CO-OH system to methane's growth rate."

Figure 7. Why is ECH4_vary closer to observations than AllVary? Does this imply a problem with the parameterization, emissions, or both?

See our response to the specific comment on Table 4 a few comments ago.

Figure 12. Not sure what the vertical line sentence in the caption refers to.

That is a mistake. Deleted.

Figure 14. Caption needs fixing.

Done.

Figure 15. Is there an explanation for why the model is frequently the wrong sign?

In short, our study isn't the only one that cannot reconcile the observations with model output, which may indicate errors in the observations, the models, or a combination of both. However, we don't explicitly say that several researchers question the validity of the observations. Instead, we subtly indicate this in Sect. 4.1:

"We compare simulated, mass-weighted pseudo first order rate constants (k'), a proxy for OH interannual variations, from each of our scenarios to that inferred from MCF measurements (Fig. 15; 1998–2007; Montzka et al., 2011). We find that none of our model scenarios are able to reproduce the inferred interannual OH variability of Montzka et al. (2011), though the simulated variability is of similar magnitude and within observational uncertainty. Our findings are consistent with other modeling studies (Montzka et al., 2011; Holmes et al., 2013; Murray et al., 2013 and references therein). While global interannual variations are informative, there can be considerable OH interannual variations regionally (as discussed in Sects. 4.2 and 4.3) that may not be reflected in the global average (Lelieveld et al., 2002; Wild and Palmer, 2008)."

Figure 16. Consider adding correlation coefficients.

Done. The following sentence is now added to the caption of Fig. 16:
The correlation coefficients ($R^2$) of the MEI index with the *Base* and *AllVary* scenarios are 0.20 and 0.59, respectively.

And the correlation coefficients are also mentioned in the text (last paragraph of sect. 4.1):

"As shown in Fig. 16, the deviations of mass-weighted OH from various scenarios over Indonesia (100°-150°E; 6°N-6°S) are generally anti-correlated with the Multivariate ENSO Index (MEI, Wolter et al., 2011), a proxy of ENSO. OH variations in the *Base* scenario, which includes meteorological variations that affect OH via variations in water vapor, clouds, etc., are ±4% ($R^2$ = 0.20), but much higher in the scenarios that include variations in biomass burning emissions (i.e., *AllVary* scenario), which better capture the ENSO variability ($R^2$ = 0.59)."

Figure 22. What are the deviations relative to? Is this the standard deviation?

That is the standard deviation. The caption is now corrected.