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Interactive comment on “Limited impact of El Niño – Southern Oscillation on the methane cycle” *by* Hinrich Schaefer et al.

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We thank Alex Turner for the time taken to evaluate our study and for the helpful comments and suggestions. Below we address each criticism individually. Please note that some points were brought up by several referees and commenters; please see our other responses for additional information and changes to the manuscript. Referees' comments are bracketed as follows: <>. Our response is in regular font. Quotes from the manuscript are in quotation marks.

<The manuscript argues for a limited role of ENSO on the methane cycle; however, the manuscript makes little mention of two important factors that impact atmospheric methane and are strongly influenced by ENSO: (1) atmospheric transport and (2) loss via hydroxyl. These factors seem particularly pertinent to a discussion of the role of ENSO on the methane cycle. There have been a number of recent papers on these two topics in the last two years that the authors seem to have overlooked. Specifically, McNorton et al. (2016), Turner et al. (2017), and Rigby et al. (2017) showed how changes in the methane loss via oxidation by hydroxyl was an important factor in the interpretation of methane trends.>

These papers are relevant for a complete picture of the methane cycle in the introduction and conclusion. We have added references in these sections. In contrast, for the core question of our study they are not relevant, just as anthropogenic sources like fossil-fuel methane are not. We note that a recent OH-reconstruction (Naus et al., 2018) finds that sink trends may be less relevant than modelled by Turner et al. (2017) and Rigby et al. (2017).

Changes to the manuscript are as follows:

Introduction: “Considering recent reconstructions of methane's dominant atmospheric sink, i.e. the hydroxyl radical OH, we consider it likely that increasing emissions contribute to (Rigby et al., 2017), if not dominate (Naus et al., 2018), the [CH4] rise. If so, the methane source type that varied can be investigated…”

Introduction: “Changes in OH have also been suggested as partial or dominant drivers in recent CH4 trends, both for the onset of the 1999-2006 plateau (McNorton et al., 2016; Schaefer et al., 2016) and for the post-2007 [CH4] increase (Rigby et al., 2017; Turner et al., 2017).”

Conclusions: “Changes in removal rates via OH have been suggested as an additional (Rigby et al., 2017) or alternative (Turner et al., 2017) driver of the increase, but recent work suggests that sink impacts are not dominant (Naus et al., 2018).”

<More directly related to ENSO, Corbett et al. (2017) showed the influence of ENSO on the spatial distribution of methane via changes in atmospheric transport… >

The role of transport is relevant for the tropical time series. We have included a discussion of the findings of Corbett et al. (2017) as a possible explanation why ENSO signals are smaller than may have been anticipated. However, we also note that the observed anomalies in mid-tropospheric [CH4] are inconsistent with the patterns expected from emission changes. On hemispheric or global scales transport processes are unlikely to play a strong role, given the short mixing time of methane relative to its atmospheric turn-over.

Changes to the manuscript are as follows:

Section 5.3.7.: "Corbett et al. (2017) show that during La Niña events high surface temperatures over the Western Pacific lead to upward transport over the Indonesian region (a CH4 source area from wetlands and rice paddies) and negative CH4 anomalies in the mid-troposphere (tropical surface air with relatively low [CH4] replaces air from the Northern Hemisphere with higher [CH4]). This mechanism would dampen the signal of higher La Niña emissions in surface records like SMO and ASC. However, the corresponding El Niño anomalies in mid-tropospheric CH4 over the Central Pacific are smaller. This indicates that Central Pacific surface air, where there are no CH4 sources, is closer in [CH4] to mid-tropospheric levels than surface air from the Western Pacific. Unless there were strong longitudinal differences in mid-tropospheric [CH4], this is inconsistent with a scenario where high concentrations of CH4 are generated over the Western Pacific in La Niñas but transported upwards and away from the surface stations used in this study. On hemispheric or global scales transport processes are unlikely to play a strong role, given the short mixing time of methane relative to its atmospheric turn-over."

<...while Turner et al. (2018) showed how ENSO can strongly influence the methane lifetime.>

The findings of Turner et al. (2018) on tropical OH-dynamics during ENSO events are very relevant to this study. They are now laid out briefly in the introduction and are

discussed in depth in the revised section 5.3.7. In short, OH-dynamics are expected to provide a negative feedback on methane concentration signals from ENSO emissions but a positive feedback on the stable isotope signal. This offers an additional explanation why ENSO impacts on methane growth rates is less than has been suggested in some studies. It would also make δ13CH4 a more sensitive tracer for ENSO impacts but our records do no show the expected δ13CH4 signals.

Changes to the manuscript that result from this discussion are as follows:

Abstract: "Dynamics of the removal by hydroxyl may counteract the variation in emissions, but the expected isotope signal is not evident."

Introduction: "A chemistry climate model suggests that ENSO modulates tropical OH (where hydroxyl levels are highest) via changes in NOx production through lightning, ozone availability and specific humidity, as well as emissions of reactive carbon (Turner et al., 2018). Resulting changes in methane removal could create their own signal in atmospheric records of [CH4] and δ13CH4. They could also either reinforce or dampen the emission impacts discussed above."

Section 5.3.7.: "The low correlations of [CH4] and δ13CH4 with ENSO rule out a dominant role for ENSO triggered sink changes in atmospheric methane records. Removal processes could lead to either amplification or dampening of source signals. Higher emissions of methane and CO from biomass burning will draw down OH and weaken the sink. Emission factors from fires for CO are between 10 and 30-fold higher than for CH4 (Van der Werf et al., 2017), so that the biomass burning dynamics dominate the source of reactive carbon, leaving less OH during El Niños and more during La Niñas to draw down CH4. This would provide a negative feedback for the emissions [CH4]-signal from ENSO forcing. In contrast, the feedback on the ENSO emissions δ13CH4-signal would be positive due to varying enrichment of 13C-methane through sink fractionation (less removal leads to less 13C-enrichment of relatively 13C-depleted wetland emissions during La Niñas; more removal increases the 13C-enrichment from biomass burning emissions during El Niños further). In addition to the reactive carbon effect, (Turner et al., 2018) found a further OH increase during La Niñas due to higher lightning rates with NOx production. Turner et al. (2018) could attribute 17% of OH variability that is forced by climate cycles (rather than emissions of other atmospheric compounds) to ENSO. This is a minor part of the variability, but in consequence, the dampening effect on [CH4] and the reinforcing feedback on δ13CH4 would be even larger. In our correlation results these sink impacts are not apparent, as the [CH4] correlations for the tropical stations are higher than δ13CH4 correlations (Tables 1 and 2). Nevertheless, the OH-dynamics provide a possible explanation for the limited ENSO impact on [CH4] variability and trends. They also make δ13CH4 a conservative proxy for the influence that ENSO exerts on tropical methane. Whether ENSO has less influence on CH4 emissions than assumed or whether such an impact is overwhelmed by atmospheric removal or other CH4 cycle processes,. . ."

Conclusions: "As δ13CH4 is subject to a mutually reinforcing signal from ENSO suppression of wetland emissions and enhancement of biomass burning CH4 (or vice versa), as well as positive feedbacks from OH-dynamics, it is particularly suited to study the role of ENSO in the CH4 cycle. Conclusions: "Counteracting OH-dynamics are expected to further dampen any influence ENSO may have on methane growth rates."

Conclusions: "Our results do not rule out that ENSO influences CH4 emissions from wetlands and biomass burning through temperature, enhanced precipitation or droughts in key regions, but any such impacts are overwhelmed by OH-dynamics or other source and sink processes."

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