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Biogeosciences Discussions

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 the referee 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.

Referee #1:

<The manuscript (. . .) provides additional evidence that emissions sources that have high interannual-variability, i.e., wetlands and fire, are unlikely to be the dominant cause

of sustained emissions.>

This is an important point that we now state in the conclusions: Conclusions: "The longer the atmospheric [CH4] and δ13CH4 trends persist, the less probable are processes that impact IAV and short-lived cyclical events like ENSO as the driver."

<First, I recommend the authors revisit the title and modify to be more specific than just 'methane cycle' because this implies the authors were looking at methane emissions, but rather the authors investigated atmospheric concentrations. I would prefer a title along the lines of "Limited impact of El Niño – Southern Oscillation on the atmospheric methane growth anomalies".>

We have changed the title to: "Limited impact of El Niño – Southern Oscillation on variability and atmospheric growth rate of methane". This addresses the concerns voiced by the reviewer and also reflects that the revised manuscript also discusses sink dynamics.

<Second, the Introduction could be clearer to reflect that the authors are motivated by understanding atmospheric methane concentration anomalies rather than anomalies in emissions. The previous studies linking methane emissions to ENSO as a key driver are not in question, but currently the Introduction mixes a little the emissions and concentrations anomalies making the reader have to work to clarify this.>

We have clarified the scope and focus of the study. Please note that changes in response to SC2 are also relevant to this point.

Resulting changes to the manuscript are as follows:

Abstract: "Here, we test the impact of ENSO on atmospheric CH4 in a correlation analysis." Introduction: "Attributing recent changes in the methane budget, and the associated impact on its growth rate, to specific natural or anthropogenic causes is essential for climate change mitigation."

Introduction: "We conduct correlation analyses between ENSO variability and [CH4], as well as δ13CH4 records to quantify how much ENSO anomalies in emissions and sinks affect atmospheric CH4. Specifically, we explore how much of the year-to-year variability in methane levels can be attributed to ENSO. . .”

Introduction: “The aim is to detect the impact of ENSO on atmospheric CH4 levels on various spatial scales.”

Conclusions: “Further identification of these processes is necessary to inform climate change mitigation policies and climate projections.”

Further, following suggestions from both reviewers and an additional short comment, the revised manuscript also discusses sink dynamics. The relationship between the latter and variability in emissions is now clarified in the introduction. For more details on the treatment of sink dynamics please see the response to SC1.

<In Table 1, I assume the lag time is in months, so 54 is a 54 month lag? If so, many are longer than 12 months, which is contrary to the statement in Section 5.2 that says most are shorter than a year. >

We have clarified that lag times in the tables are reported in months, e.g. by including this information in the table captions. The statement that detrended time series at SMO generally have their highest correlations at lag times of less than one year holds true (the only exceptions are for EMI, as well as a few cases for SMO det-gro). We have modified the text to make it clearer that the short lag times only apply to SMO detrended data series.

Section 5.1.2.: “. . .our analysis therefore allows for lag times of up to 5 years in monthly increments in the calculations and reports the maximum r2 and lag time (in months) for a given ENSO-[CH4]/δ13CH4/HCN combination.”

Section 5.2.: “Methane mixing ratios show correlations with ENSO of r2-values up to 0.36 at SMO, but only for detrended time series (Table 1). [. . .] For SMO detrended [CH4] series, lag times are fairly consistent across the various ENSO indices and gen-

erally shorter than 1 year. For other [CH4] records at SMO and ASC the highest correlations are r2<0.23 and have lags of over 3 years.

<I am skeptical of such long lags, it is difficult to judge whether shorter lags were close in terms of significance to the longer lag times because these numbers are not presented.>

We agree that allowing for lags up to 5 years leads to questionable results. However, it is difficult to define a cut-off for lags. The current presentation provides an upper limit for ENSO influence. Given that the latter is found to be low, this represents a conservative estimate. For most dependent time series, there are cases of comparable r2-values for lags both longer and shorter than 3 years. Using a 3-year cut-off for lags therefore does not really affect the conclusions. Nevertheless, for specific r2-values with lags over 3 years that are mentioned in results and discussion, we now also report the corresponding highest r2 for lags of less than 3 years. We have revised sections 5.1.2. and 5.2. to address this point.

Section 5.1.2.: “A lag time between ENSO forcing and detection of resulting δ13CH4 or HCN variability at the measurement site, (or in the global average) is likely, due to a variety of factors that may lead to lags of unknown length and some of which may be cumulative: e.g., hydrology, plant growth and decay, microbial response, seasonal triggers for methanogenesis or burning, as well as atmospheric chemistry, mixing, and transport between source regions and sampling sites. Therefore, it is difficult to define a cut-off for lags. Literature estimates of specific lags range. . .”

Section 5.2.: “Although the analysis provides r2-values for lags up to 60 months (Tables 2-4), we consider it likely that lags of >3 years indicate spurious correlations given that individual ENSO events last 1-2 years and global atmospheric mixing times are on order of 1 year. Therefore, we also report the highest r2 for lags <3 years in the following sections. For other cases with lags >3 years in Tables 2-4, the highest relevant r2-value is lower than the reported value, where the latter places an upper limit on the influence of ENSO."

Section 5.2.: "For other [CH4] records at SMO and ASC the highest correlations are r2<0.23 and have lags of over 3 years (r2<0.19 for lags <3 years). The global running mean [CH4] time series shows r2=0.24 (lag: 4.5 years; r2=0.04 for lag <3 years) with the SOI running mean for the period 1998-2016.

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