We thank the reviewer for providing these comments. Reviewer comments are shown in bold followed by our responses.

General comments

1. **In this manuscript, the authors present a new process-based model of upland soil oxidation by microbes, MeMo. They showed major results on global methane uptake, its latitudinal and spatial distribution, and seasonal change, in comparison with previous models by Potter et al. (1996), Ridgewell et al. (1999), and Curry (2007). I agree that global methane budget is gathering attention in terms of global climate change and so that the topic is timely.**

   The manuscript provides a detailed description of basic concept and equations, mathematical solution, and environmental dependencies. I know that GMD accepts such a descriptive paper but still want to recommend shortening main text to some extent. The results presented in this manuscript are basic and lack scientific novelty; again, main text can be truncated by removing redundant statements of results in figures and tables.

   I'm not clearly sure what is the substantial advancement of the MeMO model, in comparison with previous models, because the new model used the similar framework for modeling soil methane oxidation. In fact, the estimated global total (34.3 Tg CH4/yr) is around the middle of the previous estimates (Table 7), and one apparent advantage is the better agreement with recent observations. In this regard, the low methane oxidation in humid tropics simulated by MeMO seems reasonable in comparison with previous ones.

We thank the reviewer for highlighting the timely nature of our research. In order to convey to readers how MeMo builds on earlier models it is necessary to provide details about the Potter et al, 1996, Ridgwell et al., 1999 and Curry, 2007 (PRC) class of models and the changes made in MeMo to enhance model capabilities. The equations that describe processes integrated into MeMo are not new but nonetheless must be presented in order to explain how different facets of the model operate and interact. In short, the level of detail contained in the manuscript is necessary to convey the formulation and validation of MeMo.

Our study and the development of MeMo advances previous efforts to simulate global uptake of atmospheric CH_4 in the following ways:

1. The performance of MeMo, and two previous PRC class models upon which MeMo is built, were evaluated against independent observational data (Figure 5 in the manuscript). This study is the first time that a global soil methanotrophy model has been evaluated in such a manner.

2. MeMo simulates a total global soil sink for atmospheric CH_4 that is similar to previous models; however, refinements incorporated in MeMo improve the quality of regional simulations without calibration of the model to local data. For example, the new soil

moisture and k_0 parameterizations in MeMo yield a significantly improved fit to observed CH_4 uptake rates in tropical and humid area soils, which other models presently overestimate (as noted by the reviewer).

3. MeMo includes parameterization for the impacts of atmospheric N-deposition and application of N-fertilizer on soil methanotrophy (see response to comment 4). Models R99 and C07 both use agricultural land area as a proxy for application of N-fertilizer and attenuation of CH_4 uptake rates. Their approach was not validated rigorously against observational data, which resulted in attenuation rates that are significantly larger than field observations, and also did not account for atmospheric N-deposition.

4. MeMo uses an analytical (exact) solution to quantify the depth and maximum consumption of atmospheric CH_4. This feature is particularly important for soil conditions (e.g., dry soil) where L is less than 50 cm (Supplementary 1, Figure S1). In such areas, previous models (C07) slightly overestimate CH_4 uptake fluxes because a larger fixed value of L has to be assumed.

5. MeMo is capable of quantifying the influence of autochthonous CH_4 sources on rates of soil uptake of atmospheric CH_4. This feature provides the ability to examine the role of seasonal or inter-annual changes in soil moisture on soil methanotrophy as a result of anoxia and methanogenesis in finely textured soil

2. **On the other hand, my serious concern is on the nitrogen limitation factor. The author seems to consider only atmospheric deposition, but in reality, fertilizer and manure input is much more important as nitrogen input into croplands. Previous models, Ridgwell et al. (1999) and Curry (2007), implicitly accounted for the effect by using land-cover data. If this is correct, the MeMo model underestimated the effect of nitrogen input on methane oxidation (as shown in Figure 9).**

There are two different aspects of the R99, C07 and MeMo models that must be considered in responding to this comment: model parameterization and driving data.

Models R99 and C07 use land cover area as a proxy for N-fertilizer application and do not consider atmospheric deposition of nitrogen. The models are parameterized to inhibit soil uptake of atmospheric CH_4 by 75% of the agricultural land percentage per grid. Parameterization is based on data from a single location and those findings have not been replicated to date. Current data show only a 0.33% decrease in CH_4 uptake flux per g N m^{-2} y^{-1} (Figure 4 in manuscript). In contrast, parameterization in MeMo is based on multiple laboratory and field observations of the inhibitory effect of N addition on methanotrophy.

A more detailed assessment of the impact of N-fertilizer application on soil methanotrophy simulated using MeMo was planned for a future study; however, in response to the reviewer's comment we have incorporated the effects of fertilizer input and atmospheric deposition of nitrogen in the manuscript. The driving data for the former are global time-dependent inputs of N-fertilizer reported by Nischinia et al. (2017).

The new results (Figure R1) show that nitrogen input inhibits global soil methanotrophy simulated in MeMo by 4 to 5% compared to inhibition of 7.1% in models R99 and C07. Regionally, MeMo simulates 72% inhibition in Europe, China and India compared to a 75% reduction in soil methanotrophy in models R99 and C07. However, in regions where significant areas of agriculture land exist but rates of N-input are low (e.g. South America) the simulated attenuation of CH_4 uptake by soil becomes very different for models R99 and C07 compared to MeMo. In such areas models R99 and C07 continue to simulate an inhibition of 75% whereas MeMo responds to the lower rates of N-input, leading to an inhibition of only 5 to 10%.

The global impact of N inhibition on soil uptake of atmospheric CH_4 differs between models: 1.38 Tg y^{-1} in MeMo, 2.43 Tg y^{-1} in model R99, and 10.1 Tg y^{-1} in model C07. The much larger inhibition in model C07 results from the inhibition factor (r_N) residing outside of the parameterization for bacterial oxidation, which causes attenuation of soil methanotrophy to power of two relative to the formulation in model R99. As stated previously, a key benefit of the new formulation for N inhibition in MeMo relative to the earlier models is that the amount of inhibition simulated regionally and globally is consistent with field and experimental observations.

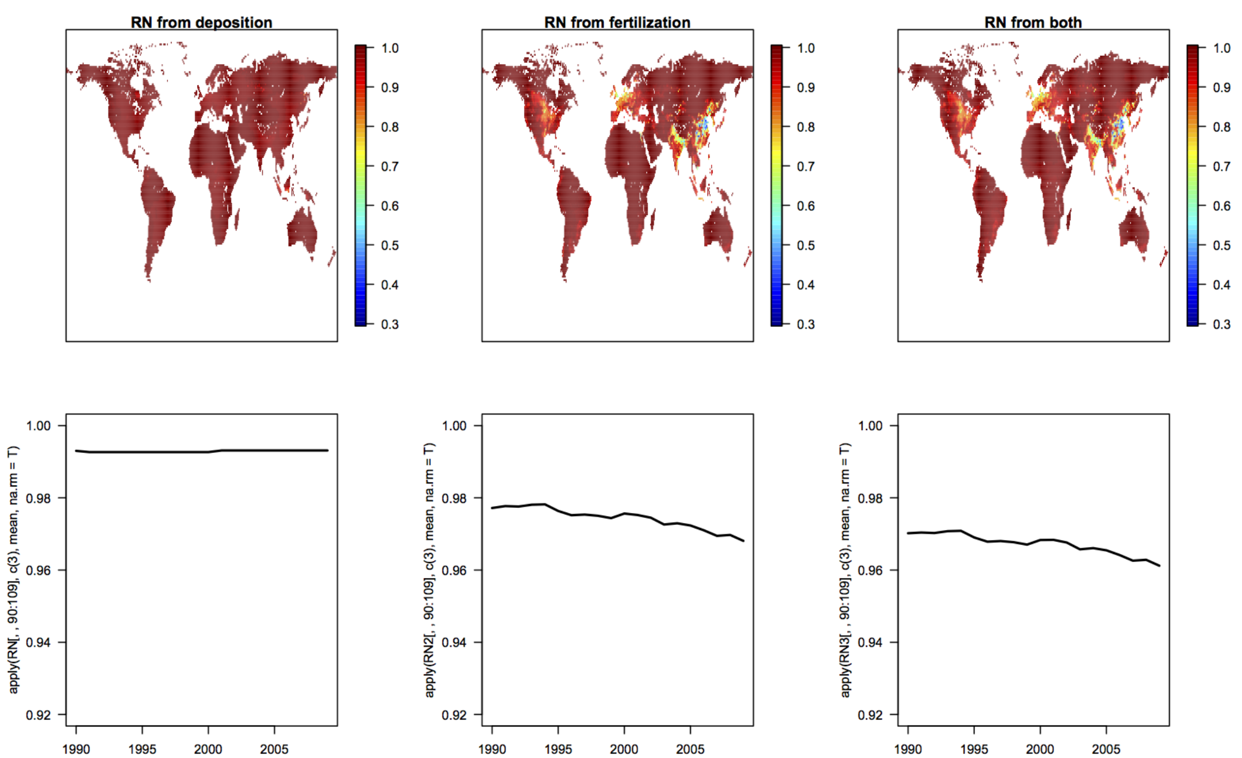

Figure R1: Nitrogen inhibitory effect (r_N) for atmospheric N-deposition (left), N-fertilizer application (middle), and both sources of N (right).

Overall, I conclude that the manuscript needs major revision and would be re- considered. I also recommend reinforcing discussion part with respect to implications to experimental and observational studies and potential impacts on climate projections and management.

In response to this comment we have incorporated new text in the manuscript on page 33, line 9:

"MeMo can be used to guide new field and laboratory experiments to address the lack of parameterization data, in particular, k0 and Q10 values for soil methanotrophy in different ecosystem and latitudes, and long-term *in situ* studies of N inhibition on CH_4 uptake by soil. It also can be used to compare results from short- and long-term investigations of CH_4 uptake in field and laboratory experiments."

On page 33, line 24 we added:

"Additionally, MeMo can be used to evaluate the impact of different proposed policies and mitigation strategies for managing the atmospheric burden and growth rate of CH_4 because of its capacity to evaluate different future scenarios based upon parameterization of key drivers that impact rates of CH_4 uptake by soil globally."

Specific comments

1. Page 2 Line 20: Please cite more recent syntheses of global methane budget (e.g., Saunois et al., 2016, 2017)

We have included the references in the manuscript.

2. Page 8 Figure 1: Please show the atmospheric CH4 concentration for this example.

We have added the CH_4 concentration as requested.

3. Page 14 Line 1: "Grosso" should be "Del Grosso".

This reference has been corrected.

References

We have added these suggested references:

Saunois M, Bousquet P, Poulter B, Peregon A, Ciais P, Canadell JG, et al. The global methane budget: 2000–2012. Earth System Science Data 2016, 8: 697–751.

Saunois M, Bousquet P, Poulter B, Peregon A, Ciais P, Canadell JG, et al. Variability and quasi-decadal changes in the methane budget over the period 2000–2012. Atmo- spheric Chemistry and Physics Discussions 2017: doi:10.5194/acp-2017-5296.