We thank the reviewers for the detailed and constructive comments. We agree with most of the suggestions and will make corresponding changes. We hope that our answers are sufficient and believe the manuscript will be much improved after the corrections. Detailed answers can be found in the files attached.

Reviewer 2

The authors investigated how simulated CH4 emissions from six ecosystem models respond to temperature and precipitation in Northern European regions. Then, simulated CH4 emissions from two ecosystem models exhibiting contrasting response patterns, and the ensemble mean of GCP atmospheric inversions, were used as priors of wetland emissions in an inversion. By doing this, they explored how the inversion changes the fluxes and alters the response of CH4 emissions to temperature and precipitation.

General comments:

Climate forcing used by the six ecosystem models are different. Previous studies have shown significant variations in process-based LSM outputs stemming from the choice of climate forcing. Four out of the six models were driven by CRUNCEPv7, one was driven by CRU-JRA and another one was driven by CRU-HARMONIE.

If my understanding is correct, temperature and precipitation data from CRU-JRA were applied to all six ecosystem models and the mean of GCP models, when studying the responses of simulated CH4 emissions to temperature and precipitation (Fig. 1). Why not use the specific climate inputs that drive each model?

To address this, we studied the effect of the climate input using results from uncoupled and coupled models (manuscript Fig. S1), where the driver data was either CRU-JRA for the uncoupled case or the ESM-specific climate model input for the coupled case. It would be expected that using coupled climate data as model input would lead to greater differences than simply using different uncoupled data sets, as all the uncoupled datasets (CRUNCEPv7, CRU-JRA and CRU-HARMONIE) are bias-corrected using precipitation and temperature measurements. The ESM-specific climate model data is not bias-corrected against such data. However, the response patterns were not significantly different ($p<0.01$). We are therefore confident that using CRU-JRA consistently throughout the paper produces robust results. To further test the impact of two different bias-corrected data sets, we created a figure (Fig. 1), where CRU-HARMONIE and CRU-JRA are plotted against JSBACH results, showing only small differences regarding the response of methane emissions to temperature and precipitation.

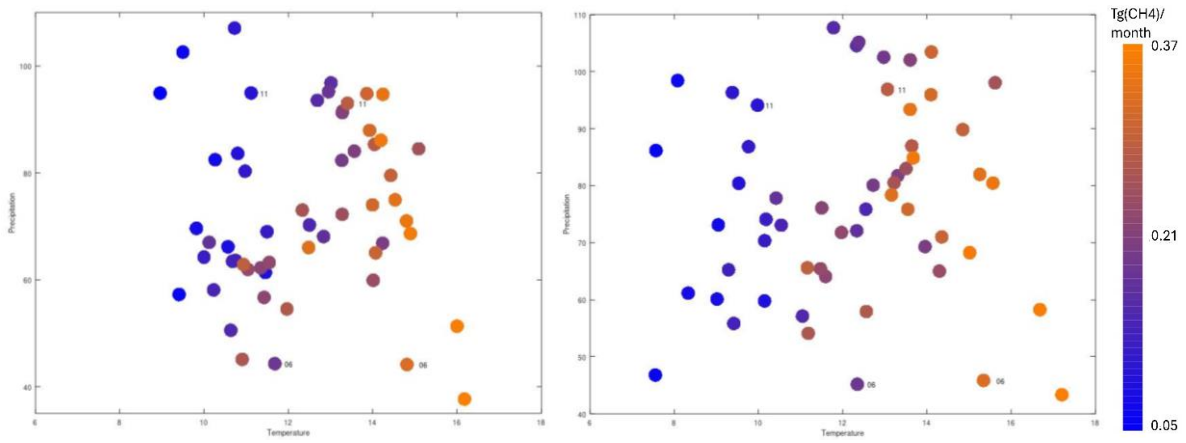

Figure X1: JSBACH ecosystem model results, plotted against left: CRU-HARMONIE (R^2_Temp =0.822, R^2_Prec = 0.054, R^2_TP = 0.834), right: CRU-JRA climate data (R^2_Temp =0.823, R^2_Prec = 0.0045, R^2_TP = 0.829).

The representation of wetland area and inundation were various among models. Some models used a static and prescribed wetland area, some models used prescribed but time-varying wetland area, and other models dynamically simulated inundation and wetland area. It would be very useful to have a figure to show the wetland area used by each model.

We will add figures of wetland areas of the models. As the area of inundated land and wet mineral land varies over time, we will provide example maps for the most relevant time periods. The combined wetland area map including peatlands, inundated lands and wet mineral lands is quite different compared to the methane emission maps, because wet mineral land can cover wide land areas but their emissions per unit area are smaller than those from peatlands (See example figures X2 and X3 below for JSBACH-HIMMELI model). ***Mineral soil was considered to be wet when the daily soil moisture, simulated for the 0.1 x 0.1 degree resolution grid cell, was high and there were methane emissions. Then the wetland fraction of the land area in that grid cell was 1.0, as the land area comprised of wet mineral land, inundated land and peatland, all emitting methane. The wet fraction of mineral lands was calculated from the individual daily 0.1 x 0.1 degree resolution grid cells up-scaled and averaged over the month in question and over years 2000 - 2018.***

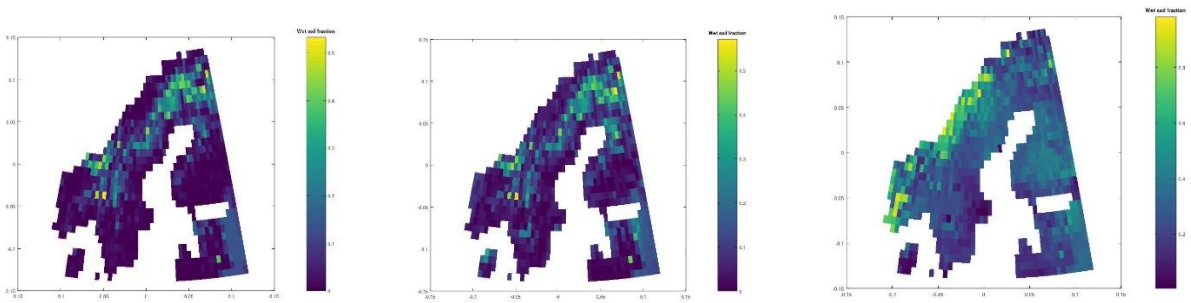

Figure X2: Methane emitting land areas in JSBACH-HIMMELI model, including a) peatlands, b) peatlands + inundated lands and c) peatlands + inundated lands + wet mineral lands. The wetland fraction is calculated as an average for the month of August over years 2000 – 2018.

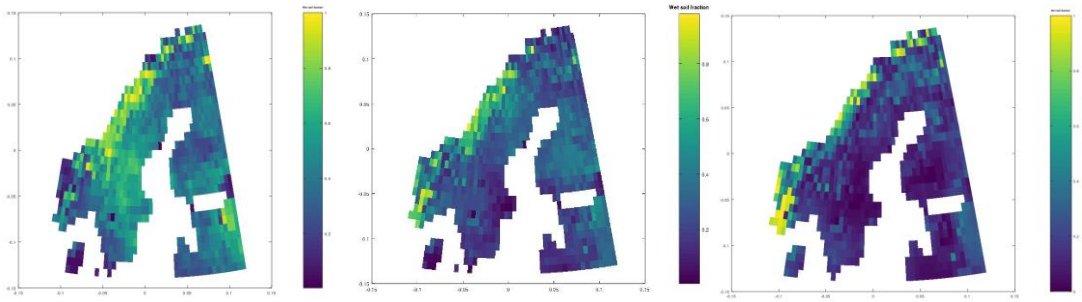

Figure X3: Methane emitting land areas (including peatlands + inundated lands + wet mineral lands) in JSBACH-HIMMELI model, for the month of a) July, b) August and c) September. The wetland fraction is calculated as an average for the month in question over years 2000 – 2018.

While the authors acknowledged the importance of wetland area in determining boreal regions CH4 emissions in both the introduction and the discussion section, the comparison of models' outputs and the analysis of precipitation and temperature responses didn't address the impact of wetland area.

We will discuss the wetland area in the results section; it was embedded in the discussion of emissions from wet mineral soils and inundated land, as the magnitude of those is determined by the extent of the wetland area.

See e.g. section 'Model components and seasonal cycle' for LPX-Bern: 'The soil moisture and consequently the wet mineral land area peaked in autumn, and thus the wet mineral land emissions were at maximum in October in contrast to peatland emissions,….

Figure 7 shows substantial difference among models in terms of both the magnitude and the seasonal cycle of CH4 emissions. The influence of climate forcings and wetland area on these differences should be explicitly discussed.

We will add the following text on the impact of the wetland area, climate forcings and model features on the seasonal cycles:

Note that each model presents differences in seasonal cycle and peak month as they differ in wetland area (Figure: wetland area) and model features. On the contrary, the use of different climate-forcing data products or results from coupled climate simulations show minor differences in methane emission responses (Figure X1and existing Figure S1).

Though the authors showed both prior and posterior wetland CH4 emissions from the inversion model in Figure 6, as a reader not familiar with inversion models, I still find it challenging to grasp how the prior wetland CH4 emissions are adjusted. To achieve changes in both the magnitude and seasonal cycle of prior wetland CH4 emissions as shown in Figure 6, what other sources or sinks of CH4 have been altered?

The inversion model used in the current work adjusts the emissions of CH4 every week. Thus, in addition to optimizing the magnitude of the emissions, the seasonal cycle is also adjusted. In addition to biospheric emissions inversions also optimize the anthropogenic emissions, but these have much less seasonal variability. Anthropogenic emissions are optimized separately but at the same time as natural emissions so that the total emissions produce modelled atmospheric concentrations that are consistent with concentration observations. There are also minor sources that are not optimized, from e.g. fires, termites and ocean, and the atmospheric sink which is calculated using prescribed data obtained from a chemistry model (e.g. OH fields).These details will be added to the description of CTE-CH4.

Specific comments:

L266: explained CH4 emission -> CH4 emission

We will correct the wording

L338: Fig 1 should be Fig 2

We will correct the number

L392: to -> of?

We will correct the wording

Figure 3: A figure for upscaled flux observations could be added to show observation-based temperature and precipitation responses of wetland CH4 emissions.

A figure will be added (Fig. X4 below), using data from Olli Peltola et al 2019. There are not as many summer months of data as for the models, but the results suggest that the fluxes are correlated with both temperature and precipitation (R^2*_Temp =0.83,* R^2*_Prec = 0.54,* R^2*_TP = 0.91).*

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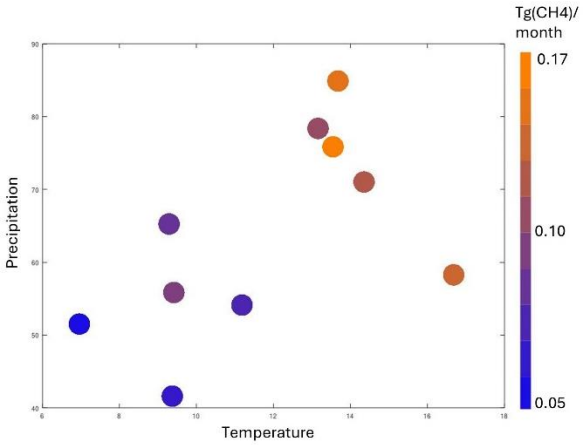

Figure X4. Temperature and precipitation responses of upscaled methane emissions in Fennoscandia. Circles refer to monthly averages in May - September during years 2013-2014.

Figure 6: The seasonal cycle of in situ atmospheric CH4 observations could be included in this figure to aid in understanding why the CTE-CH4 inversions shifted the monthly flux maximum towards August.

The seasonal cycle of CH4 observations also has components other than biospheric emissions; anthropogenic emissions and atmospheric OH chemistry. The OH chemistry sink has a strong seasonal cycle with maximum impact in spring (see Fig X5 below) and therefore the month of the summer maximum of the biospheric emissions is sometimes not clearly visible, and the visibility also depends on where the air masses have been transported. The summer maximum can often be seen as elevated concentrations in late summer, however it is minor compared to the winter maximum (which is caused by the combined effect of anthropogenic emissions continuing throughout the year, and a weak wintertime OH sink). Therefore, adding a set of observations from different sites would not help much, but would make the figure more unclear for the reader. The inversion model solves for concentration changes due to anthropogenic and biospheric emissions, OH sink and atmospheric transport.

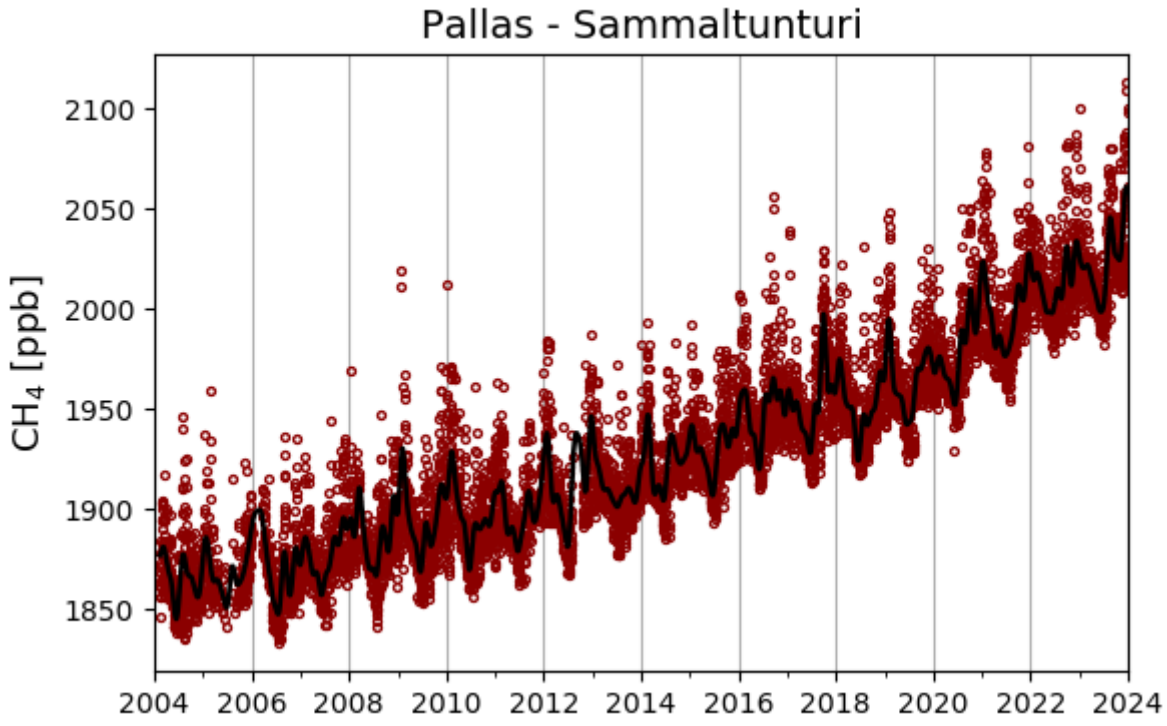

Figure X5. Methane concentrations measured at Pallas Sammaltunturi station in Finland.

Figure 7: It is difficult to distinguish lines for LPX-Bern and LPJ-GUESS, lines for the four GCPs, due to similar colors.

We will modify the lines for LPX-Bern and LPJ-GUESS and GCPs to be clearer