Review on Tran et al., egusphere-2025-2351

General comment

The study examines atmospheric CH_4 trends observed at the ZOtino Tall Tower Observatory (ZOTTO) during 2010-2021. The site has an excellent decadal observations of the atmospheric composition, and the authors study long-term trends on various aspects, including background level, seasonal and diurnal cycle amplitudes and summer night time mole fractions. The authors have also developed a method to calculate summer night time CH_4 fluxes from the vertical gradient of atmospheric CH_4 mole fraction observations, which I found unique. Not may observations over Siberia has such a long-term continuous observation of atmospheric CH_4, and ZOTTO data play really important role in understanding the effect of climate change in this region. The study is based heavily on the observed data, and it is amazing to see how much information you can obtain from the wealthy of the dataset. This requires effort in maintaining the observation site, which is not easily reachable, and continuos data quality control. I appreciate your team effort.

The study is worth of publication, but I would like to rise a few questions and comments to be addressed.

1. What derives strong GR in 2014 and 2019-2021? In the discussion, you mentioned about 2012, 2016 and 2019, but how about 2014 and 2020-2021? Why are those years have strong GR above MBL? Did you find anything particular about those years in your seasonal/diurnal cycle analysis? If not, why do you think you did not see it?

2. I am slightly surprised to see that June is included as "summer" when atmospheric CH_4 mole fractions are rather low (e.g. Fig. 5). To examine "the potential factors that might contribute to this observed increase in the late summer peak unique to ZOTTO (L370-371)", I feel it would be more suitable to use e.g. August-October rather than including low concentration months. For some years, the annual minima occur in July even. Have you checked trends in the diurnal cycles (and night time atmospheric CH_4 mole fractions) for each month separately? Do they look similar to those using all the summer months?
   2.1. Related question: from which months can you calculate the nighttime CH_4 fluxes? If possible, I would like to see trends in fluxes also for other periods than JJA.

3. I would like see an addition of trend analysis on atmospheric CH_4 for all seasons/months months and separately for day and night. You may have done this, but without knowing the results, it is slightly hard to believe the increase in the seasonal cycle amplitude is associated with increase in summer atmospheric CH_4 only. What is the trend for low-concentration months (spring)? Do you see e.g. downward trend, in which case could also contribute to increase in the seasonal cycle amplitude. In addition, the long-term trend could be assessed using winter months, too, from which you could possibly speculate about global background or anthropogenic emission trends (although you mention that it is unlikely that ZOTTO measures anthropogenic signals).

4. Regarding the seasonal cycle analysis, not only the amplitude, but I would also like to see discussion on timing of seasonal minima and maxima. What could be the reasons for differences in timing of seasonal minima and late summer peaks between different years? In comparison to MBL, it is also noticeable that the ZOTTO data often have seasonal minima earlier than MBL, and seasonal maxima earlier than MBL. Can you speculate why?

5. You have almost discarded the effect of OH in atmospheric CH_4 trends. Some studies report decline in atmospheric sinks over the decades and some specific years (e.g. 2020 due to

Covid-19 pandemic). I understand that you could not include the effect in your results, but strongly recommend to add discussion on this point.

6. It is worrying to see that summer daytime atmospheric CH_4 show much weaker trends compared to the nighttime considering that many atmospheric inverse models discard nighttime data in they assimilations and the flux estimates are based only on the daytime data. Do you think this could be a reason why inversion results have not been reporting strong increase in CH_4 fluxes over northern high latitudes, i.e. they maybe underestimating the flux trend? If you could add thoughts regarding this point, it would be appreciated.

Specific comments

L136: “monthly bins and selected the lowest 10-30% of values within each bin.”
Could you provide justification for the choice of this filtering method? I think this filtering approach works for CH_4 considering that there is no strong sink to the ground. Do you think the approach is still acceptable considering the environment around the tall tower? Have you considered using other approaches such as those used to defined marine boundary layer data, i.e. based on meteorological conditions? I suppose results do not alter significantly by using different methods, but would like to know how you come up with this filtering method, including the choices of the bin size (monthly) and criteria (10-30%).

L335-338 and Table 1:
The GR for 2021 is also very high. Why not to mark it as red in the Table, and modify text indicating that the strong growth of CH_4 continued to 2021? About comparison to MBL, I am a bit confused about the last sentence in P13. The GR in the MBL is higher than ZOTTO for 2019 and 2021. Here, I think you have two things to think: the actual values of the GR and the rate of change compared to previous year’s GR. Please consider rephrasing/adding arguments about those two points clearly separated. In addition, you focus on the high GR, but not the low ones. Why?

L367: “which is absent at MBL”
I would not say it is absent. It is not as clear as the ZOTTO data, but MBL data peaks could be found in September or October.

L369: “the late summer (August) maximum and the seasonal minimum (during May-July period)”
For some years, the late summer maximum seems to happen in other months than August. Why did you fix the month to calculate maximum while the month for minimum varies? Would your results in Figure 7 change if you use yearly varying months for the late summer maximum?

L410-411: “with the highest values occurring in August (Fig. 10), coinciding with the observed late-summer CH_4 peak (Fig. 5)”
Did high pressure days happen mostly in August or rather equally spread during summer?

L426-432:
But why are those affecting nighttime fluxes only? Do they also affect daytime fluxes? I know you were not able to calculate the fluxes from your data, but do you assume that CH_4 fluxes have also strong diurnal cycle? If not, why are the daytime mole fractions showing weaker increase?

L470-481 says anthropogenic influence is limited, while L488-489 says ZOTTO data is subject to contribution of fossil fuels also. Those contradicting arguments are slightly confusing.

L541-544:

Did you also see high mole fraction values in June 2016 at ZOTTO? Were temperatures high or soil moisture low then?

Equations: Please consider removing braces brackets and associated symbols/letters within the equation as they do not have mathematical meanings. I think it is clear from the text which part of the equation you refer to. For equations 4 and 7, you could add extra equations to define F_{Eddy}, F_{Stor} and the correction factor within each equation.

Figure 1:

- Why the net surface flux of CH_4 and and entrainment flux happen twice a day? It's a bit unclear why they are there. Instead, how about illustrating them three times a day, before sunrise, after sunrise and before sunset (mid-day) and after sunset?
- Could you change the colour of h, so that it is red when h=NBL and blue when h=CBL? Maybe the top of residual layer can be illustrated in different line type so that it is not mixed with ABL?
- It would be informative to add "measurement height" so that it is clear which layer the mole fractions in the top panel is representative of. Addition information in the caption would also be sufficient that from which layer you expect to see this kind of diurnal cycle.
- Although the terms are explained in Eq. (1), please also add explanations of w' and Φ' in the caption as well – the caption should be self-understandable without reading the main text.
- Please consider revising the y-label of the top panel as "Mole Fractions (ϕ)"

Figure 7: Could you add marks on months when you consider them to be seasonal minima and maxima?

Figure 10: Why Net surface flux are not calculated for some years?

Technical comments

L23-25: Please add references to the numbers given.

Section 2.2.2

What is the data frequency of soil measurements and precipitation?

L169-171: "the (ϕ) refer to CH_4 mole fraction, the overbars … wind speed w."
Could you consider modifying it as "the ϕ refer to CH_4 mole fraction, w to vertical wind speed, h to xxxx, ct to xxx, t to xx, S_ϕ to xxx. The overlines ($\bar{}$) refer to 30 min. time averaged values, and the prime (′) representing the deviations from the mean."

L171: "All symbols and their corresponding units in this study are provided in Appendix F – Table F1."

- Yes, but even if you have it in Appendix, I think it is very helpful to have definitions also in the main text for the first time. It's strange that some symbols are explain, but not all.
- Although it seems obvious, please add explanation for t, which appears in the derivative of left hand side ∂t).

P7 bullet points I-V: There are references to Figure 1, but instead, Equation 1 should be a primary reference. Please add reference to Eq. 1 for IV and V.

End of Section 2.4: In Fig 1 caption, it is said that the atmospheric sink is also not included in this study. Please also add the statement in the main text.

Figure H3: Please add units for the heights in the caption.