Review Report for EGUsphere-2025-2351

General Comments

The manuscript presents a valuable analysis of long-term methane variability in Central Siberia using ZOTTO tower data, focusing on diurnal and seasonal amplitudes. The topic is timely and relevant, given the role of boreal wetlands in global methane budgets and climate feedbacks. Overall, complex issues related to atmospheric dynamics are well described and the thinking is easy to follow. The paper is generally well written, and the figures are informative. However, even to have a greater impact, the study would benefit from clearer articulation of its objectives, improved transparency regarding methodological novelty, and a more comprehensive discussion of the implications of the findings. Additionally, some interpretations require clarification, and several technical issues need attention.

Specific Comments

The introduction gives a lot of background, but the main goal of the study is not clearly stated. Especially, I would like to see more discussion about how the diurnal cycle of atmospheric methane has been used in previous studies and why it is studied here.

It is not fully clear which parts of the method are new and which follow earlier work (e.g., Winderlich et al., 2014). Please make this clear in Section 2.

The paper shows that nighttime fluxes have increased. Does this also mean daytime fluxes have changed? Please discuss this.

L220: "Fits with an R^2 value greater than 0.7 were retained.": Did this threshold value exclude a lot of data?

L232-233: "By examining interannual variations in the summer NBL height, we can assess whether the nighttime stability leading to accumulation of near-surface CH_4 mole fractions have strengthened or weakened over time." Could you clarify what it would indicate if nighttime stability strengthened or weakened over time?

L335-338: Could you explain why the year 2021 is not mentioned? It has the highest annual growth rate in the MBL data and also high for the ZOTTO data.

L390-393: The detrending was done based on daytime data, right? So, in some sense, you removed the daytime trend, and it is no wonder that the trend in daytime values is close to zero after that. Or maybe the point is to show that the trend in the nighttime values is larger

than in daytime values, but that is already stated. Please, consider phrasing this paragraph differently.

L426-433: It would be nice if you explain earlier or somewhere how these environmental factors are expected to affect methane fluxes.

L451-456: There are also remote sensing products that have been studied near the ZOTTO station that could be a suitable reference or comparison. (e.g. Kivimäki et al. 2025).

L460-468: How about snow melting? How would that affect methane fluxes near ZOTTO? When does snow melt in ZOTTO? Air temperature seems to rise above zero in April-May, so I would assume that the snow melts after that.

L489-490: "These regional emissions may have contributed to enhanced seasonal amplitude observed at ZOTTO." Do you think that the enhanced seasonal amplitude is due to winter maxima being higher or summer minimum being lower?

L520-522: "These findings align with studies from other boreal and wetland-dominated regions, where CH_4 emissions peak in late summer due to sustained high soil temperature and moisture leading to high microbial activity." Could you expand on this point? For example, Rößger et al. (2022) also reported the highest methane emissions in August, but the long-term increase differs: Rößger et al. found the trend in July, while your results suggest the increase occurs in August.

Technical Corrections

It would be nice if the figures and Appendices mentioned would be in order, i.e., that the first mentioned would have A1, next one A2 or B1 etc.

L22: "global greenhouse **gases** radiative forcing" -> "global greenhouse **gas** radiative forcing"

L24: "has risen" -> "rose"

L25: Reference for the atmospheric methane levels missing.

L31: The global methane budget has been updated (Saunois et al. (2025)), you could also update this reference.

L34-35: Do the area of undisturbed and disturbed boreal and temperate peatlands overlap with the area of permafrost region? I.e., can you just sum up the two numbers mentioned in the text to get peatland emission from northern peatlands?

L90: “Data were recorded every 30 seconds from each sampling line.”: What does the “30 seconds” refer to exactly? Does it mean that there is a measurement taken every 30 seconds from the currently active sampling lines?

L185: “as mentioned in” -> “similarly to” or “following...”

L208: Was the ERA5 reanalysis data you used “boundary layer height”?

L301: “Equation 6 as in Winderlich et al., 2014 can be expanded” -> “Equation 6, as in Winderlich et al., (2014), can be expanded”

L303: “Where” -> “where”

L384: “Between 2010 and 2021, the summer diurnal amplitude increased significantly at p = 0.01 level at a rate of 5.55 ppb yr^{-1} (p = 0.002)”: Maybe you could form it a bit differently: “Between 2010 and 2021, the summer diurnal amplitude increased significantly ($p < 0.01$) at a rate of 5.55 ppb yr^{-1} (p = 0.002).”

L405-415: You could first present the results and then conclude that based on that increasing nighttime CH_4 surface fluxes during summer are the primary driver of the observed rise in nighttime CH_4 mole fractions.

L435, Figure 11: Why is the x-axis of VPD flipped?

L453: “signal has” -> “signal had”

L474: “natural gas emissions sum up to 1 to 10 % of the overall wetland emissions only”. Which area and time period is being referred to here?

L590, Figure A1: Consider using a “neutral” (neither blue or red) colour at 0 °C in the colour bar to make it easier to see where the air temperature crosses the freezing point.

References:

Kivimäki, E., Aalto, T., Buchwitz, M., Luojus, K., Pulliainen, J., Rautiainen, K., Schneising, O., Sundström, A.-M., Tamminen, J., Tsuruta, A., and Lindqvist, H.: Environmental drivers

constraining the seasonal variability of satellite-observed methane at Northern high latitudes, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2025-249, 2025.

Rößger, N., Sachs, T., Wille, C. *et al.* Seasonal increase of methane emissions linked to warming in Siberian tundra. *Nat. Clim. Chang.* **12**, 1031–1036 (2022). https://doi.org/10.1038/s41558-022-01512-4

Saunois, M., Martinez, A., Poulter, B., Zhang, Z., Raymond, P. A., Regnier, P., Canadell, J. G., Jackson, R. B., Patra, P. K., Bousquet, P., Ciais, P., Dlugokencky, E. J., Lan, X., Allen, G. H., Bastviken, D., Beerling, D. J., Belikov, D. A., Blake, D. R., Castaldi, S., Crippa, M., Deemer, B. R., Dennison, F., Etiope, G., Gedney, N., Höglund-Isaksson, L., Holgerson, M. A., Hopcroft, P. O., Hugelius, G., Ito, A., Jain, A. K., Janardanan, R., Johnson, M. S., Kleinen, T., Krummel, P. B., Lauerwald, R., Li, T., Liu, X., McDonald, K. C., Melton, J. R., Mühle, J., Müller, J., Murguia-Flores, F., Niwa, Y., Noce, S., Pan, S., Parker, R. J., Peng, C., Ramonet, M., Riley, W. J., Rocher-Ros, G., Rosentreter, J. A., Sasakawa, M., Segers, A., Smith, S. J., Stanley, E. H., Thanwerdas, J., Tian, H., Tsuruta, A., Tubiello, F. N., Weber, T. S., van der Werf, G. R., Worthy, D. E. J., Xi, Y., Yoshida, Y., Zhang, W., Zheng, B., Zhu, Q., Zhu, Q., and Zhuang, Q.: Global Methane Budget 2000–2020, Earth Syst. Sci. Data, 17, 1873–1958, https://doi.org/10.5194/essd-17-1873-2025, 2025.