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# *Interactive comment on* "Different responses of $CO_2$, $CH_4$, and $N_2O$ fluxes to seasonally asymmetric warming in an alpine grassland of Tianshan Mountains" *by* Yanming Gong et al.

**Anonymous Referee #2**

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General comments

The manuscript "Different responses of CO2, CH4, and N2O fluxes to seasonally asymmetric warming in an alpine grassland of Tianshan Mountains" by Gong et al. describes the effects of seasonal warming (growing season warming, non-growing season warming, annual warming) on CO2, CH4, and N2O fluxes during 3 years at an alpine grassland site in the southern Tianshan mountains, China.

I value the authors efforts to collect multi-year, and year-round data with manual chamber measurements. While I find evaluating the response of GHG fluxes to changes in temperature during different seasons highly important (especially the non-growing



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season), the manuscript in its current state has several shortcomings, which I have outlined in my specific comments and line edits below.

Specific comments

1) The authors discuss CO2 fluxes, however, it is unclear which component of the CO2 flux has been measured. It would seem that ecosystem respiration was measured, which should be stated clearly throughout the manuscript. Temperature is a well known control on respiration, but based on this study the authors can not draw conclusions on the effect of temperature on net CO2 exchange without accounting for photosynthesis. I suggest revising the manuscript text accordingly. 2) To understand the observed interannual variations in GHG exchange in response to temperature it would be important to include information on other climate parameters as well, especially interannual variations in precipitation, soil moisture and or water table. If this data is available, I highly recommend including it and to add discussion on this topic. 3) Adding discussion on whether the warming treatment with OTCs impacted other environmental variables (such as soil moisture, snow depth) would be needed in order to assess the effectiveness of the warming treatment and validity of results. Shortly reporting results on the achieved temperature increase in the warmed plots compared to control treatments in the results section would be helpful as well (this is only shown in the supplementary material Fig S1). 4) Introduction as well as discussion and conclusion remain rather superficial. This manuscript would greatly benefit from some streamlining, clearly stating the objectives and relevance of this study, and a more thorough literature review and comparison to other studies. For example, this study reports rather large CH4 uptake rates. How do these rates compare to what is observed in other studies from similar ecosystems? Based on the findings of this study, can larger-scale conclusions be drawn on what impact warming will have on CH4 uptake in these ecosystems? The study also reports all three GHGs, which is a strength of this study, as measurements of N2O fluxes in particular are rare in colder climates. The authors could highlight this in their study, and provide some comparison to other studies. And while inves-

tigating the effect of temperature on fluxes was clearly the aim of this study, some acknowledgement of drivers of GHG fluxes other than temperature would be useful to include. 5) The discussion is rather short and exclusively focuses on the reponse rate of the three gases to temperature, while some of the rather interesting key findings of this study are not addressed (such as for example increasing annual CH4 uptake with warming, or increasing N2O emissions with warming during the non-growing season). It also looks like the site displayed emission peaks of N2O during the shoulder periods, especially spring, which might be an important point to mention in the discussion (see for example: Wagner-Riddle et al. (2017). Globally important nitrous oxide emissions from croplands induced by freeze–thaw cycles. Nature Geoscience 10(4):279-83).

Line edits

Abstract: L13-14: specify whether CO2 fluxes are ecosystem respiration or net ecosystem exchange, not clear if the reported numbers are net CO2 losses to the atmosphere. Also, do these numbers represent the total range of fluxes between 2016 and 2019? It might be more meaningful to present growing season as well as annual mean or median fluxes in the abstract, as fluxes, especially for CH4 and N2O, are highly variable. L14-15: this is counter intuitive and does not match with what is shown in supplementary figure S3 (where CO2 and N2O fluxes show a clear positive correlation with soil temperature, and CH4 uptake increases with increases temperature). Please rephrase. L16-18: “the variation in GHG flux under seasonally asymmetric warming was different between the growing season and the non-growing season”: this statement is vague, please be more specific and state clearly what was observed. L18-24: a short explanation of the term “response rate” might be needed in this context. L24-27: A clear summary statement with the specific implications of this study would be needed here.

Introduction: L38: daytime/nighttime differences are not addressed in this study. Consider removing from the introduction or add results and discussion to address this issue. L34-36: Yes, but I would advise caution with this statement (considering the larger than average warming in higher latitudes and Arctic amplification). L39: 3rd





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assessment report. L48: delete “in the atmosphere” L47-49: some rephrasing might be needed (considering that water vapour is a major GHG present in Earth’s atmosphere as well). L47-50: a general statement with some background information on the influence of temperature on GHG production and emissions would be useful for the reader in this context. L50: Please check those % numbers (radiative forcing of CO2 is larger than that of CH4). L50-52: Not sure whether this statement is correct. At least in northern or high-elevation regions with less accessible sites, warming treatments are often conducted during the summer months. Some rephrasing might be needed. L55: please specify whether “CO2 flux” in this context refers to increased CO2 emissions or increased net uptake, and under what conditions this increase occurred (warming treatment or naturally warmer summer?). L56-57: for simplicity, replace “the effect of increased temperature in winter” with “the effect of winter warming”. L56-58: This sentence is not quite clear. Does this mean winter warming did not affect growing season CO2 fluxes, but winter warming did increase CO2 fluxes during the nongrowing season? Consider rephrasing. L58-60: replace “absorption” with “uptake. L62: start sentence with “A study by xx (2012) in an alpine grassland ecosystem showed. . .” L69: consider added examples for biotic and abiotic factors here. L75-81: This is rather vague and I suggest to be more specific and clearly state the overall aim of this study.

Methods: L87: Is permafrost present at the site? If yes, it would be useful to add this information. L93: in addition to soil, vegetation and temperature it would be useful to add some information related to typical soil moisture/water table levels at the site, since that is important for discussing GHG exchange and observed interannual differences. L95: please provide description and dimensions of open-top chambers. L101-108: please provide some more details regarding flux measurement and analysis. E.g., were pre-installed collars used for the flux measurement? Were the chambers equipped with a fan and pressure equilibration tube? Were chambers transparent or opaque? Please also mention the sign convention in this context (i.e. positive fluxes = emissions?). L105: please add the total number of sampling times. L105-108: What quality criteria were used to accept or reject fluxes? E.g. r2, RMSE, minimum number of sampling

points during one flux measurements? This information is not provided in the cited reference (Chen et al 2013).

Results: L124-125: In addition to the range, it would be useful to provide mean/median values here. I also suggest to add a few sentences describing the general pattern of fluxes as this site, before presenting the treatment results, to provide the reader with a general overview (for example stating that the site acted as a net CH4 sink, with negligible CH4 emissions, and small N2O source). L131-136: talking about an increase and decrease in CH4 flux is slightly confusing in this context, as the authors mainly observed CH4 uptake. The 6.4% increase in CH4 flux in the AW treatment that the authors report here is in fact an increase in CH4 uptake, according to Fig. S2. This would mean a decrease in CH4 from an atmospheric point of view, and I suggest to rephrase this whole section accordingly. To avoid confusion, it might be useful to refer to uptake and emissions, rather than fluxes, throghout the manuscript. L126-140: are all these reported %changes significant (standard errors seem rather large)? It would be useful to add information regarding statistical significance in Fig S2 and manuscript text. L126 and throughout: please specify which CO2 flux component is discussed (see specific comments above). L143: delete “extremely”. L141-144: Do the authors mean interannual differences between growing seasons? L141-145: Generally, this section is not very clear and would benefit from some rephrasing. It would be important to state that interannual differences were larger than impact of warming treatment (for CO2 and N2O) according to Fig. 1, whereas warming treatment had a significant impact on CH4 fluxes. L147-148: I suggest simplifying “CH4 flux showed significantly decreasing trends with increasing soil temperature” to something like “we observed increasing CH4 uptake with increasing soil temperature”.

Discussion and conclusion: Please see my specific comments above regarding the discussion section, as well as: L166-171: It would be useful to include some background information on mechanisms behind CH4 fluxes for the reader, i.e. when do emissions occur, what conditions promote CH4 uptake, why would temperature increase CH4

uptake, etc. L176-177: for the nongrowing season contribution of CH4 fluxes a comparison to other ecosystems would be useful; see for example Treat, C.C., Bloom, A.A. and Marushchak, M.E., 2018. Nongrowing season methane emissions–a significant component of annual emissions across northern ecosystems. Global change biology, 24(8), pp.3331-3343. L178-186: please see my specific comment regarding discussion of other environmental variables besides temperature. N2O in particular is rarely depend on just on variable, and the effect of temperature may often be masked by other variables such as water table, and mineral nitrogen availability. This may require at least short mention in the discussion section. See for example Pärn, J. et al. 2018. Nitrogen-rich organic soils under warm well-drained conditions are global nitrous oxide emission hotspots. Nature communications, 9(1), pp.1-8.

Figures: Fig. 2: please add r2 and P-values for all figure panels (even for non-significant relationships). Fig S2: please add number of measurement times for growing season / non-growing season mean. Also, please specify in y-axis or figure caption which component of the CO2 flux is shown (ER?). As panel b shows CH4 uptake, I suggest to flip the y-axis, showing zero on top and negative values at the bottom. Overall, I would suggest to use boxplots (including quartile ranges and outliers) rather than barplots in this figure, to capture the full range of fluxes, as it would be important to show e.g. also the occurrence of emissions (for CH4) or uptake (for N2O). The authors may also consider moving this figure into the main text.

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