

Response to reviewers;

We would like to thank the reviewers for their support of this manuscript and have noted responses to comments and editing suggestions below:

Reviewer 1

Abstract line 2 "Bulk quantities": What does this term refer to? I.e., quantities of what?

Great catch. This has been clarified.

Abstract line 3 "demonstrate the utility": Utility for what? I.e., what do these bulk quantities have utility for?

Sentence reworded

Abstract line 32 "observed in CO observations": I'd avoid word repetition. How about "evident in CO observations" for "manifest in CO observations"?

"captured in CO observations"

Line 27 "Among the most important is the uncertainty we have....": The wording here feels awkward. Here's another option: "Carbon-climate feedbacks are among the most uncertain feedbacks."

Used Carbon-climate feedbacks (Arora et al., 2020) are among the most uncertain climate feedbacks.

Line 43 "The Arctic, in particular....": I don't think this sentence is grammatically correct. It's not quite a run-on sentence, but the second clause is missing a conjunction and a subject.

Broke up sentence.

Reviewer 3:

We note that the review here may have been looking at a different MS because we find non of the references to line numbers to be correct or even quoted material. We have tried our best directly answer the comments despite the fact that references to line numbers and quotes are confused.

Line 75 The target is 'to evaluate the ability of current land surface flux models', but the conclusions indicate that the goal is not fully achieved – separating contributions of model simulated fluxes from inside and outside the study domain is difficult, as well as separating the impacts of surface fluxes from meteorology and tracer transport. It would be natural to extend evaluation target to a combination of the surface flux models and the transport model.

We think the original intent of the analysis still stands, in particular, because we have not fully evaluated the transport model.

Line 224 References may be needed to point to past results, and GCP-CH4 regional estimates are available for comparison.

Reference to Table containing references has been moved to make this clearer.

Line 245-250 Justification for the setting of 3000 m as a boundary between PBL and free troposphere was not discussed (any suitable reference?), while the PBL heights diagnosed from potential temperature, humidity, and tracer profiles are often lower than 3000 m. As there is a good volume of evidence on the connection between tracer and potential temperature profiles in the troposphere (Jin et al, 2021), an alternative approach would be to test lower altitude for separator or make it linked to isentropic vertical coordinate.

A sentence has been added in method section: "As will be explained in the results section, the 3000 m was picked as cutoff for CO₂ and CH₄ because of the low variability of these tracers above that altitude level where as the cutoff point for CO was chosen to be 4000 m."

Line 295 Here, one would guess that using inversion optimized fluxes, even made with another transport model would give a better match with observations than the unoptimized models and inventories used in the study (as mentioned on Line 510).

Unfortunately, without a proper reference the text it is hard to surmise what is being referred to.

Line 503 Said: "Modeled North Slope CH4 is underestimated throughout the measurement period

pointing to deficiencies in the wetland flux specifications over this ecoregion". What is the confidence level for this conclusion, given that the impact of the fluxes from outside of the study domain is considered significant, as discussed in Section 3.1.11?

Since there is no section 3.1.11, we assume that the section being referred to is 3.3.5 which refers to the fact that a large part of the CO2 gradients observed are formed outside of the Arctic region. Couple of points to made in defense of this statement. First, there is a bunch evidence to suggest that CH4 emissions on the North Slope generated locally (Zhang et al., 2014; Sweeney et al., 2016; Hartley et al. and Floerchinger et al., 2019). Second, it is important point out that this offset is most notable over the North Slope which draws most of its background air for the Arctic Ocean where there we would expect minimal influence to the gradient.

Line 508 Authors cite the improvements since the survey by Fisher et al (2014). This looks like a good point, should it be supported by a table or figure in the analysis?

Fisher et al. was a broad survey of many models and demonstrates a complete lack of agreement between many forward models. As stated, in the text the next step is compare multiple forward models using the AIE bulk quantity as a benchmark to test the fidelity of these different models.

Technical corrections

Line 141 fix square to round brackets

Could not locate

Line 173 what does sw mean in pco2sw? – need description

Done

Line 190 Table 1. In second LPJ-wsl reference – year is missing

Done

Line 264 words 'CH4 enhancements' can be removed - appear twice in a sentence

Not able to locate redundant use of CH4 enhancements