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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Atmospheric carbon cycle dynamics over the ABoVEdomain: an integrated analysis using aircraft observations (Arctic-CAP) and model simulations (GEOS)" *by* Colm Sweeney et al.

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Review of the paper entitled "Atmospheric carbon cycle dynamics over the AboVE domain: an integrated analysis using aircraft observations (Artic-CAP) and model simulations (GEOS)" by Sweeney et al.

General comment:

This study presents an analysis of aircraft measurements of CO2, CO and CH4 concentrations over Alaska collected in 2017. The comparison to the GEOS modeled

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concentrations brings new insights on the current performances of the GEOS global model over high-latitudinal regions. The overall analysis is sound and valid, with interesting findings over sub-regions of Alaska. The data set is highly valuable in a part of the world with a limited number of long-term concentration or ecosystem measurements. However, the analysis falls short with no definitive conclusions related to the surface fluxes or the transport at high latitudes. Some of the wind measurements have not been used, and the link between the vertical profile analysis and the model-data mismatches is unclear. By providing additional analyses of the model-data residuals, this study can improve substantially. Therefore, I recommend the following revisions before publication:

- The analysis of the vertical profiles and the model-data mismatches is mostly disconnected. Hence it remains difficult to conclude if the transport model errors or the surface flux errors are responsible for the observed mismatches. Knowing that GHG vertical profiles can provide the required information, in addition to wind measurements collected during the campaign, the authors have the opportunity to examine more closely the causes of the mismatches. Are the peaks related to large vertical gradient mismatches? Or to long-range transport errors (incorrect winds in the FT)?

- Wind measurement profiles have not been used in this study. Assessing the performances of the GEOS model, especially in the Free Troposphere, would provide additional insights on long-range transport in high-latitudes and the representation of the FT-PBL gradients used here. These measurements are quite valuable and coud be useful to this analysis.

- This study lacks a comparison to the EC flux measurement analyses available in Alaska, or even in situ tower-based concentration measurements. Considering the consistent seasonal variations in the model-data biases across sub-regions of Alaska (for CH_4 especially) (Fig. 11), an analysis of EC CH_4/CO_2 measurements would help understand the findings of this top-down evaluation, or demonstrate the differences in bottom-up and top-down evaluation of surface fluxes. In any case, the comparison to

EC flux results or tower-based concentration measurements would help with the lack of definitive conclusions on the causes of the mismatches (long-range transport, local fluxes, vertical mixing,. . .).

Technical comments:

- P2-L59: What type of scaling techniques are you referring to? Add references related to the use of eddy-flux towers and how they have been used. What about biogeochemical model calibration?

- P2-L64: Define “bottom-up” briefly. Does it include eddy-flux tower measurements?

- P2-L68: you’re describing a Bayesian inversion here. What about top-down methods without an explicit prior?

- P2-L73: What do you mean by “hybrid” approach? It seems here that you are comparing a forward transport model to aircraft data. Are you referring to the use of multiple species?

- P5-L181: “not bad” - replace with a more objective criterion.

- Figure 3 is not referenced anywhere in the text.

- P7-L216 and Table 1: It seems that yo haven’t modified the EDGAR oil and gas emissions according to Floerchinger et al. (2019). How would it affect the relative contribution of industrial and fossil emissions?

- P8-L255: The determination of background values from measurements in the Free Troposphere assumes that the air masses are similar near the surface and higher in the column to extract a local enhancement, or that the model is able to capture the Free Tropospheric winds. Assuming you have wind measurements available from the aircraft profiles as exlpained in the methods section, it would be useful to check if the model is correct (as discussed in 3.1.4 – P10-L308).

- P9-L281: Profiles of multiple species can be used to evaluate vertical mixing but not

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really advection or large-scale convection.

- P9-Section 3.1.2: this paragraph should be moved to the method section.

- P9-Section 3.1.3: Most of this paragraph belongs to the method section. The figure (Fig. 6) is hard to read and the conclusions are quite vague and limited to one sentence. It seems that focusing on the model-data mismatches would be more informative. This figure should be improved or moved to SI.

- P9-L305: it also looks like there is a trend in the offset for CO_2 and CH_4.

- P10-L310: The use of wind measurements might help identify transport model errors here.

- P10-Section 3.1.5: Similar comment than for 3.1.2 and 3.1.3. This section summarizes general knowledge on how to interpret PBL measurements. It should be moved to the method section, or the elements should be discussed later in the paper related specifically to the analysis of your measurements.

- P11-L357-369: this paragraph should be moved to the method section.

- Title of 3.1.6: The title indicates a commentary more than a result. Modify to clarify your findings.

- P11-L368: As you showed earlier, the enhancement is also related to the air mass in the Free Troposphere. It might not be an "enhancement", meaning only due to local surface fluxes. It might be a combination of the differences in the PBL and FT background as well.

- P12-L388: You need to link the model-data mismatches and vertical gradient mismatches. The analysis of Figure 9 needs additional insights and investigations. A figure showing the relationship between incorrect vertical mixing and large model-data mismatches would help identify the role of PBL height mismatches. Can it explain the peaks in CO_2 and CH_4 in Figure 9?

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- Section 3.1.8: This paragraph should be merged with the earlier analysis of Fig 8 and 9. Did EC flux analysis suggest the same (i.e. seasonal offset)?

- Section 3.1.10: This analysis is the the most interesting of the paper. With your data set, it seems possible to separate the impact of the vertical mixing from the fluxes. An analysis of the vertical profiles would allow you to identify vertical mixing issues. An analysis fo the sub-region would also be informative, related to the ecosystems.

- P13-L450: The CH4 model-data mismatches seem consistent across regions (from postive to begative to near-zero). It seems plausible that CH4 EC flux data would give you a similar conclusion, and if they don't, it would also be interesting to point out why, and discuss the value of the aircraft data. In any case, the addition of EC data would be helpful to confirm the results or to show the differences between top-down and EC data analyses, as noted earlier in this study.

- P13-L462: performed

- P13-L460: A succinct description of "three simulations" is missing.

- Section 3.1.11: More a discussion than a result section.

- P14-L487: Lagrangian

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