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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Diagnostic methods for atmospheric inversions of long-lived greenhouse gases" *by* Anna M. Michalak et al.

Anonymous Referee #3

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Review of the paper entitled "Diagnostic methods for atmospheric inversions of long-lived greenhouse gases" by Michalak et al.

General comment: The paper attempts to address a challenging topic related to the validation of atmospheric inversions of greenhouse gases. In response to the increasing demand for more robust atmospheric validation tools, the authors review the existing solutions to this problem, using independent data for an indirect validation or using sensitivity experiments with different statistical metrics. The review of methods and the analysis of previous studies is quite extensive and provides a valuable overview of the current state of the art for diagnostic methods. The later section aims at evaluating these diagnostics and discusses the usefulness of these approaches related to the problems they try to address. This part of the paper suggests that most of these metrics remain insufficient to evaluate the potential problems affecting inverse

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flux estimates. The authors fall short of providing suggestions trying to address these limitations, for example by recommending new measurements or methodologies to diagnose and identify them. The two main solutions proposed here are an increase in atmospheric data availability and the increase in spatial resolution to overcome representation errors when evaluating against direct flux measurements. Considering that both options are unlikely to happen in many vast areas across the world, other options should be considered to help the inverse modellers provide more robust results. I would invite the authors to 1. propose clear directions for inverse modellers to address these issues, including methodologies and strategies for measurement campaigns, and 2. suggest new/other statistical metrics to better evaluate inverse results and therefore overcome the limitations of the current metrics in inversion studies. Overall, this paper is a worthwhile contribution reviewing the current diagnostics for inversions but would need to develop this last section to provide more insights to the inversion community. Therefore, I recommend this paper for publication after addressing this problem and the following specifics comments.

Page 2 - L11: The studies cited here describe component-level surveys of equipment which are isolated in time. The term "monitored" does not reflect the lack of temporal coverage from these methods.

Section 3.3.1: Past studies (e.g. COBRA campaign, or CERES) and more recent ones (e.g. based on EnKF approaches) have tried to use meteorological and GHG data to improve or characterize transport models at continental and regional scales. Similarly, global scale models have also been compared to vertical profiles. The current section is short and would need a more complete list of studies related to transport model evaluation.

Section 3.4: A description of the most important metrics used with OSSE's would help the readers to understand the possible information that can be recovered from pseudo-data experiments. Past studies have also confused the meaning (or interpretation) of these metrics. For example, error reduction analysis may be the most useful metric

one could possibly study, but often suffers from over-confidence. Discussions may be useful in this regard, and link to the "grain of salt" compared to a proper evaluation of inversions.

Page 13 - L6-8: Should the readers conclude that these metrics are not addressing the problem? Could the authors provide more insights to explain why these metrics are insufficient? I think most inverse modelers would agree with the statement but examples of shortcomings or reasons for this failure are needed here.

Page 13 - L15-21: Do we need specific data to implement these methods? The spatial and temporal structures of errors are critical to inversions but the authors should provide more suggestions to address the separation of contributions from prior and transport model errors. This problem is non-trivial and has been studied in other fields in a more systematic fashion. Maybe references from non-GHG assimilation studies may help here.

Page 14 - L3-8: Few studies have tried to address this problem, for example the Global Carbon Project with a more coherent framework to compare inversion results. More generally, the authors could describe how to construct ensembles able to represent inversion errors. Again, possible examples from other communities (e.g. weather prediction systems) may help to find solutions, or at least, avenues that the inversion modelers could take to generate better probabilistic ensembles.

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