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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 #2

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Michalak and colleagues review the recent literature on methods to assess robustness and accuracy of atmospheric inversions of long-lived GHGs. Given the importance of inversions in present biogeochemistry and potentially in future GHG emission reduction verification, such diagnostic methods are of great relevance. After an excellent introduction on the need for diagnostics and the involved challenges, the paper reviews diagnostics applied in the literature. The diagnostics are put into context in a discussion section. I recommend to publish this work, subject to some comments given below.

When reading through the list of diagnostics, a question that repeatedly came up to me was "How well an inversion actually has to meet these diagnostics to be good enough?" For example, in Sect 3.1.1, how to translate the fit to independent data into a judgement of quality? I realised that it would be asking much to comprehensively answer this question here, and Sect 4 does discuss the limitations of the set of diagnostics.

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Neverthess, I was wondering whether it would be helpful to put more on that already along the way, to make the paper more practical.

I feel it should be mentioned early on that the cited literature can only provide examples, because I'm sure that for most (if not all) diagnostics there are further papers which have also made good use of them, and which in some cases may even deserve credit for actually having introduced them. In this context, the restriction to papers from between 2010 and 2015 does not seem entirely appropriate to me.

I missed explicit mentioning of the "reduction of uncertainty" (1-sigma(Post)/sigma(Pri)), a diagnostic which has been being widely used by many studies, mostly in OSSEs as an alternative to the synthetic inversions explained in Sect 3.4. (In this context, it would be good to mention that the choice of foci and examples is partially subjective according to the working fields of the authors.)

Specific comments:

p 6 l 15-19: Mention already here that the robustness of column data is not yet fully established (as said later in 3.3.2), to avoid an inappropriate message.

p 6 l 30: Add "global *decadal* atm. growth rates" because this statement is not valid at yearly or shorter time scales any more.

p 7 l 1-4: The cited study is for N2O - would this also work for CO2 with both sources and sinks? (By the way, I would find it useful to mention which trace gas is being looked at in the individual examples.)

p 7 l 5-7: I find that comparisons "across inversions" are misplaced in this paragraph on comparison to "independent estimates", as inversion-inversion comparisons only allow fundamentally weaker conclusions.

p 7 l 10: The term "assessment" is so general that it remains unclear what to take from this sentence.

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p 8 l 4-6: This is a complicated and unspecific formulation. What about something like "...check whether the flux adjustment by the inversion are still within the specified a-priori probability distribution".

p 8 l 9-10: Posterior concentration uncertainties can indeed be calculated in theory, but in most larger applications, this is computationally very involved in practice. I feel this should be noted.

p 9 l 20+: This has already been said in Sect 3.1.1

p 9 l 31-32: The sentence "The differences ... data." seems to be incomplete.

p 9 l 33: It remains completely unclear what "quantified via ... signal" means.

p 10 l 11-18: This paragraph unspecifically uses the term "sensitivity tests", but I assume it actually refers to synthetic-data tests. It therefore seems to better fit into Sect. 3.4.

p 10 l 31: add "regional inversions", as this is only relevant there.

p 11 l 7-11: This seems to have been said already in the previous paragraph.

p 11 l 12: add "or data set" after "of a model", as it is not always models that are being used.

p 14 l 10-11: The sentence "The ambiguity ... to them" may tentatively be true but due to its awkward formulation it remains unclear what it actually means.

p 14 l 29-31: Add e.g. ", used in conjunction with high-precision data". I disagree with the notion that low-quality data will ever be sufficient on their own, even if much larger in number.

p 15 l 8: Be specific which diagnostics this sentence is referring to, because otherwise one cannot take any information from this sentence.

Minor comments:

p 4 l 14: I find the specification "aimed at ...and patterns" obvious and thus dispensible

p 5 l 25: I find that "high level groupings of" is unnessecarily confusing and should be deleted.

p 9 l 3-4: replace "an inversion" by "the transport model"

p 11 l 26: Remove "However" as this sentence is not in opposition to the previous sentences.

p 11 l 30: Rather say "can also be used".

Typos:

p 3 l 32: "atmosphere"

p 7 l 1: "inform"

p 8 l 26: delete "a comparison of"

p 15 l 13-14: Exchange "artmospheric" and "for"

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