

Referee Comment for Manuscript MS No.: acp-2020-72

Direct inversion of circulation from tracer measurements – Part 2: Sensitivity studies and model recovery tests, by Thomas von Clarmann and Udo Grabowski

General comments:

This study presents a new methodology (ANCISTRUS) that provides quantitative information on stratospheric circulation in the form of effective 2D velocity fields obtained from measurements of a set of long-lived trace gases.

The paper presents clear examples of the computed fields and the transport structures they represent. It also provides a valuable illustration of the relative weights that chemical sinks and advection have on the distribution of tracers in the stratosphere. The manuscript also looks into the reliability and sensitivity of the method and shows what regions are better covered by the different chemical species.

The manuscript demonstrates the high potential the new method has to derive effective transport information for the stratospheric region that can complement other existing methods. This will help to overcome information gaps and biases that appear when applying more widely-used existing approaches.

Therefore, this study is a valuable contribution to both the modelling and the observations communities.

In its current form there are, however, several points that need further clarification or development, and editing is also required as detailed here below. Once these aspects have been satisfactorily addressed by the authors I recommend publication of the edited manuscript.

Specific comments:

Some relevant scientific questions should be addressed by the manuscript:

-To what extent is the ANCISTRUS-derived dataset limited by the biases in the original MIPAS measurements? How are those biases affecting the fields you derive?

-I miss a discussion on the generalisation of the methodology: You have applied the ANCISTRUS method to MIPAS data, but how feasible would it be to apply to other satellite products of atmospheric tracers measurements? Is there any current work on this? How would it be done? This is an important discussion to show the value of the methodology.

-Is the study of the BDC (line 31) the main application of your method or the main application in this study? Are there other applications?

-Sentence 39-41, if I understand correctly, could indicate a limitation of the methodology rather than stability: can it be that for every year the obtained circulation patterns are the same? What about interannual variability, how does your method account for this?

-More information should be included on how the method copes with, and provides information on, the diffusive and dispersive characteristics of transport.

-Why have you chosen years 2005 and 2010 for this study? The manuscript should justify this choice over other months/years in the period covered by MIPAS observations. How representative are these 2005 and 2010 months for the rest of the period?

-How much does the lack of longitudinal information affect the degree of realistic variability in your results?

- If your method does not consider SF₆ sinks (line 64) how can you overcome the biases caused by the mesospheric sink of SF₆ when using mean age-of-air methods? This needs to be clearly explained and justified as the manuscript claims this is one of the main advantages of the ANCISTRUS method in the study of the BDC.

-Line 105: It is not clear what you mean by “true velocity fields are not known”. Even if true velocity fields are not measured, can you use operational analyses from NWP models as a close to reality alternative? What are the assumed velocity fields you used in the tests discussed in this paragraph? How would the use of different assumed velocity fields affect your results and the spurious data you obtained at the boundaries?

-Lines 120-130: Why a climate model? Why not a CTM driven by operational NWP analyses, then one has the tracers distributions obtained from the CTM and the operational velocity fields used to force the simulations?

-Line 152: Is there any alternative regularization that can better resolve adjacent opposite circulation branches? Have you tested it?

Some parts of the manuscript need substantial editing:

-The Introduction Section needs to be rewritten: The scope and context for this research is not clearly introduced. Context should be added to the Introduction. Have other similar applications of inverse modelling been previously attempted? What are the reasons to develop this new approach? What are the advantages of the current one compared to previous ones?

Also, some important aspects covered by the paper are not included in the Introduction, e.g. results shown in Section 2, where the effects of sources/sinks and advection are compared. These are very relevant but the Introduction does not say anything about this being an objective of the paper, this information should be added to Section 1.

-Model recovery tests: what this means needs to be clearly explained early in the text.

-Results shown in Figures are very interesting but on several occasions they are not sufficiently explained/developed in the main text. An example is Fig 14: lines 217-220 should give more quantitative information on the amount of uncertainty the inclusion of CCl₄ contributes to reduce, as well as explain why it does so more for the vertical field than for the horizontal one.

-The Conclusions Section needs careful revision. This section should be understandable on its own as a Section that summarises the paper. Adding initial sentences summarising ANCISTRUS and why it was developed would improve its readability and completeness. Overall, statements in this section are not clearly backed up, a clearer reference to the results you have shown should be included.

Technical corrections:

Line 4: Model recovery tests – a brief explanation/definition would be helpful here.

Lines 8-9: These two sentences should be merged to make the meaning clearer.

line 17: citation here shouldn't use parenthesis

Line 22: "Similar as in other applications of inverse modelling..." some citations to reference previous work and add context to this paragraph should be mentioned.

Line 25: Please consider including some brief information on sinks here, for completeness of text.

Line 37: Change "An application of" to "Applying"

Line 39: Please develop "and so forth" to better understand what you mean here.

Paragraph 41-43 cannot be clearly understood in its present form. Please rewrite.

Line 45: "...confidence in..."

line 51: Sentence needs rewriting. The word intuitively is confusing, the mechanisms described are those providing information to ANCISTRUS, it is not an intuition.

Line 64: "due to its long stratospheric lifetime, SF₆ is considered as inert in the given analysis range." If your method does not consider SF₆ sinks how can you overcome the biases caused by the mesospheric sink of SF₆ when using mean age-of-air methods? This needs to be clearly explained and justified as the manuscript claims this is one of the main advantages of the ANCISTRUS method in the study of the BDC. (See my Specific comment on this).

65-68: This paragraph cannot be clearly understood in its present form. Please rewrite and clarify.

Line 70: "at a certain point at one day". Change point to location; delete 'at'

Line 73: Do you mean "in the real atmosphere"?

Figure 1 caption: for clarity, spell out month in the units (deg month⁻¹)

line 81: "not so much interested in the explanation of the atmospheric features", but this is the main scope of the methodology, right? If you do this in the companion Part 1 paper at least you should mention that here.

Line 85: delete "broadly speaking" or substitute by "on first approximation"

Line 88: (right panels) does not correspond to figures layout

Line 90: “regardless if sinks are estimated..” to “regardless of sinks being estimated..”

Line 99: More information should be included on how the method copes with, and provides information on, the diffusive and dispersive characteristics of transport. (also Specific Comment)

Line 101 and 120: The word severe is not the best one here, perhaps exhaustive, strict, tough..?

Most of page 6, if I understand correctly, is mainly a summary of results in vCG16. If vCG16 shown the validity of the method, this should not be repeated here in a lengthy way, but perhaps written in a way that is more clearly related to the results you show in the current study, e.g. linked to the arguments you use to choose further tests.

Line 140: “September–October 2005” does not correspond to what Fig 3 labels indicate. Please resolve.

Figure 3 and related discussion: what you mean by reference fields needs to be more clearly explained in the main text.

Lines 143-144: how do these underestimation values compare to biases/uncertainties obtained with other methodologies?

Line 149: Please check labels of Figures and corresponding references in the main text match each other.

Line 151: “..are underestimated by about 25% but broadly speaking, the inversion is successful also in quantitative terms.” Not clear what you mean, a 25% underestimation does not sound like a quantitative success. Please rephrase or explain further.

Line 155: Move “(Figs 4 and 6)” somewhere else within the sentence, it is not clear whether these two figures refer to the August-September-October 2010 cases or the previous tests.

Line 156: Include some quantitative information on the slight underestimation to put it into context with the results presented earlier. Overall, in the discussion of Figs 3 to 6, more information/explanation should also be included on the reasons for the under/overestimation of fields.

Line 157: But has it removed existing fields in any occasion? Please add some sentence on this.

Figures 3 to 6 use different color scales for the differences (lower panels in the figs.), wouldn't it be better to use the same color scale to facilitate comparison?

Line 172: Why this particular year?

From results in Figure 7 it seems as if weaker regularization produced better results (middle right panel), why haven't you chosen that regularization instead of the nominal one? If it is due to convergence problems, wouldn't it be useful to show also results for other month/year where the stronger regularization does not work so well?

Line 196-197: If you mean that low sensitivity to the omission of a single species shows the robustness of the methodology, I agree and suggest rephrasing this sentence to make it clearer.

198: “respective” to “corresponding”

Line 199: “similar to a jackknife method”, not sure what this means in this context and not sure this part of the sentence is necessary, the set-up is clear.

Line 202: gradients between regions

Some of the Figures 8-13 could/should be combined as multi-panel figures (6 or 9 panels/fig) to reduce the number of Figures and facilitate looking at results in a more straightforward way.

When describing the figures in the main text, some quantitative data should be added, e.g. percentage contribution for each species.

Lines 214-216: If the information coming from the mentioned species contributes to reduce uncertainty, then it is neither useless nor redundant; please consider rewriting these sentences to avoid confusion.

This is also a general suggestion for the whole of Section 5, results in this section show the importance of the different species and the different role they play in forming the final resulting fields, therefore I would suggest not using the word “redundant”. Otherwise, why would you use, and show here, redundant information? As far as I understand you have included all species to obtain the final ANCISTRUS results, right? If not, this should be more clearly stated early in the manuscript.

Figure 14: How does the standard deviation responds to the omission of some of the other “minor” species? It would be worth adding one sentence to the main text and perhaps some additional panels to this figure.

Line 221: Please introduce ANCISTRUS at the start of this Section. See also my Specific Comment about Conclusions. Some sentences read as contradictory. For example you say “fairly accurate”, then “perfectly reproduced”, and then again that there is still room for fine-tuning for a better retrieval of velocities. Overall statements in this section are not clearly backed up, a clearer reference to the results you have shown should be included. The meaning of the last sentence is not fully clear.