

OVERVIEW:

The quality of the previous manuscript was hampered by the absence of any significant validation of the method. This has now been at least partially rectified by the validation paper, which has shown that the qualitative features of ANCISTRUS results are at least somewhat reliable. With that in mind, I believe that this paper can be published without additional validation work. Before publication, I recommend that minor revisions be undertaken for clarification of the paper. In two places ("major" comments L027-029 and L201), some changes in content are warranted.

I want to provide one important comment to the author with regards to the validation of their work. The ANCISTRUS recovery tests performed in the validation paper are, in my view, a partial validation of the method. Comparing reference and result effective velocities only shows the effectiveness of the method in reproducing its own results. This does give credibility to the claim that the ANCISTRUS tool does not produce spurious structures, which is the most critical requirement of an inverse method. However, the quantitative claims in the paper are difficult to verify because no differences between the reference and result fields were shown. See my comment under "Non-Revision Comments" for L133-134 for more thoughts on that. I am inclined to believe the text in your validation paper on those quantitative claims, but as I cannot verify these results myself, I will not be able to remove my doubt.

Furthermore, the absence of a comparison between effective velocities and "standard" quantities remains as a source of doubt on the interpretation of your results. By standard quantities, I mean the various residual circulation quantities. A comparison of effective velocities derived from model tracer fields with the model residual circulation velocities which produced those tracer fields is, in my view, a necessary task. Without this, the relationship between effective velocities and residual velocities will remain unclear, and any comparison of the two from different sources will be clouded by the absence of this validation. For example, your results show a mesospheric overturning circulation and BDC deep branch that are not clearly separated, but what if mixing is playing a role in the effective velocities at this location?

That all being said, I think it would be excessive to request a comparison of effective and residual velocities from model results be performed now, before publication. Nor should a more explicit quantitative investigation be requested. However, I think these absences weaken what would otherwise be an exceptionally strong contribution to middle atmospheric science.

MAJOR:

L027-L029: "the true picture of middle-atmospheric circulation is more detailed and too complicated to be characterized by a scalar intensity of the circulation." This statement suggests that scalar measures cannot characterize the stratospheric circulation at all. In my view, scalar measures are the very first or most basic characterization of the circulation. I do, however, agree with the notion that scalar measures cannot capture the details of the circulation (such as the activity of different pathways), and that progress towards understanding the stratospheric circulation will require understanding these details. I suggest changing this statement to focus on the insufficiency of scalar measures to characterize the details (nuances, pathways, etc., I think a lot of terminology would fit here) of the circulation, or on the insufficiency of scalar measures to provide a complete description of the circulation.

L039-L040: A comma or hyphen is necessary between "overturing circulation" and "which brings" and between "ozone chemistry" and "has been". This is necessary to provide a clear boundary on the aside

about NO_x rich air and stratospheric ozone chemistry.

L047-L050: The meaning of this sentence ("While the...") is not clear to me. Are you suggesting that the comparison of modelled trace gas fields with observed fields is used to estimate the stratospheric circulation? I can't think of any true, published attempts at that. Is that what you mean? It seems like this sentence needs rewriting. Also, in relation to age of air methods you could cite the work of Fritsch et al. (Fritsch, F., Garny, H., Engel, A., Bönisch, H., and Eichinger, R.: Sensitivity of age of air trends to the derivation method for non-linear increasing inert SF₆, Atmos. Chem. Phys., 20, 8709–8725, <https://doi.org/10.5194/acp-20-8709-2020>, 2020), who demonstrate some difficulties of using age of air methods (in particular the AirCore-derived results of Engel et al.).

L050-L052: This sentence ("Our results...") seems to state the same information as the following sentence. Furthermore, the mention of "our results" comes before any mention of the work of this study, which is an atypical form. I do not see any point to this sentence, nor to the previous sentence. I suppose the goal of this paragraph was to clearly establish the need for your work (and there is certainly need) but I think this has not been effectively communicated.

L201: You write here about air mass transport. I agree with the basic principle (weaker velocities at lower levels may easily transport more air mass than stronger velocities at higher levels). I have some concern, however, that the effective velocities may not correspond directly to air mass transport. In my view, noting the possibility of a discrepancy in this regard is important.

L216-217: You write here about the stratopause location. Would it be possible to include estimates (even approximate) of the stratopause and tropopause locations on your figures? I'm not sure what data source would be most appropriate for that information. Even a long-term monthly-resolved climatology would be very helpful for the reader to interpret the results. In my view, this would be very helpful, but not necessary.

Figure 1: I think you should consider using streamfunctions to visualize the velocity field. The figures as they are do somewhat show the qualitative information, particularly for stronger velocities, but the quantitative information is somewhat difficult to interpret. In my view, streamfunctions would be a more effective and familiar quantity for the visualization of this qualities of the effective circulation.

Figure 1 caption: You mention "non-converged inversions" here, but I do not see that mentioned anywhere else in the text. In my view, that should be addressed in the main text somewhere.

Figure 5: I like these figures, but I think you only quantitatively reference variability in comparison with local velocities. Due to that, you should consider showing variability relative to the local monthly-mean velocity. In my view, this isn't necessary, but it has the potential to assist the reader in interpretation greatly.

L496-499: The region you describe here sounds a lot like the startospheric surf zones, but that's not mentioned in the text anywhere. You might consider making a mention of that here, if you also agree that the variability in velocities that you've found in the region could be related to surf zone activity.

L525: Mentioning funding is not really appropriate for a peer-reviewed publication. This should be removed and some other introduction to the sentence should take its place.

MINOR:

L055: Probably you should say "effective circulation vectors" right

away, as opposed to leaving the information about the "effective" nature of your results for later.

L083: "than with the age-based method" suggests that there is only one age-based method, which I think is not the case, so this should be "than with age-based methods".

L086-087: Here you write the name of the method, but that should probably be written the first time the method is mentioned, which is earlier in this section.

L089: "future tracer gas" would be more precise. Or "subsequent".

L117: Can you estimate these inaccuracies?

L118: You should either provide some quantification of this "minor relevance" or at least provide some citation for that information.

L124: Do you mean SF6 sinks? It's not clear to me. That should be clarified.

L179: About the words "allows to better resolve", because resolution is something you discuss as an advantage of the method, "resolve" seems to suggest that there is some difference in the method here. I suggest replacing this with the phrase "allow easier interpretation of".

L181: Saying "inter-annual averages" or "climatological averages" might be helpful for the reader.

L190-191: Was this uncertainty quantified?

L208: About "signal of subsidence": do you mean in Figure 6? If so, that should be specified ("signal of subsidence in the inter-annual variability"). If the velocity figures are indicated instead, I think this should be expanded upon, as there are certainly some cases where subsidence seems to occur, in particular november-december of Figure 4.

L217: New paragraph at "Most parts".

Figure 1 caption: You mention missing species are indicated in the headers, but I don't see any species indicated.

L298: "there" is not very precise. I think "present" would be more precise.

L343: The word "it" could refer to multiple entities. It would be better to state this explicitly.

L416-417: "Figures 7-8 (middle right panels)" or "the righthand middle panels of Figures 7 and 8"

L444: "large interannual variability is expected based on current theory" would be more precise

L444-L446: About "The stability...", I don't see how this sentence helps. As far as I can tell, the flow of the paragraph would be better without this sentence and the meaning of the paragraph would not change. The next sentence is much more to-the-point anyway.

L461: "From our results" is better, as you just mentioned MIPAS "data".

L494: I don't understand what "this" is referring to, or what this part of the sentence (everything after "km," means).

L510: "common" is confusing here because it seems to leave the possibility that you use an uncommon a priori distribution to nudge your method.

L511: After "patterns." might be a good place to add a sentence briefly

describing the iterative nature of the method. "An initial velocity distribution was used to begin the iterative inversion calculation, but the choice of this initial field does not have significant effects on the resulting fields" or something like that.

L515: I think what you mean by "features" is "novel results". Of course there are very many more features, but these are certainly the most interesting ones of your results. They are very interesting, by the way.

L520: "The particular figure quoted" is somewhat strange. I recommend removing the citation in the previous sentence and replacing this text with "For example, the schematic of Bönisch et al 2011 (their Figure 1)" or something similar.

TYPOS:

L006: "THE stratospheric circulation is found to be"

L018: "and is called THE 'Brewer-Dobson circulation' "

L027: "the true picture of THE middle-atmospheric"

L090: Comma after "coefficients"

L098: 'field' not 'fields'

L102: 'is started', not 'ist'

L102: 'final' not 'finally resulting'

L104: "Since inferred velocities, due to the correlation of velocities and atmospheric composition, are not the zonally-averaged velocities but include eddy transport effects, we call the inferred velocities 'effective velocities'."

L109: Comma after H2O.

L110: Comma after "band". These commas, and the ones I mentioned earlier, are called "Oxford commas" if you want to look that up. It's a practice used to avoid confusion in lists.

L112: "photolysis"

L112: "and" instead of ", as well as"

L115: Probably you want to say something like "equilibrium assumption", but I know this as the "steady-state assumption".

L119: Comma after CO.

Figure 1 caption: ", the months" should be ", and the months"

L459: "pole-to-pole"

L467: "THE NH atmospheric circulation"

L490: "transport pattern"

L501: "broadly reproduces well" doesn't make sense, just say "broadly reproduces"

L502: "but" instead of "however"

L506: remove "of air sampling instruments" as it's not necessary

L507: "the sense" not "a sense"

L518: Comma after e.g.

L522: "future steps" should read "future steps for this work"

L523: "analysis"

L523: remove "the" in front of "interannual"

NON-REVISION COMMENTS (I.E. NO CHANGE SUGGESTED):

L133-134: I found it difficult to verify this claim in the validation paper. The validation paper does show the two (reference and result, if you will) velocity fields, but does not display the differences between them as far as I can tell. Because the claims of the present paper do not depend on quantitative information, there is no need to establish this point further. However, I think you should be aware of this in future work. What would help is a simple depiction of the reference velocities, the result velocities, and the differences between them, all next to each other. That would make interpretation rather easy for readers. Again, I do not think this is necessary for this paper, but please consider this for future work.

L525: In my view, the distinction of transport and mixing is absolutely the most important future step for this work. It is still not clear to me what aspects of your results are due to the inclusion of mixing, and this brings me to view the results with some uncertainty. It would also be very, very cool to have estimates of mixing in the resolution that your results have.