Review on egusphere-2023-2877

Northern vs southern hemisphere differences in the stratospheric influence on variability on tropospheric nitrous oxide by Nevison et al.

Nevison et al. present a follow-up study of their publication in ACP from 2011. In their current study they present simulations with a GCM using a tagged stratospheric tracer of N_2O to investigate the stratospheric influence on the seasonal cycle of tropospheric N2O. Additionally, they use the QBO and ENSO index and the polar lower stratospheric temperature as proxy for atmospheric transport and correlate these parameters with the N_2O atmospheric growth rate. They find that the atmospheric growth rate anomaly in the southern hemisphere is better correlated to the QBO index, than to polar lower stratospheric temperature and that this hemispheric difference is consistent with the current knowledge of hemispheric difference in atmospheric dynamics.

This is a very interesting study and a valuable continuation of the previous work of Nevison et al. (2011). However, the current version of this manuscript is completely overloaded. There is too much analyses presented and a lot of necessary information missing, this is especially the case for the result section. You cannot expect the reader to read several papers additionally to your current manuscript to be able to follow the presentation of your current results. On the other hand, a very extensive discussion section is provided which rather confuses than helps to understand the dynamical processes behind.

Thus, I would suggest major revisions before publication in ACP based on the comments and corrections given below.

General comment:

- My major comment and suggestion for improvement would be to remove the entire part with the ENSO and QBO index and correlation of these to the atmospheric growth rate. I would suggest to instead focus on the experiment with the tagged stratospheric tracer which is a really great and convincing tool to study the stratospheric influence on the tropospheric seasonal cycle of N_2O. From the correlation analyses part you could make a second paper where you also use model experiments to better substantiate the dynamical processes behind. So far it has been done in a rather speculative way than providing real proof. With skipping that part you would still have 8 figures plus 2 from the supplement, thus 10 in total which would be a reasonable number.

- In many occasions your provide already statements on the results before you have shown the respective figure/analysis. This is not a good way of writing and causes only confusion. Thus, I would suggest that you first describe what is shown in the figures/what analyses has been done and then provide the results you gain with exactly stating what leads you to your specific result/conclusion.

- A lot of explanation/description of the figures/analyses is missing in the result section. It is really hard to follow what exactly has been done and why. This definitely needs to be improved. This of course will make your manuscript somewhat longer, but more valuable for the scientific community. Further, to have a not too long paper, we are back at my first comment to then skip the part with QBO and ENSO index, because the results of the tagged tracer experiment provide enough content for one paper.

- In the submission form you stated that your paper is a follow-up study of Nevison et al. (2011), but unfortunately, nowhere in the paper you state what is the new analyses/finding compared to your previous study.

- Figure captions should generally only describe what is shown in the figure not provide any statements on the results or method. This should be rather described in the respective sections. Thus, all figure captions need to be revised.

Specific comments:

P1, L20ff: The abstract needs to be revised. See ACP guidelines. You solely describe your results, but you do not provide any introduction to the topic (e.g. why is it important?). Further, the abstract should end with some sentences stating what the importance and implications of your results are.

P3, L82-83: This is a result and should not appear in the introduction.

P3, 87: In the introduction I would have expected more information on the tagging experiment you have done. What is tagging and for what is it used. Not every reader is familiar with this technique. So a short explanation is needed.

P4, L102: Add here some sentences stating how good the model is plus references. Are there evaluation studies that show the quality of the model simulations especially with respect to atmospheric dynamics? That many models have problems simulated a proper QBO is discussed e.g. in Khosrawi et al. (2013).

P5, L137: "local Kriging"? What to you mean with "Kriging"? I have never heard about this and I guess you should provide some more explanation. Further, the reference should appear without parenthesis (should be embedded in the text).

P5, L150: What is meant with "2-4"? Are these the campaign numbers? Please clarify.

P5, L152: What does this mean? Is thus data missing for this time/time period? Please clarify and rephrase sentence accordingly.

P8, L236: It would be better if you first would describe what is shown in the figure and what kind of analyses you have done before you make statements of what the result is. What exactly in this figures does point to your interpretation that there is a stratospheric influence?

P10, L251: Not stratospheric loss. I guess you mean here stratospheric air or air characterized by low N2O.

P10, L257: This deviation could have many reasons. Either the model has deficiencies in the sources and sinks of N_2O or atmospheric transport. Not clear if stratospheric or tropospheric processes are the cause of the shift. It could be that N_2O_{ST} is correct, but N_2O not.

P10, Figure 1: You show 6 stations for the NH, but only 3 for SH. Why do you show less for the SH than for the NH. How have these stations been selected? What where the criteria for choosing these?

P10, Figure 1: This figure is overloaded. You do two analysis in one figure. First, you use observations to evaluate the N_2O seasonal cycle from the observations. Then you use N_2O_{ST} and the other curves to investigate the processes that affect the seasonal cycle. Thus, I would suggest to split the figure. One where you compare N_2O_{obs} with N_2O model and one where you show N_2O_{ST}, N_2O_{soil}, N_2O_{ocean} and

N_2O_{anthro}. The complete figure showing all curves in one plot as done now, could be provided in the supplement.

P10, Figure 1: The amplitude of the seasonal cycle is max +-0.6. Assuming a tropospheric mixing ratio of 330 ppbv, this corresponds to less than 1 %. Thus, I would state that this is a minimal change and have difficulties to understand why is nevertheless still important to investigate the seasonal cycle of N_2O?

P10, Figure 1: Another comment on the figure or the discussion of this figure in the paragraph above. This figure indeed shows a stratospheric influence on the seasonal cycle of N_2O, but generally, I think there is now requirement that the minimum in N_2O_{ST} overlaps with the minimum of N2O. Especially, with the known atmospheric transport time scales I would rather expect a time shift between the minima.

P11, L270: That descent is underestimated in atmospheric models has been shown in e.g. Brühl et al. (2007) and Khosrawi et al. (2009, 2018).

P11, Figure 4: Also here, first the figure should be described and then the results you get.

P11, Figure 4: Looking at the scale of the figure, the variation is +-1 ppb. As stated above, for a species having a mixing ratio of a few hundred ppb this change could be rated as being neglectable. Why is it nevertheless important to investigate the seasonal cycle?

P11, Figure 4 and respective text parts: Why is the anomaly strongest in summer. Shouldn't that rather be the case for winter/spring? Why do you detrend the data by using the de-seasonalized time series from Mauna Loa? Why do you do this and why is Mauna Loa used and not one of the other stations? Why you do what should be clearly described in the manuscript.

P12, L295: It is not clear why you use the HIPPO data here. You provide an explanation based on altitude, but although you show somewhat different figures than the previous one (latitude vs altitude instead of time vs altitude), the altitude region considered is the same. So the reasoning you provide is not clear at all.

P12, L292: Why is here now also the Atom data used? Repeat once again what your intention is of additionally using data from aircraft campaigns.

P12, Figure 5: Also here, it is not clear to me why you de-seasonalize the data with the N_2O from Mauna Loa.

P13, Figure 6: Why does the HIPPO data show positive values ΔN_2O in the NH polar regions. I would have (at least in the winter months) expected negative values. I think I am now completely confused, because there is so much explanations/descriptions on your analyses missing.

P13, L300: The section title does not really reflect what you are actually showing in this section. You show here correlations between T and delta N_2O and not the minimum in N_2O or the seasonal variation of it.

P13, L301: There is a correlation but I would not call it significant. Have you checked if it is statistically significant? Is that what you mean here?

P13, L304: In figure 4 however only the South Pole is shown.

P13, L310: What are Atom and ORCAS? Campaigns? Even though you have described your data in the method section it should be repeated here once again.

P13, L300ff: This is all too quick and condensed described. Figure 7 and 8 definitely need more description and explanation so that it is possible to follow your analyses and results.

P14, L318-319: What does it mean that you derive only for Mace Head a significant correlation, but for all other stations not?

P14, Figure 7: You show here measurements and the results from the model, but why you show both and how they differentiate is not discussed in the text. Why then showing both?

P14, Figure : In this figure is too much information (see my previous comment). Also here it would be better to skip some of the subpanels or to split the figure into two figures.

P14, Figure 7 caption: "seasonal anomalies" since you look for minima I am confused, but the seasonal anomalies are also positive. Thus, as stated in my previous comment the section title is rather misleading.

P15, Figure 8: In order that these figure panels can be more easily compared with each other, they should be plotted in the same manner. Thus, the left panel should also be plotted from -70 S to 80 N, but masking the parts of the data that are not considered as white area.

P15, Figure 8 caption: The figure caption text is really confusing and needs more structure. Describe what is shown on the left and right (stick to the facts) and put everything else (results, reasoning etc.) into the main text.

P15, L339: Here, you should repeat again what your intention is with using the QBO and ENSO index.

P16, Figure 9 and P17, Figure 10: Add a legend? What is shown be the different colors and line styles?

P16, L345: Why is this correlation significant? Is it just statistically significant? From the correlation coefficient itself I would say that there is no or only a low correlation found.

P18, L375: Finishing reading this section I was wondering why these correlations are shown at all. It seems that there is no correlation or anti-correlation found. Why then discussing the correlation between N_2O and QBO and ENSO?

P18, L380ff: Here you start to describe the atmospheric processes in detail, but that should be rather done somewhere in the paper between method and result section or embedded at the respective places in the result section. In the discussion you should just put your results rather in broader context of the scientific field and discuss uncertainties, agreements or disagreements with previous studies etc.

P19, L385: I do not see this.

P19, L398: Why slow? Couldn't also fast descent bring N2O depleted air down? Wouldn't it be that the amount of N_2O depleted air would differ dependent on slow or fast descent?

P21, L456: What exactly is different in the NH compared to the SH? Wave activity is also high in the SH, so that alone cannot be responsible for the differences in dynamics between the hemispheres.

P21, L473: I am not sure if the differences in dynamics between the southern and northern hemisphere as described in Holton et al. (1995) are still valid. This should be checked. There have been many studies and new findings on atmospheric dynamics in the recent years.

P23, L521: The discussion section is much too long, too detailed and too speculative. This section should be significantly shortened and rewritten so that it is more concise. Focus on what is really important and directly related to your study and your results.

P23, L526: I would not say that the air accumulates there. The air descends during winter in the stratosphere and is then transported to the troposphere.

P23, L526: When exactly the air crosses the tropopause has not been shown and also no references are provided. How do you know when and to what amount (e.g. N_2O fluxes) N_2O is transported down to the troposphere? You get some information on this from the tagged tracer in your model simulation experiment, but that should be clearly discussed here.

P23, L526: Another question on this text line is, what is happening with N_2O on its way? It is not chemically reacting in the troposphere, but the N_2O depleted air will mix with the tropospheric N_2O rich air on its way that will result in that the stratospheric signal will get less and less as longer N_2O is on its way to the surface.

P23, L533: Stratosphere-troposphere exchange and how it is linked to the BDC is not shown and also no references have been provided.

References: The formatting of the references is not correct. See ACP manuscripts/guidelines. Further, there are several citations in the list that are not used, as e.g. Khosrawi et al. (2008) and Glatthor et al. (2007).

Technical corrections:

P5, L134: magl -> m AGL

P5, L149: four ~ month-long -> ~ four month-long

P7, L194: The abbreviation PLST has not been introduced.

P7, L198: Add which months you consider as winter months and which as spring months.

P15, L333: Figure 8 caption: First sentence not correct. Please rephrase.

P15, L334: I guess here it should read ORCAS and not Atom/Atom-2.

P15, L336-337: Sentence not clear. This needs more explanation. However, this should not be done in the figure caption, but in the main text.

P15, L338: Check title, some of the words should be rather starting with a small letter than a capital letter.

P17, L367: August-July -> July- August

P22, L505 and 506: The abbreviations OMZ and ETSP have not been introduced.

References:

Brühl, C., Steil, B., Stiller, G., Funke, B., and Jöckel, P.: Nitrogen compounds and ozone in the stratosphere: comparison of MIPAS satellite data with the chemistry climate model ECHAM5/MESSy1, Atmos. Chem. Phys., 7, 5585–5598, https://doi.org/10.5194/acp-7-5585-2007, 2007.

Khosrawi, F., Kirner, O., Stiller, G., Höpfner, M., Santee, M. L., Kellmann, S., and Braesicke, P.: Comparison of ECHAM5/MESSy Atmospheric Chemistry (EMAC) simulations of the Arctic winter 2009/2010 and 2010/2011 with Envisat/MIPAS and Aura/MLS observations, Atmos. Chem. Phys., 18, 8873–8892, https://doi.org/10.5194/acp-18-8873-2018, 2018.

Khosrawi, F., Müller, R., Urban, J., Proffitt, M. H., Stiller, G., Kiefer, M., Lossow, S., Kinnison, D., Olschewski, F., Riese, M., and Murtagh, D.: Assessment of the interannual variability and influence of the QBO and upwelling on tracer–tracer distributions of N_2O and O_3 in the tropical lower stratosphere, Atmos. Chem. Phys., 13, 3619–3641, https://doi.org/10.5194/acp-13-3619-2013, 2013.