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Atmospheric Chemistry and Physics Discussions

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Interactive comment

# *Interactive comment on* "The importance of interactive chemistry for stratosphere–troposphere–coupling" *by* Sabine Haase and Katja Matthes

**Anonymous Referee #1**

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The paper is generally well-written and well-organized. In particular, I like how the authors make an attempt at explaining the full dynamical storyline rather than just relying on statistical metrics. However, there are also several points that require improvement. For example, the importance of interactive chemistry has been realized in many other types of simulations and contexts, which is not mentioned at the moment. In addition, certain scientific aspects need revision and/or clarification (see general comments). More specific points and technical corrections (typos etc) are grouped separately. Subject to these revisions, I would recommend publication.



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**General comments:**

1. The importance of interactive chemistry has been shown in many contexts other than in relation to the polar vortices. A non-exhaustive list of examples includes effects on global climate sensitivity and the Walker circulation (e.g. Dietmueller et al. 2014, Chiodo & Polvani 2016, Nowack et al. 2017, Noda et al. 2018) as well as the mid-latitude jet-streams (Chiodo & Polvani 2017, Nowack et al. 2018). This wider context should be highlighted briefly either in the introduction or discussion section.

2. A wider perspective would further allow the authors to discuss the relevance of certain climate feedbacks such as changes in stratospheric water vapor. The authors discuss the feedback loops (Figure 1) purely from the perspective that ozone depletion leads to cooling and corresponding changes in the zonal wind and wave propagation, which in turn affects temperatures and ozone due to changes in meridional transport of heat and ozone. However, the same changes would affect the transport of, for example, water vapor into the vortex, which is important for PSC formation (cf. winter 2011) and temperatures in the lower stratosphere (more water vapor, more longwave cooling). Do you find such dynamically-induced changes in water vapor and how would these qualitatively modulate the described feedbacks? Finally, I assume that stratospheric water vapor anomalies due to historic stratosphere-reaching volcanic eruptions are similar in both the interactive and non-interactive simulations, as you take ozone time series from the interactive runs. However, are there any significant differences in the background water vapor levels between the interactive and non-interactive simulations?

3. Concerning volcanic eruptions and the way you prescribed ozone (e.g. mentions on p.1 l.16-18, p.5 l.1-14): while the forcings are the same, the free-running sea surface temperatures from the interactive ocean are not. a) How do you

think this affects the dissimilarities/occurrence of the SSWs between the runs? b) Could the use of the model-consistent ozone time series be a reason why you find that 3D climatologies work fairly well? I assume that taking a 3D ozone field from another model would much more negatively affect the vortex climatology. In that case, you would have to recommend model-consistent 3D ozone forcings, which are much harder to produce (i.e. why not run interactively anyway in that case)? Finally, most models would also not use a daily updated ozone forcing, which could lead to even larger differences than those found here. These details in the set-up need more discussion/context beyond what you have done here...otherwise general climate modelers will just take the next best 3D climatology.

4. The study would greatly benefit from more ensemble members for each run, which could consolidate many of the conclusions reached. From my side, this is to be seen as a recommendation rather than a request. However, this could help overcome some of the significance issues (as raised by the authors themselves in the conclusions and as is clear from Figure 7).

**Specific comments:**

1. p.1 l.23: ...ozone is MAINLY produced in the tropics; cf. Grewe 2006.
2. p.2 l. 2-4: it is not just ozone absorbing but also the production of ozone from molecular oxygen.
3. p.2 l.33: slightly awkward sentence with confused reasoning. Maybe: "The impact of ozone depletion on...spring (when sunlight returns) and, following our above discussion, will be very sensitive to the background state of the polar vortex.

4. next sentence: ...into the summer circulation, thus implying enhanced wave propagation (dynamic heating) as a result of ozone-depletion-cooling (?). Link it back to the discussion. In the next sentence, I am not sure any more what you exactly mean by 'negative feedback' (p.3, l.1).

5. p.3 l.8-16: you mention all these different treatments of ozone, but you actually use a different way of a time-dependent model-consistent ozone. Therefore, you also explore a different error space than if you had used the climatology by Cionni et al. This paragraph leads the reader on the wrong track, see also my general comment 3. This point requires additional clarification here, in the abstract, and in the conclusions.

6. p.3 l.24 Son et al. 2008 would be another good citation here

7. p.4 l.2-3: there are only a few studies that are designed to systematically compare the effect of including and excluding interactive chemistry in the same model. See my general comment 1. This might be true in this context but all studies I mention there did indeed the same, just focusing on different phenomena.

8. p.4 l.15-21: could the authors say more about why the various studies found different results. Did they use different climatological ozone fields? Coupled oceans? Stratospheric resolutions? Is it simply dependent on the chemistry-climate model used? Equilibrium vs transient runs?

9. p.4 l.33-35: so how specifically is your approach different to the one used elsewhere in terms of quantifying surface impacts in particular, or is it just the STC you are referring to?

10. p.5/6 model description: were all runs initiated from the same ocean spin-up run in 1950?







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11. p.6 l. 22: how is it possible to prescribe the total heating rates? I understand correctly that this applies only above 65km?
12. p.6 l.25: specify all necessary components, is this next to ozone also methane,... Here you mean the entire atmosphere again, not just above 65km?
13. p.7 l.2-4: I find this quite a non-standard procedure for calculating the anomaly. Is this the global mean for that year? Please add some more detail rather than just referring to a reference.
14. p.7 l. 6: slightly awkward formulation. 1hPa is the entire stratosphere.
15. p.7 l.16/17: Why would you omit the criterion if it has no influence. In that case, you might just as well say you included it.
16. p.9 l. 34: Since a statistically[...]. You say that but don't actually show it. However, I would indeed be interested in seeing those correlation plots from CHEM-OFF as well. Can you put them just next to the other plots in Figures 5? That would be quite convincing!
17. p.10 l.10-12: could you iterate a bit more here. Which other processes do you have in mind? Could water vapor play a role? How would ozone waves specifically perturb the picture that you outlined before? Enhancing local dynamical wave propagation?
18. Figure 8: I find the different effects impacting these results difficult to comprehend. As you show in Figure 7, the timing of SSWs occurring in CHEM-ON and CHEM-OFF is very different. Could these average changes simply be due to different background states (many CHEM-OFF events happen later during the year) between these two cases, affecting downward propagation? Could you maybe provide a similar plot just for January and February when you have a similar number of events in total?

19. I would recommend adding results for CHEM-OFF-3D to Figure 7. How is the timing of events in that case?
20. Further recent studies that could be cited: Silverman et al. (2018) when talking about ozone waves and Nowack et al. (2018)b when talking about possible alternative representations of ozone.

**Technical corrections:**

1. p.1 l.9: ...statistically significantly...
2. p.2 l.6: revise: ...over the thermal wind balance...
3. p.2 l.8: ...and, by extension, surface climate...
4. p.3 l.2: swap 'accurate' to 'sophisticated'
5. p.3 l.5: reformulate, for example: However, fully interactive atmospheric chemistry schemes are computationally expensive. (...the ocean is completely separate, so not sure why to mention...). An alternative way...
6. p.3 l.19: ...once sunlight returns...
7. p.5 l.27: ...chemistry-climate...
8. p.5 l.30: On the SH (?), cold bias in the stratosphere, or surface, or where?
9. p.7 l.10: italicize 'A'
10. p.10 l.6: typo
11. p.10 l.22: fewer SSWs





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