

***Interactive comment on* “Linking the uncertainty in simulated arctic ozone losses to modelling of tropical stratospheric water vapour” by Laura Thölix et al.**

Anonymous Referee #2

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General

The authors investigate the sensitivity of modelled Arctic ozone loss to the water vapour mixing ratio entering the tropical stratosphere in a chemical transport model. They guide the reader well step by step through the causal chain water vapour concentration → PSC volume → chlorine activation → ozone loss. The authors clearly state that the investigated question is different from investigating the effect of water vapour changes due to climate change (which would occur on such a timescale that also the concentration of chlorine- and bromine-containing species changes considerably). They also clearly state that they investigate only one aspect of the above-mentioned question,

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namely the effect of water vapour on the surface area density of Polar Stratospheric Clouds (PSCs), neglecting the (probably stronger) effect of water vapour changes on ozone loss via changes of stratospheric temperature.

Comments

- An increase of water vapour may enhance heterogeneous chemistry by enlarging the air volume in which PSCs are formed (shown in Figs. 4 and 5) or via enlarging the surface area of existing particles (not shown). The authors seem to assume that the first effect is the dominant one. A discussion of this topic would help to complete the logic of the paper.
- The authors claim an important role of NO_x chemistry in warm winters. I would appreciate plots showing this, e.g., altitude-time plots of vortex-averaged NO_x or / and altitude-time plots of the corresponding reaction rates ($\text{NO}_2 + \text{O} \rightarrow \dots$ for NO_x chemistry, and, for comparison, $\text{Cl}_2\text{O}_2 + h\nu \rightarrow \dots$ and perhaps $\text{ClO} + \text{O} \rightarrow \dots$ for ClO_x chemistry).
- The authors do not discuss the influence of heterogeneous NO_x chemistry on ozone. Can the model results be used to answer the question whether the heterogeneous reaction $\text{N}_2\text{O}_5 + \text{H}_2\text{O} \rightarrow 2 \text{HNO}_3$ reduces NO_x and thus NO_x -driven ozone loss in cold years (compared to other years)?

Minor comments

- 1/17: "2-7% more ozone loss than in colder winters" \Rightarrow Does this mean "2-7% stronger increase of ozone loss than in colder winters"?

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- 2/1 and 14/3: “warms the climate” means “warms the troposphere”?
- 3/2-3: “cooling stratosphere ... slowing down some gas-phase reactions”: Which gas-phase reactions are meant? In the polar stratosphere (during winter / spring) an important reaction is the three-body reaction $\text{ClO} + \text{ClO} + \text{M} \rightarrow \text{Cl}_2\text{O}_2$, the rate-constant of which **increases** for decreasing temperature.
- 5/3: “around 80 hPa”: In view of the discussion in 5/29-31 this should be formulated more precisely, e.g. “at the cold point, which lies approximately x hPa below 80 hPa”
- 5/29-31: “leads ... by 3-4 weeks ... Brewer-Dobson circulation ... too fast”: Does this mean that between the cold point and 80 hPa the ERA-Interim circulation takes 3-4 weeks less than the real circulation. Is the distance between the cold point and 80 hPa large enough to gain such a difference?
- 6/3: “gains a small amount of water”: How, by horizontal mixing?
- 8/4: “For example too dry models may not be able to simulate a large Arctic ozone loss such as of 2010/11”: How does this sentence relate to the preceding sentence?
- 9/15: “in spring”: and also during southward excursions of air masses during winter
- 9/16: “PSCs sustain the regeneration of ClO_x ”: This is only possible if both reaction partners for a heterogeneous reaction are still present.
- 10/9: “rather short”: The green curve in Fig. 6d lies above 60% for about 2 months. Is this meant by “rather short”?
- 10/17: “differs significantly ... during the period with high ClO_x ”: The difference is mostly less than 10%. Is this meant by “differs significantly”?

- 10/18: What exactly is meant by “chlorine activation period”: the time when most chlorine exists in active form?
- 11/4: “... only at the 475 K level”: Does this mean that the 475 K level is used for the definition of the whole vortex? If so, this should be mentioned (and perhaps be discussed) already in 6/7.
- 11/11: “FinROSE seems to underestimate the ozone loss, possibly due to a general 10% negative bias in total ozone”: Why does an underestimation of the ozone concentration lead to a significant underestimation of the ozone loss? The rate of ozone loss in polar winter/spring is largely determined by the rates of reactions like $\text{ClO} + \text{ClO} + \text{M} \rightarrow \text{Cl}_2\text{O}_2 + \text{M}$ and $\text{BrO} + \text{ClO} \rightarrow \dots$.
- 11/23: “stopping the catalytic ozone cycles and ozone loss early”: The ozone loss stops around the beginning of March (Fig. 7d). Is this meant by “early”?
- 13/4: “the heterogeneous chemistry destroyed about 36 DU of ozone”: In fact, ozone is destroyed by gas-phase reactions. Heterogeneous chemistry produces (some of) the corresponding reactants.
- 14/24: “in higher level”: Does this mean at higher altitudes?
- Tables 1, 2, 3: As a “service” for the reader the character of the years (warm, intermediate, cold) might be added (as was done in the figures). Perhaps the winter 2015/16 might be called “initially cold”, in order to distinguish it from 2010/11.

Technical details

- Please check the “s” of the plural of substantives or singular of verbs (1/13, 2/3, 10/12, 10/16-17, 14/4, 15/29).

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- 1/22: "processes. Especially" ⇒ "processes, especially"
- 2/7: "(2002)" ⇒ ", 2002"
- 4/9: "lagrangian" ⇒ "Lagrangian"
- 6/27: The abbreviation "BD" has not been defined before (and is used only once).
- 6/33: "(Fig. 3)" ⇒ Fig. 3
- 7/18: Really "0.3 ppt" (or 0.3 ppb)?
- Table 1: Please show only 2-3 non-zero digits.
- Table 2: "mixing ratio integrated over the winter of activated chlorine" ⇒ "mixing ratio of activated chlorine integrated over the winter"

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