

Atmos. Chem. Phys. Discuss., referee comment RC2
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Comment on acp-2022-730

Anonymous Referee #2

Referee comment on "Montreal Protocol's impact on the ozone layer and climate" by
Tatiana Egorova et al., Atmos. Chem. Phys. Discuss.,
<https://doi.org/10.5194/acp-2022-730-RC2>, 2022

This paper uses the Earth system model SOCOL4 to examine the impact of the Montreal Protocol on ozone, atmospheric chemistry, temperature and surface climate variables. It is straightforward in design, and a useful addition to the literature (e.g., it was noted in the 2018 WMO Ozone Assessment that there had been very few 'world avoided' studies performed since the previous assessment in 2014). I enjoyed reading this paper and recommend publication after the following comments are addressed:

Major

No model validation is done in the paper, instead the reader is referred to Sukhodolov et al. (2021). While Sukhodolov et al. (2021) evaluated ozone, temperature, water vapour and various other chemical species, they did not evaluate precipitation, cloud cover or sea ice, which are shown in this study. This should be addressed.

I was surprised to see almost no mention of polar stratospheric clouds (PSCs) in the analysis. Newman et al. (2009) discuss that the ozone layer collapses as a result of heterogeneous chemical processes. When are PSC formation temperature thresholds reached in the model, and how widespread are PSCs by the end of the simulations?

Section 3.3: discussion of studies by Garcia et al. (2012), Goyal et al. (2019) and Young et al. (2021). It would help the reader to give some context as to the models, assumptions and GHG emissions scenarios used. I see that Goyal et al. (2019) used RCP 8.5, so it is not surprising that the temperature response is smaller in SOCOL4 ssp245 simulations (line 217-218).

The authors seem surprised that warming in the model is weak until 2060 with a sharp decrease thereafter. I see from Figure 6 that cloud fraction drops away sharply after the 2060s and it could be that positive cloud feedbacks have come into play (for more explanation see FAQ7.2 in Chapter 7 of IPCC 2021).

The paper would benefit from proofing by a native English speaker; I have recommended a few suggestions under 'specific' comments below.

Minor

It would be pertinent to cite Young et al. (2021) in the introduction when previous studies that looked at 'world avoided' scenarios are reviewed.

Please give more details of how tropospheric chemistry was included (or not) – was it as in Egorova 2003, or as in Figure 2 of Sukhodolov et al. 2021?

For how long was the model spin-up time?

Please give details of how statistical significance testing was done (i.e. which test was used).

It would be useful to include a plot showing how hODSs change over time in the MPA_ssp245 and noMPA scenarios. Similarly, a table summarising the different simulations performed would be useful.

How do VSLs get into the atmosphere in SOCOL4? Are they all prescribed as surface mixing ratios, or does the ESM component simulate some of the natural VSL emissions? (eg sea spray inorganic bromine)

lines 76-77: "the fixed tropospheric ozone approach is difficult to justify for the no MPA case due to the expected dramatic increase of UV radiation in the troposphere caused by stratospheric ozone depletion and strong tropospheric ozone radiative forcing." Given that tropospheric ozone is not fixed in SOCOL4, why do we not see increases in tropospheric ozone in Figure 3? Is it because of increases in tropospheric OH?

Specific

Line 12-13: suggest rewording as 'Previous research has demonstrated the success of the Montreal Protocol' or similar (as it stands the sentence reads a little oddly).

Line 32: should read 'The ozone layer' not 'the ozone'

Line 61-62: "in the case of hODS uncontrolled increase their radiative forcing..." this statements needs to be referenced.

Line 66: "comparable to the effects of carbon dioxide increase" this is vague – how much of a carbon dioxide increase? Over what time frame/under which scenario?

Figure 1: please clarify that the 'saved total ozone' is MPA_ssp245 minus noMPA (if that is the case).

Figure 2: there is no upper or lower part; please add labels (a) and (b). Since all areas are statistically significant (95% level of confidence; ? test) you may as well state that in the caption.

Line 168: should read 'the secondary maximum in cooling' so that readers do not think you mean a secondary maximum in temperature.

Throughout, please ensure that chemistry is typeset properly, ie $O(^1D)$ not $O(1D)$, the Greek letter Nu (ν) not the English letter v when representing photolysis ($h\nu$), arrows instead of equals signs in chemical reactions.

Figure 3: I don't understand the colorscale used. On the CH_4 plot it appears (from the dark blue shading) as though there are large decreases in tropospheric methane, but the contour lines say it is only \sim -3%, while larger decreases (shaded white) are visible in the upper stratosphere. In contrast temperature, for example, uses dark blue to show large cooling and light blue to show weaker cooling. Also, the text colour on the contours is very hard to read over dark red and blue. Please ensure you state (here or elsewhere) how Cl_y , NO_x , NO_y are defined. The caption should state explicitly that results from the noMPA minus MPA_ssp245 simulation are shown. What do the black dots show? (I assume where the difference is not statistically significant, but this needs to be defined as it is inconsistent with the caption). Finally, what does 'st.' height refer to on the y axis?

Figure 4: How were the anomalies calculated? The coloured lines stated in the caption are inconsistent with what is shown on the legend (e.g MPA-ssp585).

Figure 6: do you show cloud volume fraction or cloud area fraction? (I think the latter?) In the plot on the right, why not be consistent with the plot on the left and report the difference in %?