

Interactive comment on “Implications of potential future grand solar minimum for ozone layer and climate” by Pavle Arsenovic et al.

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We would like to sincerely thank the reviewers. Their comments and suggestions significantly improved the paper quality and readability. We have included/addressed all the comments below and corrected the typos.

Anonymous Referee #1

GENERAL COMMENTS

This is a relatively straightforward paper that makes use of the SOCOL3-MPIOM chemistry-climate model to simulate changes in climate and ozone under strong and weak grand solar minima. The primary conclusion of the paper is that even a strong grand solar minimum, under a very aggressive GHG emissions reduction scenario

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(RCP2.6) will not completely offset projected increases in global mean surface temperatures.

I have made some minor suggestions for corrections below. Once these have been addressed, the paper will be suitable for publication in Atmospheric Chemistry and Physics.

SPECIFIC COMMENTS

Page 1, line 11: Replace 'greenhouse gas scenario' with 'greenhouse gas emissions scenario'.

We put "... greenhouse gas concentration scenario RCP4.5" as suggested.

Page 1, line 21: I would suggest replacing 'chlorine-induced' with 'halogen-induced' since it is both chlorine and bromine that drives the depletion.

Fixed. We put "halogen-induced".

Page 1, line 27: Replace 'of greenhouse' with 'of atmospheric greenhouse'.

Fixed. We have done as suggested.

Page 2, line 17: I am not sure that this is true. I don't think that the Montreal Protocol prohibits emissions of ODSs into the atmosphere. I think that it only prohibited their production. I encourage the authors to seek clarification on this.

Yes, the reviewer is right. We changed "emissions" with "production".

Page 2, line 21: Why the specific focus on terrestrial climate here? Is this not an issue for the ocean also?

Good point, "terrestrial and aquatic" would be appropriate, but this phrase usually stands before "ecosystem". We have changed it with "Earth's" instead.

Page 3, line 5: The way in which this is written it is not clear whether the sunspots became rare in 1715, or whether they were rare between 1645 and 1715.

Fixed. Sentence is changed to “A grand solar minimum, which was even more prolonged than the Dalton Minimum was the Maunder Minimum, the period between approximately 1645 and 1715 when sunspots were exceedingly rare.”

Page 3, line 19: I would suggest changing ‘cancel global warming’ to ‘completely offset GHG-induced global warming’.

Fixed. We have done as suggested.

Page 3, lines 30-31: The statement ‘globally cool the surface by around 0.1 K’ suggests that the cooling is spatially uniform. Was this indeed the case?

Good point, now this sentence is “...would decrease global mean temperature by around 0.1 K...”

Page 4, line 6: I would suggest ‘dissipates’ rather than ‘recovers’ since it is not clear what the grand solar minimum is recovering from.

Fixed. We have done as suggested.

Figure 2: Why is there a disconnect between the blue and purple lines in 2090 (and similarly for the red and orange lines)? From figure 1 I thought that WD and WDR would be identical up to 2090 and likewise for SD and SDR?

They are identical up to 2090 but the Savitzky-Golay filter makes this disconnect. Please see the plot below that shows SD and SDR w^* without the filter.

Page 7, lines 13 and 14: I am sure that Zubov (2013) was not the first to show that tropospheric warming is mainly caused by the surface warming due to increase of down-welling infrared radiation by GHG, enhanced by latent heat release in the middle troposphere. Why did you specifically choose this reference?

Good point, we have changed this reference to IPCC.

Page 7, line 15: I think you need to be clearer what you mean by ‘results from increased

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cooling rates of GHGs' and you should provide a citation to support this assertion.

We rewrote the sentence to "The temperature decrease in the stratosphere and mesosphere comes from increased cooling rates due to the GHGs rise (IPCC, 2013)".

Page 9, line 14: I think that this would be clearer if you replaced 'show lower surface temperatures' with 'show lower surface temperature reductions'.

Fixed. We have done as suggested.

Page 9, line 28: If I remember correctly, you had two ensemble members for each simulation. I can't recall that you have said anywhere to this point how they were used. Are the responses shown the average of the ensemble pairs?

They are ensemble means (written in the figure captions). We have added this information for all figures as well.

Page 10, line 2: You state that the increase in upper stratospheric ozone of 15-20% is a result of reduced intensity of the catalytic ozone destruction by reactive chlorine species. How did you do this attribution solely to chlorine chemistry? Is there no component at all that results from upper stratospheric GHG-induced cooling that slows the $O_3 + O_3 \rightarrow 2O_2$ reaction?

Good point. The ozone increase is due to the reduced rate of ozone depleting cycles – chlorine, NO_x, HO_x and also $O_3 + O_3 \rightarrow 2O_2$ reaction. We have rephrased this statement to: "The increase in the upper stratosphere of 15 – 20% is a result of reduced intensity of the ozone destruction cycles." Further discussion describes this in more details.

Page 12, line 9: At this point I am wondering how you are treating N₂O emissions in your simulations. N₂O was supposed to be the biggest depleter of ozone through the 21st century. There seems to be no discussion of this in the context of your simulations. I understand that N₂O emissions are the same in all of your simulations, but this statement that the dominant effect on ozone will be solar activity made me wonder about the relative contribution of N₂O.

N₂O itself is not threat to ozone, but it reacts with O(1D) and gives NO which is an ozone depleter. We are discussing NO_x in a separate chapter. Although we can't distinguish between NO_x coming from tropospheric N₂O and energetic particle precipitation, NO_x coming from N₂O is included in the projections and discussions.

The below errors in the manuscript have been corrected.

GRAMMAR AND TYPOGRAPHICAL ERRORS

I understand that the authors' first language may not be English. The paper would benefit from a thorough grammar check. I have highlighted just a few of the grammatical errors below.

Page 1, line 25: Replace 'since preindustrial' with 'since the preindustrial'.

Page 1, line 26: Replace 'The mean global' with 'The global mean' or otherwise be specific about which mean you are talking about.

Page 2, line 4: Replace 'RCP8.5' with 'for RCP8.5'.

Page 2, line 6: Replace 'under United' with 'under the United'.

Page 2, line 23: Delete 'basically'.

Page 3, line 30: Replace 'the reduction' with 'a reduction'.

Page 5, line 2: Replace 'assumed previous' with 'assumed in previous'.

Page 6, line 13: Replace 'increase of GHG concentrations' with 'rate of increase in GHG concentrations'.

Page 7, line 16: Replace 'ODSs emissions' with 'ODS emissions'.

Page 8, line 20: Replace 'predict a warming about 2 K' with 'predict a warming of about 2 K'.

Page 9, line 31: Replace 'in polar lower stratosphere' with 'in the polar lower strato-

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sphere’.

Page 10, line 18: Replace ‘ODSs concentrations’ with ‘ODS concentrations’.

Page 12, line 27: Replace ‘to conclusion’ with ‘to conclude’.

Interactive comment on Atmos. Chem. Phys. Discuss., <https://doi.org/10.5194/acp-2017-818>, 2017.

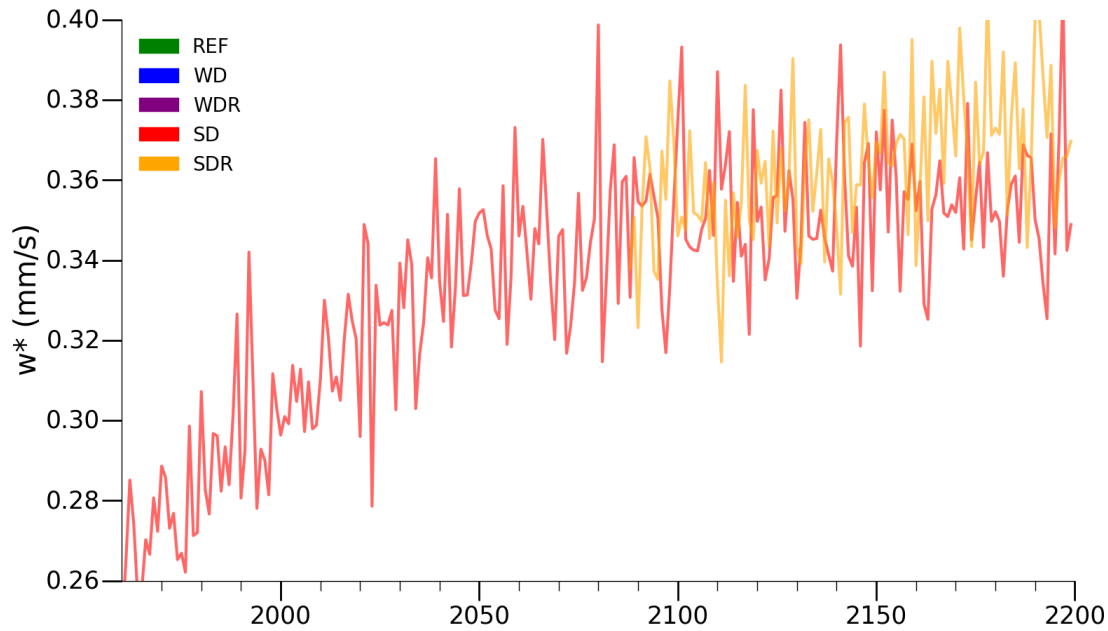
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**Fig. 1.**[Printer-friendly version](#)[Discussion paper](#)