ACPD: Review #2

"Forcing of stratospheric chemistry and dynamics during the Dalton Minimum" by J. G. Anet et al.

We would like to thank the anonymous referee #2 for his/her constructive review of our publication and provide here the answers to his/her questions.

P15063L20: “where” -> “were”
P15065L19: “halogen-contaminated”

These changes have been done according to the feedback provided.

P15067L5: Actually, odd nitrogen (NOy + HNO3 + ClONO2) is probably more long-lived than a few days and is indeed distributed globally. I take the “Brewer-Dobson circulation” to mean the diabatic, overturning circulation of the stratosphere which operates on timescales longer than a few days, which indeed affects the distribution of NOy considerably. There is also the faster adiabatic circulation, e.g. the jets, which transports chemical species around the planet within days. I suggest to be more precise about which circulation and which form of nitrogen you mean here.

Thank you, we revised as follows: "In the stratosphere, while HOx has a short life-time in the range of minutes to hours and thus affects atmospheric chemistry only locally, reactive nitrogen (NOy) and its members nitric acid or chlorine nitrate have lifetimes comparable to or even longer than the characteristic times for vertical and horizontal mixing occurring for instance via the Brewer-Dobson circulation (BDC)."

P15069L17: Out of interest, why do you not use the IPCC “historic” scenario here, which covers the DM period?

This has largely historical reasons. As these simulations are part of a longer run ranging from the year 1600 to the year 2100, we needed to choose a GHG reconstruction not only ranging back to the DM period, but even further to the year 1600 AD.

P15072L17: “was” ! “were”

Has been adapted.

P15074L16: I suggest to insert “forming HNO3 and H2O2, respectively,” for clarity.

We reformulated this sentence to "The main reason for the ozone increase in the tropical UT/LS after volcanic eruptions is the transformation of NOx to N2O5 and the subsequent hydrolysis of N2O5 to HNO3 via heterogeneous reactions on/in the sulfuric acid particles, formed in the stratosphere from the products of the volcanic eruptions."

P15076L12: Please put in a reference to where you discuss the mechanism for this, namely warming of the tropical tropopause.

We added a reference to A. Robocks paper (2000) thesis and modified the sentence to: " Due to a warming signal (which will be shown in Section ``Temperature"), a strong increase….".

P15080L7: Do you mean the troposphere or the stratosphere here? This sentence is
a little strange.

We reformulated that mysterious sentence to "The blocking of the solar visible and infrared radiation by volcanic aerosols leads to a cooling in the troposphere."

P15080L11: “are going back to an average level” -> “revert to climatology, which is in
agreement with Robock (2000).”

The sentence has been adapted to the suggestion of the referee: "This has an implication on the temperature anomalies: we find that lower stratospheric temperatures revert to climatology, which is in agreement with Robock, 2000."

P15080L16: “southern pole” -> “South Pole”

The sentence has been adapted

P15081L25ff: This sentence is difficult to follow. Please rephrase.

We changed the sentence to "Following the heating of the lower stratosphere by the volcanic aerosols, the vertical residual circulation drops due to strengthening of the temperature gradient at the tropopause."

P15082L18: “forcings”
P15083L3: “the following effects”
P15084L11: “except for temperature”

These changes have been taken into account.

P15084L28: “then becomes a threat to life”. In order to make this claim, you have to show that during the Dalton Minimum, there is a substantial change in the incident UV radiation at the Earth’ surface. There would have been some cancellation of effects due to decreased ozone (which would increase UV at the surface) and due to decreased UV at the top of the atmosphere (which would decrease UV at the surface). Short of seeing a plot of what the net UV changes actually are in the model, I am not convinced that the net change, even for a moderately bigger event than the Dalton Minimum, would have been big enough to constitute a threat to life. Life on Earth has been sustained through periods of substantially different solar irradiance from now, thanks in part to this buffering effect of the ozone layer. Of course the buffering effect has been weakened by ozone-depleting substances, but this weakening is set to heal during the coming decades. This claim comes across as somewhat unmotivated

by the previous sections which do not focus on impacts on the biosphere. On the other hand, even a limited increase in UV, such as caused by anthropogenic ODSs, does have measurable effects on public health and the biosphere, but it does not quite constitute a threat to "life on Earth".

We agree that this sentence is a bit alarmistic. However, we did not have a possibility to run a line-by-line radiation model to simulate the changes in incoming erythemal radiation on the surface of the Earth. A shortly accepted publication to GRL ("Impact of a potential 21st century "Grand Solar Minimum" on surface temperatures and stratospheric ozone" by Anet et al. 2013) deals with the problem of a future grand solar minimum. There, a strong weakening – or even cancellation – of the ozone layer recovery was modelled. Also in this paper, we did not run a line by line radiation model to look at the exact changes on the Earth's surface. Yet, this will be done in a future publication.

We thus changed the paragraph the following way:

"With respect to a possible future grand solar minimum in the 21st century a drop of ozone column by up to 7 % due to the reduction of the UV radiation is a very significant finding. In combination with a similar decrease in the ozone layer thickness due to ozone depleting substances may become a possible health issue on Earth. As well, the effects of reduction of UV, volcanic eruptions and increase of oxidation by GCRs should be thoroughly investigated in future research of the 21st century with an AO-CCM. The evolution of the ozone layer remains an important scientific topic, as e.g. crop yields or health of living beings are subject to both anthropogenic and natural influences."