

Interactive comment on “Quasi-biennial oscillation of the tropical stratospheric aerosol layer” by R. Hommel et al.

Anonymous Referee #2

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The authors use a microphysical aerosol model to study the effects of QBO on stratospheric aerosol properties. This is an important topic due to changes in observed stratospheric aerosol optical depth over the past 15 years, the prolonged lifetime that stratospheric aerosols have on radiative forcing, and the lack of understanding of the natural periodic processes sustaining background aerosols. The model used by the authors is a good fit for this research, their focus on the poorly-understood impacts of QBO phase is good, and their approaching plotting anomalies in terms of the onset of QBO is illustrative. There are several minor items that should be addressed before publishing in ACP. This work is well within the scope of ACP.

General concerns:

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1) I think it would be useful to compare the magnitude of the stratospheric aerosol variations due to QBO to that of seasonal variability, annual variability, and volcanic influences. For instance, how much stronger is QBO than seasonal or annual (e.g. tape recorder) variations on stratospheric aerosol? Does the QBO phase impact aerosol properties more than recent volcanic eruptions in the lower stratosphere? upper stratosphere? This could be included in the abstract and some discussion and particularly the conclusions.

2) the recent SO₂ observations by Hopfner et al which included the contributions of QBO phase is a very relevant comparison to your model. It would be useful to conduct a more detailed comparison between the ranges observed by Hopfner et al and your model, provide a more detailed description of this dataset in your introduction and/or section 2.2, and compare seasonal, annual and QBO-induced variability between the model and dataset.

3) There are many places in the paper where you provide qualitative terms like "strongly", "more or less", "substantially smaller", "QBO effect exceptional", "indicates to a certain extent", "heavily influenced" and "rather in-phase" etc. It would be useful to provide more quantitative terms such as x % larger or smaller in x region.

4) There are also many places in the paper with grammatical errors and typos. I've tried to list most of them in my specific comments but please double check other places.

5) How might contributions from aerosols that you don't include in these simulations convolute your analyses? Please provide some discussion around that. For instance meteoritic dust contributes significantly to upper stratospheric aerosol (see Neely et al., 2011), and recent volcanic eruptions (Vernier et al 2011) and other aerosol species such as carbon (Murphy et al 2007) contribute to lower stratospheric aerosol.

6) The discussion of ozone on p16256 is confusing. Are you presenting any of your ozone results here? If not, it seems risky to compare your model's aerosol extinction to observations of ozone and make conclusions regarding the relative changes.

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7) I find it a little concerning that your section 3.4 Microphysical processes ignores coagulation and sedimentation. Aerosol microphysical processes occur together in complex ways, and for instance coagulation and sedimentation can alter the rates of condensational growth and evaporation. Perhaps you could devote some discussion as to the caveats of your approach in section 3.4.

Specific items:

Abstract: Add a dash to "QBO-induced"

Abstract: Please quantify the relationship between QBO and the anomalies. Instead of saying that the aerosol load is "predominately influenced by QBO-induced anomalies...", please state the relationship (easterly-phase causes xxxx to happen). Instead of saying "large impacts are seen" quantify the percentage change from one QBO phase to the other.

p16244 line26: change "is influenced by" to "may be influenced by" (since for example Neely et al 2013 found very little contribution of asian aerosol to the stratospheric aerosol)

p16345 line 15: Please provide more details with regards to "These problems are addressed in the current study". perhaps something along the lines of: "In this study we propose to quantify the contributions of QBO to changes in stratospheric concentrations of background aerosols and their precursors."

p16246 line 19, 21: Add English et al., 2013 citation to the sentence describing Pinatubo studies using size-resolved models, and Campbell et al 2014 to the list of citations for background aerosol.

p16246 line 22: Be more specific in the "In this study" sentence, describing that you are mainly focusing on the impacts of QBO on stratospheric dynamics and aerosol.

p16246 line 24: In addition to geoengineering, this work is valuable to understand the contributions of QBO and natural variability to recent observed changes to strato-

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spheric aerosol.

p16247 line 6: change "focus" to "focusses"

p16247 line 11: I'd remove the line "and are in the scope of following studies" (there's always future improvements planned)

p16247 line 13: change to "nineteen-seventies"

p16248 line 19: 39 levels is somewhat coarse to capture stratospheric dynamics. Have you conducted any studies to determine whether the vertical resolution is sufficient to capture stratospheric processes?

p16249 line 20: What are prescribed "climatological" oxidant fields? Do they include the variations in stratospheric concentrations due to QBO? If not, it would be useful to quantify how much they vary between different phases of QBO, and how that might impact your model results.

p16249 line 28: why does it take 6 years to reach steady state? stratospheric lifetime is typically a year or 2.

p16250 line 4: Describe the specific "aerosol forcing data set" you are referring to. Extinctions? SAD?

p16250 line 10: I've seen the new SAGE 2 referred to as "v7" not "vn7"

p16250 line 11: remove the dash from "wavelength"

p16251 line 1: change "to" to "too"

p16251 lines 19-25: these two sentences aren't very clear, and the grammar could be improved.

p16253 line 16: "extra-tropically" is mis-spelled

p16253 lines 14+: this paragraph could use more citations.

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p16253 line 23: I realize this is somewhat standard practice, but I and others find the (parentheses) describing opposite trends confusing

p16253 line 27: bad grammar with the word "also"

p16254 line 24: there are a few instances of "nicely seen" that should be reworded, possibly to "clearly shown"

p16255 line 20: change "east" to "easterly"

p16256 line 25: "wavelength" is one word

p16257 lines 1-4: It is important to take what into account? condensational growth? Is this more important than coagulation? It seems that several microphysical properties are important.

p16257 line 5: please quantify "strongly depends". For instance something like "including particles smaller than xx nm increases SAD by xx %"

p16257 lines 14-15: I don't believe that larger particles evaporate at higher rates than small particles. As large particles start to evaporate they become small particles. Please clarify.

p16257 line 16: change "more or less" to a quantifiable term e.g. "which varies by only +/- x %"

p16257 line 20: change word to "distinctly"

p 16257 line 22: do you mean greater than 0.005 um instead of less than?

p16258 line 10: remove the comma after "region"

p16258 line 11: "datasets" is one word

p16258 lines 12-20: how does your modeled SAD compare to SAGE when you cutoff particle size smaller than the detection limit of SAGE?

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16259 line 18: negatively biased to what kind of observations – satellite or aircraft? Satellite observations have known biases as you've stated but aircraft observations are more reliable

p16261 line 2: "infer with effect" grammar could be improved

p16261 lines 4-7: this sentence uses the word "anomaly" yet fig 8g is not an anomaly.

p16261: the paragraph discussing nucleation should probably go before the current preceding paragraph which discusses other microphysics. References

p16261 line29: nucleation mode does not prove BHN occurs as other processes such as ion-mediated nucleation may occur. perhaps state that it suggests BHN is occurring.

p16262 line 8: "more and more inhibit" grammar could be improved, and the following sentence starting with "However", the grammar and sentence structure could be improved. Also, before this sentence you could state what happens "below this layer".

p16262 line 21: "vapour contents" is not a common way to describe the thermodynamics. Perhaps use the words "supersaturation of h2so4 and water, which depends on temperature and vapor concentration..."

p16263 line 2: improve grammar for "tends to zero"

p16263 line 6: improve grammar for "QBO east shear"

p16263 line 9: What do you mean by "can amount to 50%"? under which circumstances?

p16263 line 16: what are the units of time-averaged molecule concentration transferred? seems like time should be on the denominator, but this is not noted in Fig. 9.

p16264 line 21: does warmer T also explain the changes in saturation vapor pressure above 20 hPa?

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p16265 line 9: "imposes" mis-spelled

p16265 line 14: remove comma after "mentioned"

p16265 lines 14-19: could the temperature biases affect modeled nucleation and growth in addition to evaporation as you've noted?

p16266 line 18: how does QBO "interfere" with the annual cycle?

p16267 line 11: improve grammar of "regularly base"

p16267 line 27: add Campbell et al 2014 citation.

p16268 lines 16-25: A more direct comparison between your model SO₂ and Hopfner et al would be useful. How do each SO₂ vary between QBO phases? how do so₂ annual and seasonal variations compare?

p16269 lines 17-21: this reasoning is not clear to me. To me, aerosols in the lower stratosphere seem strongly driven by transport from upper troposphere, but aerosols in the middle stratosphere are more driven by OCS oxidation. Please clarify your reasoning.

p16269 line 26-27: add "and so₂ measurements (Hopfner et al 2013)."

p16270 line 30: change to "easterly phase"

p16271 lines 24-27: the assumption that condensation and evaporation occur concurrently seems risky. I would suggest that you analyze your instantaneous model output to determine whether this is true, or change your discussion of it.

Several figure captions need superscripts for units

Fig 1: caption has a duplicate "zonal mean zonal"

Fig. 2. Why is there a sharp gradient in ERA-interim at 15 hPa?

Fig. 3: I thought your control simulation had prevailing easterly winds? why are there

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some non-dotted lines (e.g. westerlies)? Also "Ratio" is mis-spelled in the title

Fig. 4: add "(a)"

Fig 5: suggest you change lower panel description to "50 nm \leq R < 2.6 μ m" for consistency

Fig. 7: Add "modelled" to caption description. and to other figure captions where appropriate to clarify that this your model output.

Fig. 9: shouldn't there be a unit of time in the denominator?

References

Campbell, P., M. Mills, and T. Deshler (2014), The global extent of the mid stratospheric CN layer: A three-dimensional modeling study, *J. Geophys. Res. Atmos.*, 119, 1015–1030, doi:10.1002/2013JD020503.

English, J. M., O. B. Toon, and M. J. Mills (2013), Microphysical simulations of large volcanic eruptions: Pinatubo and Toba, *J. Geophys. Res. Atmos.*, 118, 1880–1895, doi:10.1002/jgrd.50196.

Murphy, D. M., D. J. Cziczo, P. K. Hudson, and D. S. Thomson (2007), Carbonaceous material in aerosol particles in the lower stratosphere and tropopause region, *J. Geophys. Res.*, 112, D04203, doi:10.1029/2006JD007297.

Neely, R. R., III, J. M. English, O. B. Toon, S. Solomon, M. Mills, and J. P. Thayer (2011), Implications of extinction due to meteoritic smoke in the upper stratosphere, *Geophys. Res. Lett.*, 38, L24808, doi:10.1029/2011GL049865.

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