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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Simulation of the climate impact of Mt. Pinatubo eruption using ECHAM5 – Part 1: Sensitivity to the modes of atmospheric circulation and boundary conditions" *by* M. A. Thomas et al.

M. A. Thomas et al.

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Answers to the comments of Anonymous Referee #3

We would like to thank the reviewer for very constructive and informative comments that have led to improvement of the manuscript. Please find below response to your comments individually shown in the bold text.

General comments:

Thank you for the comments. The introduction part of the manuscript has been re-written taking into consideration the points mentioned above. We in principle agree

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that we need further detailed analysis to really pinpoint the reasons for the failure in reproducing the dynamical response in our simulations. But, this in itself is a comprehensive task and would be the scope for another paper. However, please note that in the current study, we have argued about the possible aspects which could be further improved or examined in detail to simulate the dynamical impact more realistically.

Minor comments:

Abstract: Line 1-8, Line 19, Line 24: The abstract has been re-written to incorporate and clarify all the main points raised in the comments on the abstract.

Introduction: Thanks for the helpful comment. The introduction was accordingly revised. A separate paragraph is included in the introduction that highlights the climate effects after Pinatubo eruption from observations thus improving the clarity of the text.

Line 8: References to Stenchikov et al. (2002) and Graf et al. (2007) are added.

Line 13: The sentence has been re-structured and the word "middle atmosphere" is replaced by stratosphere.

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Line 5: The sentence is re-phrased.

Line 16 and 16-17: text is changed to: "This is important as this gives us insights on how climate responds to the radiative forcing of the observed Mt. Pinatubo eruption, in which either one or more of the concurrent forcings such as the El Nino sea surface anomalies, the QBO phase are included".

Line 22: Changed to: "None of the model simulations ...."

Line 27 to 4 (next page): changed as suggested.

Page 9213:

ECHAM5 is a name including EC of ECMWF, HAM of Hamburg, and 5 for the 5th

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generation of this model. The name ECHAM reflects that the very first ECHAM GCM was derived from an ECMWF GCM. But ECHAM was used from the very beginning as a name, not as an acronym for a long name, though often long names are invented to satisfy the request of journal editors to provide a long name.)

Lines 16-17: "follows" is no longer repeated

Line 20: Re-written as "The number of spectral bands in the shortwave has been increased from 4 to 6 and the range expanded from [0.250-4.00 micro-m] to [0.185-4.00 micro-m] (Cagnazzo et al., 2007)."

Line 20-23: new: "Additionally the original shortwave code has been generalized for large optical thicknesses of volcanic sulphate aerosol layers in the stratosphere as necessary for the aerosol loading after Pinatubo. This improvement is documented in Thomas (2007)"

Line 24 and Line 25: The description is now more detailed: "The radiative transfer calculations are made every two hours using temperature, cloud, water vapour, etc of the current time and solar zenith angles for the middle of the following two hour interval. While longwave fluxes are kept constant over the two hour interval, shortwave fluxes are linearly corrected by the local cos(zenith angle) at each 15 min. time step in the two hour interval with respect to the local cos(zenith angle) in the middle of the two hour interval, and shortwave fluxes are set to zero during night time" .

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Line 4-5: Modifications are made to avoid repetition.

Do you use a zonal aerosol climatology? The tropospheric aerosol climatology of Tanre (1984) is spatially explicit for sea, land, urban and desert aerosols. This is explained in the text.

Line 12: The sentence is re-phrased as "The retrievals at 0.55 micro-m are used to calculate the aerosol parameters"

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Line 18-19: changed to "compiled by Stenchikov et al 2002", as suggested

Line 25: The total ozone column concentration in Dobson Units after Mt. Pinatubo eruption is cited from Stenchikov et al., 2002 and is added in the revised manuscript.

Maximum ozone loss at polar regions is? In which altitude does it occur? The maximum loss at polar regions is up to 1.0 micro-g/g at 20 hPa. A sentence has been added.

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Line 16: SIC is an acronym for sea ice. SIC is defined in the revised text

Line 20: is corrected.

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Line 7: Tests showed that the nudging of zonal winds between 90 or 70 and 10 hPa is sufficient to generate the QBO structure through the whole vertical extent up to ˜3 hPa. It was found that the equatorial zonal wind structure, as enforced below 10 hPa, acts as a filter for the resolved and parameterized vertical flux of momentum such that the drag acting between 10 and 3 hPa generates a realistic QBO structure above 10 hPa. Hence the nudging was restricted to the lower equatorial stratosphere below 10 hPa.

Experimental set up: Unfortunately Table 2 in ACPD was not reproduced exactly as in the manuscript Actually, there are vertical and horizontal lines which cannot be seen in the printouts and that makes it difficult to understand them. Experiments are represented by acronyms in italics in the 2nd row (Ou ... OQp) and 3rd column (Cu ... OQu). Differences between simulations of the 2nd row and the 3rd column are shown in regular font. For example, Aer2 is the difference of two simulations Op and Ou (written in italics). This is the best way I can fit all the simulations into one table.

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Line 4-9: This motivation has been included in the introduction part.

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Line 14-16: This has been re-written.

Line 23 We have mentioned the percentage level of significance in the text. Unfortunately, we could not plot the levels of significance on top of a shaded plot using GraDS software.

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SH simulations: The maximum ozone loss at southern polar latitudes is seen in winter at levels between 50 hPa and 20 hPa., so at 30 hPa we are at the top of the ozone hole.

Line 11: We agree that these might be other reasons, however, our argument was based on the studies by Sassi et al., 2004, Manzini et al., 2006 and Chen et al., 2003.

The cooling in the tropics is less by what degree? The cooling in the tropics is less by 50% at 30 hPa. A sentence is added.

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Role of the SH ozone hole? How does it look like w/o the observed ozone field as input? Robock et al., 2007 investigated the SH response after Mt. Pinatubo eruption and their study pointed out that no significant anomalies are observed in the atmospheric circulation in the SH compared to the NH after the eruption. We had carried out a run with volcanically induced ozone anomalies only to see the response of these anomalies on temperature and circulation. These runs are currently analyzed.

ERA40 ... : A paragraph on ERA-40 data used for validation is included in the Model and data section

Line 25 ff Fig 5 should be figure 4: This has been corrected.

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Line 2 and Line 7-8:Minor changes are made to incorporate the above points.

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Line 25-30: Changes are made to describe it more clearly.

Figure 4. Text on the significances is added.

Page 9221 The figure caption is changed. The significance levels were 95% and 90% levels

Page 9223: Modifications are made as per your suggestions.

Page 9224 Conclusions point 3: We meant the aerosol response in the tropics. Hence the sentence is re-written as "The pure aerosol lower stratospheric temperature response in the tropics is insensitive to boundary conditions"

Page 9225 Conclusion point 4: Re-written as "The tropical signature of the easterly and westerly phases of the QBO in stratospheric temperature is simulated realistically in the pure QBO forcing experiments."

Conclusion point 7: Re-written as "Observations show that the volcanic aerosol forcing tends to strengthen the polar vortex irrespective of the QBO phase. Our simulations show that the model tried to simulate the polar vortex deepening in the second winter, when the QBO is in its westerly phase in Aer3 response and the combined responses of AQ and AOQ, though the simulated response is weaker compared to the observations. The vortex is disturbed during the first winters due to the enhanced wave propagation in boreal winter that in turn disturbs the vortex."

Line 19: Re-written as "A recent study by (Stenchikov et al., 2006) showed that also 20th century simulations made for IPCC AR4 could not reproduce the surface winter anomalies after volcanic eruptions. Hence, further investigations are necessary to understand better the difficulties in modelling the surface warming pattern derived from the winters after major volcanic eruptions of the 20th century." This is mostly to emphasis the fact that the difficulties to reproduce surface winter anomalies after volcanic eruptions is common to many models used in climate research, and is not a particular problem of the model used in our study. More research is needed to understand the

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possible reasons why this response is not simulated.

Line 20-21: We have taken this into consideration and dynamical response has been replaced in most of the manuscript to surface winter response. We still feel that the surface winter pattern seen after explosive volcanic eruptions is a dynamical response (Stenchikov et al., 2002).

How about adding ...: Thanks for the comment. A link to the second part is added in the introduction part of this paper. In the 7th point of the conclusion, a sentence is added as "The second part of this paper gives more details on whether the climate response to the volcanic aerosols depends on the phase of the QBO."

Table and figures: Different simulations are given in italics, while differences between simulations are in regular font, as explained above. We will ask the ACP production office to improve the formatting of table 2.

Fig 1-3 and 5: The figures have been plotted from 90N to 90S for Fig.1-3 and from 10N-90N for fig.4 and from 15S-90N in fig. 5. This is because in fig.4, we are looking into the north polar vortex and in fig. 5, we are looking into the NH winter anomaly after volcanic eruptions.

Fig. 2: The QBO phases are included in fig.2. The contour intervals have been added.

Fig. 3: It is not possible to show the level of significances over a shaded plot using grads software. I have mentioned the level of significances in the caption and in the text.

Fig. 4: The plots are grouped as 91/92 to the left and 92/93 to the right for each of the experiments.

You don't show the same hemispheric section ... : This has been modified and the information of the latitudinal extend and contour levels are included in the caption

Fig 5: The figures can be made bigger in the final manuscript. Thanks a lot for pointing

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this out. The latitude extends from15S to 90N. The observations have been modified too to show the same latitudinal extend.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 9209, 2008.