

***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 1

We would like to thank the reviewer for the very constructive and informative comments that have led to improvement of the manuscript. Please find below our responses to your comments.

In section 4.2, the observed response calculated from ERA40 is used to assess the quality of the simulations. How are the anomalies calculated? Deviations from a run-

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ning mean in observations time series? It would be very helpful to explain how the observed response is derived....

- A separate paragraph on the ERA-40 data set that is used for validation and the calculation of the anomalies has been added in the section 2. The anomalies are calculated as a difference of the fields for the Pinatubo period (June 1991 - May 1993) from the mean climatology. Monthly data for 43 years are used for the computation of the mean climatology. Consequently these anomalies represent not only the effect of the volcanic forcing, but also internal variability of the atmosphere, like the QBO in the stratosphere, and the climate system, like ENSO. As it is not possible to separate the different possible causes for the observed anomalies, the experimental design was chosen to allow a separation.

...And I suggest to derive the model-calculated anomalies in the same way to ensure consistency in the observed-versus-model anomalies comparisons...

- The model calculated anomalies are not derived exactly the same way as the observed anomalies, because we wanted to exploit the ensemble technique for different combinations of forcings, as described in the paper. In our simulations, we have 10 ensemble members for each experiment and the anomalies are calculated as the difference between the perturbed and unperturbed ensemble means or as the difference of the ensemble mean from the 15 year control run (with climatological SST as boundary conditions). The intention of this methodology is to obtain signals for each forcing difference, where the ensemble averaging removes features related to internal variability.

...There is also a potential problem in deriving the observed response to the volcanic forcing. In the model, the mean response and its statistical significance are derived

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from ensemble runs. Apparently, the Pinatubo eruption is only one volcanic event and so, in a sense, the Pinatubo observations correspond to 1 member of the PDF. In order to estimate the observed mean response and the width of the PDF, one would need to consider, for example, 10 similar volcanic events by analogy with the model ensemble runs. Therefore, the authors should be very cautious with quantitative comparison. I would suggest to highlight this point.

- This is a good comment. Indeed the "surface warming patterns" after Agung, El Chichon and Mt. Pinatubo have differences, though the warming in high latitudes from Scandinavia to Eastern Siberia seem to be robust as well as cooling in the Mediterranean and Northern Africa. More details on this uncertainty are given in Thomas (2007). The text is modified accordingly.

The different model simulations are partly evaluated based on comparisons with the observed response. Unfortunately, the authors do not explain how the response to the Mt Pinatubo forcing is derived from observations. Is it deviations from an extrapolated running mean or from the previous 10 year average? The response in the model simulations should be derived as much as possible in the same way as it is done with the observations to be able to compare like to like.

- A separate paragraph on ERA-40 data set that is used for validation and the calculation of the anomalies has been added in the section 2. The anomalies are calculated as a difference of the fields for the Pinatubo period (June 1991 - May 1993) from the mean climatology. Monthly data for 43 years are used for the computation of the mean climatology.

Abstract, I2: short-lived but can trigger climate shifts.

- The abstract is completely re-structured.

Abstract: the terms "pure responses" is not defined, so it is not clear what it means.-

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Overall, the abstract could be sharpened in order to make clear what the paper brings:
The abstract is completely re-structured.

P9211, I18: This sentence is re-written as "Natural internal variability mainly arises from the non linearity of the dynamics of the circulation in the middle atmosphere."

P9212, I17: What does "pure" mean? Do the authors mean the averaged effects of volcanic forcing (averaged of simulations with different boundary conditions) or the part of the volcanic effects that is independent of the boundary conditions or the effects for each model set up?

- Question 1 is related to the response of the atmosphere to the volcanic radiative forcing in the stratosphere alone, in comparison to a reference case without volcanic forcing but otherwise identical boundary conditions. (In Table 2 these are the differences Aer1, Aer2 and Aer3).

P9214, I2: Strange set up. The concentrations of CH₄, N₂O and CFC drop in the stratosphere with very small mixing ratios in the upper stratosphere. Why are the mixing ratios of these radiatively active gases assumed to be constant?

- The experimental design presented here is part of a larger experimental framework including also traditional "low top"; simulations, i.e. ECHAM5 simulations without the middle atmosphere extension. As the latter have been made with constant CH₄ and N₂O concentrations, it was decided to use exactly the same greenhouse gas concentrations in the middle atmosphere version of ECHAM5, although the standard middle atmosphere ECHAM5 makes use of vertically resolved profiles of CH₄ and N₂O.

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P9216, I1-7: The nudged simulations are not really fully interactive CCM simulations. I would suggest indicating what kind of limitations the tropical QBO nudging bring in terms of couplings/interactions.

- The following explanation is added to the text: "..The nudging rate is 1/(10 days). Hence, the nudging interferes with the dynamics in this well defined domain only on time scales of 10 days and longer. Practically this means that only zonal wind features of timescales longer than 10 days are directly influenced by the nudging scheme. QBO signals in meridional and vertical wind or temperature within the nudging domain, or QBO signals outside the nudging domain result from the primitive equation dynamics of the model."

P9216, I13: There is some confusion here. Aer2 is supposed to correspond to the response to volcanic forcing under observed SST. Observed SSTs also include the surface cooling due to the Pinatubo aerosols. Therefore, it is difficult to see Aer2 as the aerosol response under another boundary condition when some part of this boundary condition is also the atmospheric response to the volcanic perturbation. - This is an interesting point. In our study, Aer2 is calculated as a difference between the perturbed run with observed SST as boundary conditions (Op) and the unperturbed run with observed SST as boundary conditions (Ou). Since, both these runs include the surface cooling due to the Pinatubo aerosols and since we know that the responses are linear in the tropics, we consider, Aer2 as a pure aerosol response under observed SST as boundary conditions.

P9217, I9-10: Too high. Please provide references for this 40 km. - References, Stephens and Lynch (1996) and Holasek et al. (1996) are included.

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P9219, I19-21: it is figure 4, not 5. - This has been corrected

P9220, I1: Is the anomalously strong vortex observed in the second year after the Pinatubo eruption a robust feature? In other words, is it statistically significant? It is difficult to be certain from only one volcanic event - We are writing a paper on the variability of the climate responses after tropical explosive volcanic eruptions that takes into consideration the three major eruptions of the last 50 years. So we have 6 winters as case studies. Four out of the 6 cases showed this pattern.

P9223, I20-21: this sentence needs to be rephrased. The sentence is re-phrased as "Our analysis also shows that the ENSO signal is dominating and partly masks the effects due to volcanic forcing"

P9224, conclusions: Points 3 and 6 seem to contradict each other. I suppose that the response of the atmosphere mentioned in point 6 is not the same as in point 3 (lower stratospheric temperature). Which atmospheric response is discussed in point 6?

- Thanks for pointing this out. I have re-written conclusions 3 and 6.

Point 5: cooling over Middle East and Greenland. Again, are these regional features robust just for one volcanic event or are they observed every all the large volcanic eruptions? Without the range of observed responses to volcanic events, it is difficult to conclude unambiguously regarding discrepancies between observed and model-calculated anomalies on a regional scale.

- Please see the comment above. This is a robust feature as it has been observed for most of the volcanic eruptions. Please refer Thomas, 2007 for details.

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P9225, I18: The last part is a bit obscure. The variables tested were temperature and geopotential height. Why conclude that the "radiative response" is correctly simulated? I am not sure that I understand what "radiative response" means here?

- The text is changed to "The model simulates the stratospheric temperature response to the volcanic aerosols correctly,..."

Also, does "remain a challenge" mean the dynamical response is not correctly simulated? Which part of the response?

- Our simulations cannot reproduce a statistically robust surface winter warming pattern in the analysed ensemble mean differences, though some of the single members show warming patterns similar to those presented for the 1991/1992 and 1992/1993 winters in ERA-40. Hence the simulations cannot be used to attribute a winter warming pattern to the applied volcanic forcing. From other model studies it may be concluded that this difficulty is not specific for the model used here. Hence there remains the challenge to find out if the expectations are false or why several atmospheric GCMs and climate models do not reproduce the winter warming pattern at the surface.

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

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