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Atmospheric Chemistry and Physics Discussions

Interactive comment on "The initial dispersal and radiative forcing of a Northern Hemisphere mid latitude super volcano: a Yellowstone case study" *by* C. Timmreck and H.-F. Graf

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General comments

A chemistry climate model has been used to simulate the impact on the atmosphere of a 'super-eruption' from Yellowstone. The main findings of the study are that the dispersal of the aerosol is significantly affected by: (i) the season of the eruption; and (ii) allowing the volcanic aerosol to interact with the climate model's radiation scheme. Most previous studies of this sort have found that increased levels of volcanic stratospheric aerosol lead to warming of the stratosphere (i.e. warming of the aerosol layer), due to enhanced absorption of near infrared (solar) and infrared (terrestrial) radiation. However, this study finds significant zonal mean cooling within and above the aerosol layer - due to less terrestrial radiation passing through the aerosol layer. The difference is ascribed to the higher aerosol number density associated with a super-eruption, compared to previous studies that have typically considered Pinatubo-type eruptions. At the base and below the aerosol layer, there is significant heating. This suggests significant non-linearities in the radiative response dependent upon the aerosol number density. The implications of this should be stated and discussed more clearly: are the authors suggesting that super-eruptions, with very high levels of aerosol loading, lead to tropospheric (and hence surface) warming, rather than cooling, at least during their initial stages?

The study is preliminary in many respects: it only considers 12 months post-eruption; it uses fixed sea-surface temperatures (and so doesn't attempt to simulate the effect of the eruption on tropospheric climate); it assumes fixed bulk aerosol properties (i.e. there is no interactive microphysics; the aerosol size distribution does not evolve); it also doesn't consider chemical feedbacks, such as the depletion of OH by the massive SO2 loading, which is likely to prolong the SO2 lifetime, and hence affect the production rate of sulphate aerosol. The implications of each of these simplifications should be addressed - do they significantly compromise the results? For example, an unconstrained ocean would warm/cool in response to the eruption, changing the outgoing terrestrial radiation, and presumably would significantly affect the calculated heating rate anomalies at all altitudes. The authors indicate that the results illustrate the need for a more detailed study (including many of these couplings) - but it would be useful if they could indicate the likely impact of including such effects, and which ones may be most important.

Specific comments

Title: hyphenate 'mid-latitude'

Abstract

P7284 L5: fix -> fixed

A maximum cooling of -1.6 K/day three months after the eruption for the upper tropical stratosphere is quoted in the abstract - it should be clarified if this value is for the zonal average field, or a local maximum (from Figure 3, the YESTJUN case appears to show a peak cooling of -3.2 K/day).

P7284 L20: add to end of last sentence: '...to such a super-eruption.'

Introduction

There is some inconsistency in describing the size of eruptions. Pinatubo is initially described as a 'medium' sized eruption; but then 'large' eruptions are described as injecting 'several Mt of ...gases (...SO2...) ... into the stratosphere'. But the Pinatubo eruption added around 20 Tg of SO2 to the stratosphere - so this would make it 'large'. I understand the point that a Yellowstone super-eruption would be significantly larger than Pinatubo, but keep the definitions consistent.

P7285 L3: it's -> its (twice)

P7285 L8-9: delete 'was' and 'to'. 'Volcanos' and 'volcanoes' are both used - stick to one or the other.

P7286 L1-2: change text to: 'dependent upon whether or not they are trapped at high latitudes'

P7286 L10: fix -> fixed

P7286 L11-12: change text to: 'most likely possible sites for such an event at higher latitudes'

P7286 L13: impact -> dependence

P7286 L15-17: an -> a; km2 should be km3 (3 times)

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Interactive Comment

The choice of a sulphur emission of 100x Pinatubo seems somewhat arbitrary. I would like to see some further speculation about the possible range of SO2 emissions from a Yellowstone eruption - what is the uncertainty on this?

Experimental Description

Please clarify that the simulations include no feedbacks of the volcanic emissions and volcanic aerosol on chemistry (e.g. via PSC surface area, or indirectly, via changes in radiation). The aerosol is only allowed to feedback via the climate model's radiation scheme. Therefore oxidant levels (OH) are unaffected by the huge SO2 loading.

Please also clarify what is meant by 'the H2O/H2SO4 aerosol is considered by a bulk approach'. Do you mean that the volcanic SO2 is converted to SO4 using the background OH fields, and then this mass of SO4 is distributed into aerosols with a fixed size distribution? This would mean that the aerosol number density is directly proportional to the mass of SO4. This aerosol number density and size distribution then feeds into the radiation scheme.

You should state that each model run is only 12 months duration.

P7288 L19-20: delete 'the' and 'of' (twice) - released in mid-June/December

Results

P7289 L21: in -> at

P7289 L25: predominately -> predominantly

The period of elevated levels of volcanic aerosol would almost certainly be prolonged relative to those calculated, because of the neglect of oxidant depletion. This is slightly different to saying that the aerosol lifetime will be prolonged, as it is the SO2 lifetime that is prolonged, and hence the SO4 production rate. The aerosol lifetime is determined by purely physical processes (e.g., coagulation, growth, settling and scavenging) that should be independent of the oxidant levels.

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Why is the Yellowstone case so different from the Laacher See case? These two mid-latitude eruptions might be expected to produce similar impacts. Is this only because it is dispersed in a different way, or are other factors important?

P7291 L1-2: When you say the SH optical depth differs by a factor of five between the interactive and non-interactive cases, do you mean the hemispheric average at a certain time, or the peak at a certain time after the eruption? Please clarify.

P7291 L8: interactively

P7292 L20: ‘much less dense aerosol’ - clarify that you mean aerosol number density.

P7293 L4: then -> than

P7293 L4-5: more than -16 and more than -32 W/m2 - should be ‘less than’. Similarly, ‘maximum values less than -32 W/m2’ should be ‘minimum’.

Conclusions

P7295 L8-9: The reason

P7295 L15: the maximum optical thickness

Figures

The top two panels of Figure 1 are both unnecessary - I suggest simply add an ‘X’ to the lower panels to indicate the location of Yellowstone. The continuation of Figure 1, as far as I can tell, is an exact repeat of the first part of Figure 1 - I assume this is an error - should it be for other time slices after the eruption?

The Figure 2 caption should indicate that the top panels are for the interactive aerosol cases, whereas the lower to are for the non-interactive cases.

Figures 5 and 6 - the contour labels are illegible (the labels in the preceding figures are just legible). What does the shading signify? A colour figure may be clearer.

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