Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2020-1191-RC1, 2020

Atmospheric Chemistry and Physics Discussions

Interactive comment on "The Impact of Volcanic Eruptions of Different Magnitude on Stratospheric Water Vapour in the Tropics" *by* Clarissa Alicia Kroll et al.

Anonymous Referee #1

Received and published: 22 December 2020

Overview: This paper examines changes in stratospheric water vapour in the presence of volcanic aerosols. This is done through several model runs with varying amounts of SO2 introduced into a model. They find the input of water vapour into the stratosphere increases due to aerosol induced heating at the tropical cold point. They quantify radiative forcing, surface temperature changes, and changes to the water vapor annual cycle. Below I've listed a number of points the authors should consider in revision to best represent their results.

1) First sentence is rather convoluted. It says "Volcanic eruptions increase the stratospheric water vapour (SWV) entry via long wave heating through the aerosol layer in

the cold point region, and this additional SWV alters the atmospheric energy budget." Why don't you say instead "Increases in the temperature of the tropical cold point region through heating by volcanic aerosols results in increases in the entry value of stratospheric water vapour and subsequent water vapour feedbacks." (or something like that) And, an question, what exactly are you referring to as long-wave heating? I think it should be made clear that there is near-IR solar and terrestrial long-wave heating going on.

2) Line 43/43 says: "reducing the "freeze trap" effect originating from the increasingly low temperatures and consequent loss of WV due to ice formation and fallout. The reduced freezing trap character enhances the entry of water vapour into the stratosphere." I don't think "reducing the freeze trap" is the appropriate way to express what's going on, and the phrase at the end of the first sentence and second sentence are excessively wordy and not entirely clear. Regardless of the temperature change, the freeze trap still exists, you've just effectively changed the set point by increasing the cold point temperature. Water values in the troposphere are still much larger than those in the stratosphere, and the fluctuations discussed here are on the same order as that induced by the seasonal cycle in cold point temperatures. How about saying instead "thereby increasing the stratospheric entry value of water vapour."?

3) Line 44-68: this needs to be edited for clarity, or even deleted, but definitely shortened. I believe the genereal point being made is "Although we understand the mechanism, internal variability and scarcity of observations has made this difficult to observe in practice."

4) Suggestion: rather than using the term "the indirect pathway" why not talk about "changes in SWV due to aerosol induced changes in tropical cold point temperature?"

5) General note. . ..Does ACP allow references to papers "in preparation"? I would suggest not doing so, and instead include a supplement with the relevant information from the "in prep" manuscript.

6) I would recommend a reorganization. . .instead of going from AOD straight to TOA radiative imbalance, instead, progress through temperature, water vapour, then radiative imbalance and surface temperature.

7) To put runs in perspective, it would be useful to note how the simulations would compare to known volcanic eruptions. This manuscript describes 5 quantities of S input, ranging from 2.5 Tg to 40 Tg. Pinatubo estimates are $\sim$20 Tg of SO2 (or 10 Tg of S). This should be noted, in particular when discussing resultant cold point perturbations. (In particular when considering what would be observable over internal variability)

8) Line 183/184 says "The month of September was chosen as an example since it lies in the time frame within which the annual cycle of water vapour entry into the stratosphere is enhanced." What do you mean by the annual cycle . . . .is enhanced? Are you simply stating that is when you expect the maximum water vapour entry into the stratosphere, or are you implying something about the amplitude? Please revise to make clear.

9) Question, I assume it is not just total AOD that is relevant for cold point warming, but also the vertical distribution of aerosol. Could you provide a plot of the vertical aerosol distribution (perhaps for your extreme case) and discuss whether that is realistic for a volcanic eruption? You note an extreme warming for the 40 Tg case, however, what happens for the 10 Tg case (which would be akin to Mt Pinatubo)?

10) Line 187 states there is a downward shift of the CP with increasing sulfur. I do not see that in Figure 3. The CP location appears to be at 100 hPa for all cases, it is just the temperature value at 100 hPa that changes.

11) Line 195. . .I asked this before, but I would recommend noting what long wave radiation is warming the aerosol layer. Is it terrestrial radiation (from below) or absorption of near IR (from the sun)?

12) Paragraph starting with line 195: Here would be a good place to compare with what

really happened during Pinatubo (which I assume the 10 TgS case would most closely match)

13) Line 217: The annual cycle is not described as the tape recorder, the manifestation of the annual cycle of tropical SWV (as seen in the vertical profile) is the water vapor tape recorder.

14) Line 247/248 states "The season SON was chosen as it is the period of highest SWV values in the lower stratosphere." It would be more accurate to state that SON follows the period where the entry value of stratospheric water vapor is highest, or restrict your statement to "highest SWV values in the tropical lower stratosphere". This is likely not the case in the polar regions.

15) Discussion at 255 and rest of paragraph. Does your model keep track of overshooting ice? If so, is there any in the tropics? If the model doesn't keep track of it, and there is none in the tropics, then delete this discussion.

16) Line 262-264: The text states "However, the water vapour enters the tropics mainly in the inner tropical region and then spreads throughout the globe, leading to values lower than expected according to the Clausius Clapeyron equation." I question whether this is actually true, that water vapour (and by extension mass) entry into the stratosphere is "mainly" through the inner tropics (which I assume is defined here as 5N to 5S). You should be able to demonstrate this with your model output. 17) Line 283. . .this should be stated at the start of the paper.

18) What does this mean? "In particular the seasonal cycle of the tape recorder is more strongly amplified in the Mt. Pinatubo run in 1992. . ." Are you saying that the difference between the WV minimum and the WV maximum is larger in 1992 that for climatology? Or, or you saying that the maximum in 1992 is larger than climatology?

19) And, just a general terminology comment: Why do you call the entry of water vapour into the stratosphere through the cold point "indirect". That is pretty much how

all water enters the stratosphere, with overshooting convection not being predominant, and methane oxidation being the other significant source.

20) Line 378-383: Mote et al. used both SAGE II and MLS data. There is plenty of additional satellite data following the publication of the Mote et al. papers from which the annual cycle in the entry value of stratospheric water vapor can be calculated. Until you have compared with that whole body of data, I don't think you can say that the initial tape recorder analysis is biased such that the model output is correct.

21) Section 4.2: although the solar occultation satellite measurements immediately following Pinatubo were contaminated by the presence of aerosol, the microwave measurements should be OK (MLS water worked for 1.5 years), and there should be at least some sonde measurements (from FP and in situ aircraft instruments). However, instead of directly looking at WV, why don't you look at how the model compares for the tropical tropopause temperature anomalies. There should be good operational sonde data in addition to any satellite information from which to deduce an increase in CP temperature causing an increase in SWV. And, if SWV did increase, it should also be detected in the regular mid latitude frost point measurements done by NOAA at 40N.

22) Line 443: change "second poster" to "second post"

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-1191, 2020.