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Atmospheric Chemistry and Physics
Discussions

Interactive comment on "Systematic satellite observations of the impact of aerosols from passive volcanic degassing on local cloud properties" *by* S. K. Ebmeier et al.

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General

In this study, the authors investigate aerosol indirect effects (AIEs) resulting from passive degassing of volcanoes located in remote oceanic regions by use of satellite data. The authors do so by employing an analysis technique which allows them to systematically sample aerosol and cloud properties up- and downwind of the emission sources (i.e. the volcanoes). The motivation behind this approach is that mean aerosol and cloud properties downwind of the volcano are expected to be different from those up-

wind and that these differences are consistent with AIE hypotheses. Because the authors consider volcanoes located in remote oceanic regions, which are assumed pristine with respect to anthropogenic aerosol, this study is a promising step towards characterising the impact of volcanic emissions on properties of the pre-industrial atmosphere. This is especially important in the light of the recent study of Carslaw et al. (2013) who found that uncertainties in quantifying pre-industrial aerosol emissions, and thus the pre-industrial atmospheric reference state, dominate the uncertainty in estimates of total aerosol radiative forcing.

Using their approach of separating polluted from clean environments with respect to volcanic emissions, the authors show that aerosol and cloud properties downwind of passively degassing volcanoes are systematically different from those upwind of the volcanoes. As expected, changes in aerosol properties (an increase of aerosol optical depth, AOD), are more evident that those in cloud properties (reduction of droplet effective radius and increase in optical depth τ). To substantiate their findings, the authors provide an analysis of "reference islands" to exclude the effect of dust emissions and orography on aerosol and cloud properties as well as an elaborate and convincing discussion of the uncertainties of their approach.

This paper constitutes an important contribution to the study of AIEs and their quantification from observational datasets, especially as it demonstrates the feasibility of extracting small, but statistically significant signals from long-term satellite data records. The paper therefore fits very well into the scope of ACP.

The paper is generally well written and structured, the motivation and approach are clear and the figures are well chosen and displayed. However, I think the manuscript lacks detail in some instances and some aspects of the results warrant explanation (e.g. not showing results from AATSR for most of the study or the assumptions/conclusions regarding the sampled cloud populations). I recommend the paper for publication in ACP after the following mostly minor issues have been addressed.

Specific comments

- P2677, L24-25: Here, I suggest a change/modification to the list of references. Although concerned with quantifying the effect of shipping emissions on aerosol and cloud properties over remote oceans, Peters et al. (2011) did not focus on the analysis of ship tracks. Instead, we aimed at quantifying AIEs from shipping emissions on climatically relevant scales beyond those of individual ship tracks. We did so by systematically sampling for unpolluted and polluted air masses up- and downwind of major shipping lines. So in a sense, the working hypotheses in the present paper and in Peters et al. (2011) are very similar. However, contrary to the present study, we did not find statistically significant effects of shipping emissions on aerosol and cloud properties in our study. Comparing the two studies, I am certain that the analysis presented here clearly benefits from volcanoes representing a point source, whereas ships obviously represent a moving point source of (in our study) unknown location and strength.
- P2678, L3-5: I can't follow your argument in the last part of the sentence.
- P2681, L3-6: With regards to anthropogenic emissions, the environment of Piton de la Fournaise may not bee as pristine as you think. That island is located right along a somewhat major shipping line connecting the southern tip of Africa with Malaysia (see e.g. Peters et al. (2011), Fig. 1). Also, it would be good if you compiled multi-annual maps of cloud cover and cloud top pressure including the associated standard deviations for each of the islands and instruments so that readers get an idea of the sampled low cloud population and variability.
- P2681, L20: Please explain the MODIS QA value of 0. Many readers will not be familiar with it.
- P2681, L21: Why did you pick the aerosol product cloud fraction to be $<$0.8? 0.8 to me seems to be a quite large value and I would assume that at such high cloud

fractions, the retrieved AOD could be enhanced due to humidification of aerosol particles in the presence of clouds (e.g. Quaas et al., 2010, and references therein). Did you check if changing the threshold has an effect on the results ? For completeness, you may also want to mention the different resolution of aerosol and cloud properties as provided in the ATML2 products (5×5 km^2 for cloud and 10×10km^2 for aerosol).

- P2682, L1: I wonder if the threshold for cloud top pressures actually has an effect on the results. I would assume that every cloud reaching that high is well above the freezing level and is therefore at least of mixed phase. Those clouds would be already filtered by the cloud top phase criterium, wouldn't they ?
- P2682, L2: I am not sure what you mean by "bin". Do you mean the 10km resolution the data are resampled to ? If so, it is not clear from the text where those large numbers come from because the data itself has a resolution of either 5×5 km^2 or 10×10 km^2.
- P2682, L7: Later in the text, you mention that you use ERA-Interim. This should be noted here as well. Also, please mention the time and spatial resolution of ERA-Interim here.
- P2683, L3-4: What do you mean by low sources of uncertainty here ?
- Section "General features of rotated cloud and aerosol properties": It would be good to mention the results shown in Table 2 at this point. Regarding Table 2, can you also provide corresponding standard deviations? Comparing the numbers between MODIS and AATSR, it seems AOD differences are larger, but CER and τ differences are smaller in AATSR compared to MODIS. Can you comment on this ? Furthermore, the results obtained from AATSR are only really mentioned in this part of the paper, the rest focuses on MODIS(Aqua). Why?

- Section 3 in general: I suggest the volcanoes and their emission profiles be introduced before the actual observed aerosol and cloud properties are discussed.
- P2685, L27 - P2686, L2: This is also what we found in all the regions we analysed in Peters et al. (2011) and one of the reasons we could not identify statistically significant AIEs from shipping emissions. In light of the plots shown in Fig. 2 of the submitted manuscript, I suggest adding a note to various parts of the manuscript that the observed cloud properties at Yasur do not clearly indicate statistically significant AIEs, but that changes in aerosol properties are evident. This is needed especially because very similar linear trends can be seen for two of the control islands: Fiji (τ) and Samoa (AOD and τ).
- P2687, L12: I find it very hard to depict a decrease in droplet size for Tristan da Cunha from the plots in Fig.2.
- P2688, L3 and many later instances: Sometimes, you refer to emissions from volcanoes in terms of Mg, sometimes in terms of t. For the sake of consistency, could you please stick to similar units throughout the paper?
- P2689, L12-14: The term cloud seeding is normally used for methods which enhance the precipitation efficiency of clouds, therefore reducing cloud cover.
- P2692, L9-10: Why would that be ? Long range transport of especially dust aerosol can occur for 1000's of kilometers under certain conditions. Are there estimates for those kinds of emissions from the considered islands ? In any case, I would assume they are low compared to volcanic emissions.
- P2693, L6-7: An increase in τ is associated with the Twomey effect. An increase in cloud lifetime would be seen in an increase in liquid water path and/or cloud fraction. It would be informative to show at least one or even both of these cloud properties.

- P2693, L9-13: Can you comment on the influence this might have on the observed cloud properties and why this could be important?
- P2694, L6-7: The way you use the data, i.e. level2 products for both aerosol and cloud properties, it is fair to assume that clouds and aerosols are exposed to the same air mass. However, as indicated earlier, this may also mean that AOD is biased high by the presence of clouds.
- P2694, L12-14: It is not clear to me what you mean by this. Do you mean cloud cover in general (which I assume would be highly autocorrelated)?
- P2695, L7-9: This needs explanation, e.g. secondary sulfate aerosol formed from volcanic emissions of gaseous SO_2 downwind of the volcano is of nucleation or Aitken mode size and thus cannot act as CCN in environments of small supersaturation because that requires at least Accumulation mode sized particles (for typical supersaturations in stratocumulus clouds (e.g. Pierce and Adams (2007))).
- P2695, L9-13: I don't agree with this argument. First, you do not show plots of mean cloud cover and cloud top height to substantiate your claim of observing primarily stratocumulus clouds. Second, by filtering your data for liquid water clouds with cloud tops below 440hPa, these clouds may be well above the top of the boundary layer in the regions considered. Thus, you also sample clouds which are exposed to free tropospheric aerosol, and this may very well be of volcanic origin considering that Kilauea and Piton de la Fournaise have summit heights in excess of 1000m. However, these volcanoes also emit from smaller side vents which would definitely be in the boundary layer. Are there estimates of how much of the emitted SO_2 stems from the side vents relative to the main vent?
- P2696, L5-6: see above
- Fig. 4: I assume this plot also refers to data obtained from MODIS(Aqua)?

Technical edits

- P2677, L6: air parcel → parcel of cloudy air
- P2677, L8: smaller cloud droplets "may" results in... You should also mention that especially secondary aerosol indirect effect hypotheses are highly debated and far from being verified from observations (e.g. Stevens and Feingold, 2009; Rosenfeld et al., 2014)
- P2677, L14 and anywhere else: indirect effect(s) → aerosol indirect effect(s)
- P2679, L1: significant → large (significant is a statistical term)
- P2680, L5: remove the "etc"
- P2680, L9: such as "the one published by" Andres and ....
- P2681, L11: What do you mean by "deep"?
- P2682, L22-24: Rewrite this sentence
- P2694, L10: light levels → solar irradiation levels
- P2695, L23: thin → shallow

References

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