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Atmospheric Measurement Techniques
Discussions

Interactive comment on "Big grains go far: reconciling tephrochronology with atmospheric measurements of volcanic ash" *by* J. A. Stevenson et al.

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From A. J. A. Smith, E. Carboni, R. G. Grainger, G. McGarragh, A. Povey, and L. Ventress.

This paper explains why measurements of volcanic ash particle size distributions obtained by ground based sampling and inferred from brightness temperature difference (BTD) satellite retrievals exploiting the varying and distinct differences in volcanic ash reflectivity between 11 and 12 μm differ. While we agree with the conclusions of the paper and think it worthy of publication, we feel that there are several modifications

required in the sections discussing satellite retrievals.

Our main issue is that this work does not discuss generic remote sensing, but rather the BTD method which is a far more specific technique. For example, while in the narrow band of IR frequencies used in this study there is no ability to resolve particle sizes when the radius is $> 17\,\mu$m, there is demonstrated sensitivity to millimetre sized volcanic particles for remote sensing in the microwave using ground based and satellite radar instruments (Delene et al., 1996; Marzano et al., 2006). Other satellite retrievals which use more or different wavelengths can also have a wider range of sensitivity to size.

Additionally, there is a lack of precision in the discussions of BTD retrievals. Many of the comments on systematic bias and insensitivity to larger particle sizes would be more convincing if framed in terms of the information content, degrees of freedom, and the averaging kernels used. For example, Figures 10 and 11, which show the retrieved effective radius compared to the mass median forward modelled radius, would be far better demonstrated by a single figure showing the averaging kernel element $\frac{\partial \hat{r}_{\text{eff}}}{\partial r_{\text{eff}}}$, the sensitivity of the retrieved radius to the true radius. This would also remove our concerns that the low bias in retrieved size is caused by the low a priori effective radius of 3.5 μm which will affect the retrieved state more and more as the information content in the retrieval decreases. If the a priori effective radius was set, for example, at 40 μm, we would expect that in the absence of information in our measurements, the retrieved radius would also be around this value.

In Fig. 9, it would be informative to discuss or show how many degrees of freedom are available for each pixel, and where in the averaging kernel the information is partitioned. For example, what happens if the altitude of the ash cloud is held constant so that only the column mass loading and radius are allowed to vary? We would strongly disagree with the statement that the cost of a retrieval *"can be used as a measure of uncertainty"* [P82L11–15; P82L23; P118 figure caption]. The cost is a measure of how well a measurement is fitted by a specific solution i.e. how well satisfied with a retrieval's convergence one is, whereas the uncertainty is a measure of the error-bar on a retrieved parameter i.e. the reasonable range within which we believe our solution lies.

Finally, some errata:

- While non-sphericity certainly has an effect on the light scattering of volcanic ash, particularly the larger particles, this is not in itself going to change the fundamental issue of the very similar light scattering properties of large particles observed between a very narrow range of frequencies. Additionally, since this is not addressed at any point in the text, with the exception of in references to other work, we don't consider it a conclusion of this paper.

- It would be instructive to compare the various size metrics used in the paper. Perhaps with some conversion examples. e.g. For spheres, an effective radius of 15 μm with a lognormal spread of 2 is equivalent to a volume average radius of 19 μm. Measurement techniques that rely on mass, or particles that have asymetrical shapes will lead to larger deviations between the size distributions reported by different measurements.

- Though Devenish et al. [2012] is an excellent comparison of lidar observations to the NAME model, we do not feel it suits the overall argument of this paper to simply cite its estimate of the fraction of ash remaining in the distal plume. They derived mass loadings by assuming a constant mass-extinction cross section of 0.6 $m^2\,s^{-1}$, which was calculated from comparison with AERONET observations on April 16th 2010. Following the arguments of the proposed paper, there should be little surprise that the distal ash fraction they report is in agreement with satellite retrievals as they both draw information from observations at similar wavelengths with a similar lack of sensitivity to large particles.

  The citation of (Dacre et al., 2013) is not limited to the same extent. They estimate the distal ash fraction using column-integrated particle size distributions from the Cloud Aerosol Spectrometer, which has a nominal diameter range of 0.6–50 μm. That is a more appropriate comparison, though the relative sensitivity of the instrument at the edges of its nominal range could be significant.

- Figure captions are extremely long, and often contain scientific content that should be included in the main text.

We thank the authors for bringing this paper to our attention and soliciting comments.

References

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