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Atmospheric Measurement Techniques Discussions

Interactive comment on "Ash and ice clouds during the Mt. Kelud Feb 2014 eruption as interpreted from IASI and AVHRR/3 observations" *by* Arve Kylling

Anonymous Referee #2

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Review of "Ash and ice clouds during the Mt. Keldu Feb 2014 eruption." by A. Kylling

The present paper deals with the study of high resolution thermal infrared space observations of volcanic ash clouds which contain both ash and ice particles. The focus of the paper is on the retrieval/radiative transfer aspects. The methodology is good, and the results interesting. Although the impacts of ice particles on ash retrievals are widely known, to date there has been no study quantifying the retrieval effects for hyperspectral sounders for an example eruption. There are however a series of improvements which can be made and which will significantly improve the paper (see below). I can recommend the publication of this paper after the following issues have been addressed:

- The introduction does not mention a word on the importance of ice in volcanic clouds. While satellite measurements can be affected by under or overlying meteorological clouds, ice can also be present within the volcanic cloud (see e.g. Durant et al, 2008 for the main sources of water/ice in volcanic clouds). The fact that ash can act as CCN and that ice can coat ash particles should also be mentioned. In the satellite era there have been many other eruptions which where characterized by ice rich plumes. The literature on this topic should be thoroughly summarized and cited. Some entry points:

Rose, W. I.; Delene, D. J.; Schneider, D. J.; Bluth, G. J. S.; Krueger, A. J.; Sprod, I.; McKee, C.; Davies, H. L. & Ernst, G. G. J. Ice in the 1994 Rabaul eruption cloud: implications for volcano hazard and atmospheric effects Nature, 1995, 375, 477-479

Rose, W. I.; Bluth, G. & Watson, I. Ice in volcanic clouds: When and where? Proc. of the 2nd Int. Conf. on Volcanic Ash and Aviation Safety, OFCM, Washington, D. C., Session 3, 61, 2004

Durant, A.; Shaw, R.; Rose, W.; Y.Mi & Ernst, G. Ice nucleation and overseeding of ice in volcanic clouds J. Geophys. Res., 2008, 113, D09206

- First sentence of Section 3, repeat use of "polar orbiting" (typo)

- Section 3.2 The numbers on the effect of SO2 on the DBT seem inconsistent: 0.13 DU: 0.31K, 10 DU -0.99K, 100 DU: -0.47K. Two problems: (i) These differences should grow monotonously as the amount of SO2 increases. (ii) They should become more and more positive (as BT1097.25 becomes smaller and smaller)

- Figure 3. The behavior for an ice cloud top temperature of 18 km is odd, the DBT first increases, seems to reach a local maximum around 0.1 g/cm3 and then decreases again. Could you show example spectra?

- Section 4.1: please give a bit more explanation on how the ice cloud RT simulation was done, so that the reader can catch the gist without having to consult other papers. Without having read the paper, the title of the Key et al. reference seems to suggest that paper deals with shortwave radiation.

- Please give some references on high resolution RT simulations of ash/ice clouds:

E.g. for ash

Newman, S. M.; Clarisse, L.; Hurtmans, D.; Marenco, F.; Johnson, B.; Turnbull, K.; Havemann, S.; Baran, A. J.; O'Sullivan, D. & Haywood, J. A case study of observations of volcanic ash from the Eyjafjallajökull eruption: 2. Airborne and satellite radiative measurements J. Geophys. Res., 2012, 117, D00U13

E.g. for ice

Wang, C.; Yang, P.; Platnick, S.; Heidinger, A. K.; Baum, B. A.; Greenwald, T.; Zhang, Z. & Holz, R. E. Retrieval of Ice Cloud Properties from AIRS and MODIS Observations Based on a Fast High-Spectral-Resolution Radiative Transfer Model J. Appl. Meteor. Climatol., Journal of Applied Meteorology and Climatology, American Meteorological Society, 2012, 52, 710-726

- Figure 4: the examples, although instructive could be chosen much better, and although it is a bit of work, I highly recommend the following changes:

+ I would suggest removing either B or C since they are very similar

+ I would suggest adding a spectrum where there is a non-saturated ice cloud, so that the reader can see what the spectral signature looks like in the infrared (a saturated ice cloud is basically a black body)

+ I would suggest adding a spectrum of pure ash. It might be difficult to find a 100% ice free observation in the eruption of Kelut, but it would be worth showing the one with the least amount of ice, so that the "pure" ash signature can be seen. In this way, both signatures (ash+ice) can be recognized in the ash+ice spectra.

+ Following these suggestions there would be 5 spectra: ash, ash+ice, ice, clear, and saturated ice. Naming these spectra as such would also make the manuscript easier

to read (A/B/C is not very telling).

- The look-up-table strategy that is applied here for the retrieval has been applied before for hyperspectral retrievals. Some example should be given to show that this is not a new method. E.g. Peyridieu, S.; Chédin, A.; Capelle, V.; Tsamalis, C.; Pierangelo, C.; Armante, R.; Crevoisier, C.; Crépeau, L.; Siméon, M.; Ducos, F. & Scott, N. A. Characterisation of dust aerosols in the infrared from IASI and comparison with PARASOL, MODIS, MISR, CALIOP, and AERONET observations Atmos. Chem. Phys., 2013, 13, 6065-6082

- The channels selection: 37 channels mostly between 750 and 1250 makes sense, however, the part most sensitive to "only-ash", namely 1070-1250 cm-1 has only 3 channels, and thus the spectral range 750-1000 cm-1 with 34 channels will dominate the retrieval. This can be seen very clearly in Figure 6, where the "ash only" fit shows huge residuals around $\sim$1200. To make the retrieval representative for the entire spectral range 750-1250, the RMSD formula could be replaced by a weighted RMSD, where more weight is attributed to the channels above 1070 cm-1. The effect on the retrieval results of the unbalanced number of points left and right to the O3 band should be commented on, and preferably retrieval tests should be made. It could very well be that by assigning due weight to the part 1070-1250 cm-1 would result in much more ash being retrieved.

- In Table 1, there is a retrieved reff of 4 micron - at the edge of the look up table. This is an indication that the range of reff of the look up table should be expanded. In this context, please also see Stevenson, J. A.; Millington, S. C.; Beckett, F. M.; Swindles, G. T. & Thordarson, T. Big grains go far: understanding the discrepancy between tephrochronology and satellite infrared measurements of volcanic ash Atmos. Meas. Tech., 2015, 8, 2069-2091

- End of section 5, discussion of figure 11. The RMSD is generally larger for the ice only case. Should it not always be the case, by definition? Since the ice only case is a subset of the ash+ice case (i.e. there should not be as single point below the diagonal in figure 11).

- Figure 8/9. Discussion/interpretation/comparison is much too short. I.e. How do these retrievals compare with previously published results (Kristiansen et al. 2015)? How much ash/ice total mass within the volcanic plume was measured? How does this compare to other ice/ash retrievals in the literature (from this and other eruptions)?

- The paper focuses on the technical / radiative transfer aspects of the problem, but more interpretation of the results would be highly welcome. E.g. at the end of the discussion it is pointed out that there is no correlation between retrieved ash/ice loadings - does this mean that the ice is not of volcanic origin? From the retrieval plots it seems that the retrieved altitude for the ice does reach 18 km. How common is it to have ice clouds at that location at such a high altitude? Some comparison with Calipso could help to increase confidence in the presented data.

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