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Interactive comment on “Volcanic ash infrared signature: realistic ash particle shapes compared to spherical ash particles” by A. Kylling et al.

Anonymous Referee #2

Received and published: 6 December 2013

Volcanic ash infrared signature: realistic ash particle shapes compared to spherical ash particles

by A. Kylling, M. Kahnert, H. Lindqvist, and T. Nousiainen

In this paper the thermal infrared optical properties of highly irregular and porous ash particles are computed and compared with the mass and volume equivalent spherical models optical properties. The results show that the non-spherical shapes and volume-equivalent spheres produce a detectable ash signal for larger particle sizes than mass-equivalent spheres and that the mass-equivalent spheres assumption underestimate the mass loading by several tens of percent compared to the inhomogeneous ash particles.

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The analysis is methodologically correct and the topic original. However the results and the discussion are not always clearly presented. I recommend the publication after minor revisions and corrections outlined below.

General Comments

- The premise that for spherical ash particles the detection (then the retrieval) is possible only for radii below $5 \mu\text{m}$ is not generally true. Such a detection limit depends in particular on ash optical properties then on ash refractive index and particle size distribution. Different authors (also cited in the paper) showed the possibility to retrieve ash parameters (AOD, effective radius and mass) until $10 \mu\text{m}$.
- The computation of the bell-shaped curves (dBT vs BT11), needed to define the ash detection limit and used to compute the ash parameters, is one of the key point of this work. Some clarifications are necessary on how the brightness temperatures have been computed. The SEVIRI response functions centered around 10.8 and $12 \mu\text{m}$ varies between approximately 10 and $13 \mu\text{m}$ but the ash optical properties are obtained only for the fixed wavelength of 11 and $12 \mu\text{m}$.
- Some figures should be improved because the lines result totally indistinguishable.

Specific Comments

- p. 8938, r. 18-20. “For spherical ash particles the radii have to be below $5 \mu\text{m}$ to give a negative brightness temperature difference (Wen and Rose, 1994, using monodispersed particle distributions).”

This sentence is not generally true. The upper limit of the detection is function of different variables as in particular the ash optical properties (i.e. the ash refractive index and the size distribution) but also the volcanic cloud geometry (altitude and thickness) and the instrument response function. Many authors showed the possibility to retrieve the ash particles effective radii until at least $10 \mu\text{m}$ (see for example, Prata et al., 2001, Yu et al., 2002, Corradini et al., 2008). In these papers the bell-shaped curves

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have been computed by considering different ash refractive indexes (andesite-Pollack, pumice-Volz) and instrument response functions (MODIS, AVHRR). Change “radii” with “effective radii”

- p. 8939, r. 11-13. “For a refractive index with a larger imaginary part (larger absorption), the electromagnetic field will not penetrate that far into the particle.”

Please clarify this sentence.

- p. 8939, r. 18-29. “. . . while infrared (IR) detectors, such as the Spinning Enhanced Visible and Infrared Imager (SEVIRI), measure the radiation emitted by the Earth’s surface and atmosphere.”

Together with SEVIRI, also MODIS, AVHRR and IASI should be cited. All these satellite instruments are used for the ash retrievals in the TIR spectral range.

- p. 8942, r. 20. “. . . for 10 sizes of 1, 2, . . . , 10 μm , and for 2 IR wavelengths, 11 and 12 μm ”.

What does “size” mean? Is it the effective radius? Which refractive index has been used for these computations? Andesite?

- p. 8944, r. 8. “. . . for particle size larger than . . .”.

As above, what does “size” mean?

- p. 8944, r. 14-15. “The asymmetry parameter is quite insensitive to the shape assumptions, which is surprising.”

A deeper discussion on that sentence is required. Have the authors an explanation of such a result?

- p. 8944, r. 15-19. “Nevertheless, for thermal emission the phase function is not important. It will play a role when scattering is involved, and, as shown in the third row of Figs. 2 and 3, the single scattering albedo is sufficiently large to make scattering

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effects have an impact for particles larger than about $2 \mu\text{m}$.”

This sentence is not clear to me. It states that for thermal emission the phase function is not important. But it play a role when the scattering is involved, then for particle larger than about $2 \mu\text{m}$ that are the particles interested in the TIR retrievals. Please clarify.

- p. 8944, r. 20-21. “For discrimination of volcanic ash from other atmospheric constituents the ratio of the extinction coefficients at 11 and $12 \mu\text{m}$ is of importance.”

Such statement is not obvious. Please clarify the sentence with a small description of the link between the extinction coefficient and the TOA radiance (then brightness temperature) to understand why if this ratio is positive the BTD should be negative.

- p. 8945, r. 12-14. “Brightness temperatures were calculated for the 11.0 and $12.0 \mu\text{m}$ (BT11 and BT12, respectively) channels of SEVIRI for various ash optical depths and particle sizes.”

The SEVIRI channels used for the BTD computation are centered around 10.8 and $12 \mu\text{m}$. Please substitute 11 with 10.8. More, the brightness temperatures are computed for the two SEVIRI response functions (centered at 10.8 and $12 \mu\text{m}$) that vary approximately between 10 and $13 \mu\text{m}$, but the ash optical properties are computed only at the fixed wavelength of 11 and $12 \mu\text{m}$ (see comment above). Please clarify. Change “particle sizes” with “particle effective radii”.

- p. 8945, r. 22. “The upper left plot is similar to those used to visualize the retrieval of ash mass loading and effective radius from BT11 and BT12 measurements under the assumption of spherical ash particles (Wen and Rose, 1994; Prata and Prata, 2012).”

I think there are significant differences between this plot and the curves published in Wen and Rose 1994 and Prata and Prata 2012. The first is the solid line for effective radii equal to $2 \mu\text{m}$ that, in Figure 5, is too close to the curve of effective radius equal to $1 \mu\text{m}$, and the second is the detection limit that can be derived from the plots. The

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bell-shaped curves in Figure 5 indicate that such a detection limit is around $5 \mu\text{m}$, while in the paper of Prata and Prata (that uses the same response functions and refractive index) is certainly higher than $8 \mu\text{m}$. I think that the RTM simulations should be checked. In the introduction on RTM simulations (chapter 3) the authors stated that they use the DISORT routine. How many streams do you use to take into account the multiple scattering?

- p. 8947, r. 10. Add the description of the term $\tau(\lambda)$.
- p. 8947, r. 11. substitute “radius” with “effective radius”
- p. 8947, r. 10-27. This part is a bit confused. At first the ash retrieval differences are computed by considering “the mass-equivalent sphere model and the ash large vesicle model” (r. 15-16), then the “effect of particle shape may be quantified comparing non-spherical particles and volume-equivalent spherical particles” (r. 20-21), and finally the “difference between the mass loading retrieved with mass-equivalent spherical particles and porous ash particles may be compared with the uncertainty arising from lack of knowledge of other factors” (r.23-25). Please clarify.
- p. 8947, r. 21. Substitute “BT12” with “dBT”.
- p. 8947, r. 5-6. “... the total mass error estimate, will increase the total mass error estimate to 45–50 %.” Is the total error computed by considering the 25% of ash mass loading difference found by comparing the “non-spherical particles and volume-equivalent spherical particles” (r. 20-21)? Maybe the total error would be more representative if computed by comparing the ash retrieval obtained by mass-equivalent spherical particles and the non-spherical particles instead of the volume-equivalent spherical particles vs non-spherical particles.

Figures

Figure 4 and Figure 6: many of the lines are completely indistinguishable each other. Please simplify the plots.

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 8937, 2013.

AMTD

6, C3591–C3596, 2013

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