Response to Anonymous Referee #1
Ash plume top height estimate using AATSR

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We thank the Referee for the positive feedback and constructive comments. The numbered comments are answered below and the changes to the manuscript are listed at the end of the document.

1. *This is a good paper, using parallax from the nadir and 55° AATSR data to obtain volcanic ash plume height. In my view, it would be acceptable to publish in AMT after minor revisions; in particular, more careful interpretation of the comparisons in the validation section.*

   We thank the referee for appreciating our work and for the useful discussion.

2. *P3865, line 14. The following paper might be relevant here, particularly with regards to the identification of ash with MISR:*

   Kahn, R.A., and J.A. Limbacher, 2012. Eyjafjalljökull Volcano Plume Particle-Type Characterization from Space-Based Multi-angle Imaging. Atmosph. Chem. Phys. 12, 9459-9477, doi:10.5194/acp-12-9459-2012.

   The paper by Kahn et al. (2012) is relevant for ash detection by MISR, although the work is not directly related the plume heights. The reference is added to the manuscript in section 4.

3. *P3871, Equations 3, 4, 5. You use μ_N and μ_F here for mean values, whereas on P3969, you use the same symbols for the view angles. This is confusing, and easy to fix. In fact, μ is usually used for the cosines of the angles, and theta for the view or zenith angles themselves.*

   We have changed the notation so that μ is used for the averages only, and θ is used for the viewing angles.

4. *P3875, Section 2.5.4. Does Earth rotation affect the cross-track displacement in the collocated images? This might be a factor in the assessment of cross-track wind speed, and might bear upon the collocation discussion in Section 2.7.4.*

   We use the collocation provided by ESA in the original AATSR data. To our knowledge the Earth rotation is not an issue here.

5. *P3875, line 21. '...due to effects related to the different viewing angles, plume structure, and...' Ash plumes often have non-uniform structure.*

   There are many possible reasons for the SPH height variation, one of which is the non-uniform structure of ash plumes. We have added this to the text.

6. *P3879, line 10. By 'pixel' here, do you mean CWS?*

   When speaking of the cross correlation coefficient (or any related parameter) of a 'pixel', we mean the corresponding value of the correlation window centered at the said pixel, with the two-dimensional shift which maximizes C. This is now explained in the text.

7. *P3879, lines 24-25. This might also occur for an ash plume very near the surface.*

   We don't see how a plume very near the surface would lead to low σ_c (the standard deviation of C within the correlation matrix i.e. with respect to all possible shifts). In such case a small or zero along-track shift would cause large C, but a larger shift would lead to small C. This would then produce large σ_c. However, the standard deviation of C within an averaging window (σ_{av}) might be low for a plume near the surface.

8. *P2882, lines 22-23. There is a comparison between MISR plume detection in the visible and several IR techniques in:*

   Ekstrand, A.L., P.W. Webley, M.J. Garay J. Dehn, A. Prakash, D.L. Nelson, K.G. Dean, T. Steensen, 2013. A multi-sensor plume height analysis of the 2009 Redoubt eruption. J. Volcanology Geothermal Res. 259, 170-184.

I realize your technique is based on spatial correlation rather than thermal structure, but I'm wondering whether temperature differences within the plume might affect where within the plume the 11-micron contrast matcher samples. In any case, the vis and TIR spatial contrasts might not be equivalent, and this could affect the comparison. Interestingly, the differences are not uniformly of the same sign. As you also have vis channels, it would be worth making the comparison at similar wavelengths.

We thank the Referee for pointing us to this article. It shows a valuable comparison between the thermal and stereoscopic height retrievals (although not plume *detection*), and is now cited in the manuscript.

We recognize that the wavelength issue is an important point. Preliminary tests were made with visible wavelengths, but there was no decisive improvement in the comparison results. This manuscript presents the first version of the ACM algorithm, and shows a base-line comparison with some of the existing methods. Further improvement of the algorithm and more detailed comparison with e.g. the MISR results, including using various wavelengths and accounting for the wind correction, is expected in the future. This is now indicated in the text.

9. *P3383, Line 25. I think you are using the MINX product (Nelson et al., 2013) rather than the MISR Operational stereo heights (Muller et al., 2002). For MINX, the reference would be:*

   Nelson, D.L., M.J. Garay, R.A. Kahn, and B.A. Dunst, 2013. Stereoscopic Height and Wind Retrievals for Aerosol Plumes with the MISR INteractive eXplorer (MINX). Remt. Sensing 5, 4593-4628; doi:10.3390/rs5094593.

   We agree, and have added the proper reference to the manuscript.

10. *P3385, line 14-17. Validation of the MISR technique is provided in the Ekstrand et al. and Nelson et al. papers cited above, which might be helpful in evaluating comparisons between MISR and the 11-micron technique.*

    We have performed a preliminary comparison with MISR data which is easily available in the web. We agree that a more detailed comparison taking into account the details of the instruments and methods, including wind correction, would be useful, but is left for future studies. Text is edited accordingly, and the reference to Ekstrand et al. is added.

11. *P3385, lines 17-18. The wind correction might have a significant effect under some circumstances. I'm wondering how much uncertainty in the height determination reported here is caused by the along-track wind.*

    We have to admit that this was not very clearly written in the manuscript. The error estimate reported here is for the basic method under the naive assumption of no wind; the uncertainty of 1-2 km is based on the validation of the basic method against the surface height. The other uncertainties discussed in section 2.7, in particular the along-track wind, may be significantly larger than 1-2 km. This is now worded more carefully in the text.

- After the submission of the manuscript we have also learned of another paper on the subject (Grainger et al., doi:10.1144/SP380.7, 2013), which is now referred to in the introduction.

Change log

The changes made to the manuscript are listed below.

- Page 3865, line 18. Added the text: 'Ash plume heights have also been studied by Grainger et al. (2013) using the AATSR, SEVIRI, and MIPAS (Michelson Interferometer for Passive Atmospheric Sounding) data.'
- Page 3869, lines 9 and 12; page 3872, line 25. Changed the notation from μ_N (μ_F) to θ_N (θ_F).
- Page 3875, lines 20-22. Replace

  'The single pixel height (SPH) values vary considerably from pixel to pixel, presumably due to effects related to the different viewing angles, and the time development of atmospheric features between the observations.'

  by

  'The single pixel height (SPH) values vary considerably from pixel to pixel. Part of this variation may be due to nonuniform structure of the ash plumes, but noise may also be caused by effects related to the different viewing angles, and the time development of atmospheric features between the observations.'
- Page 3878, lines 24-25. Replace

  'We estimate a typical total error of 1-2 pixels, corresponding to 1-2 km in height.'

  by

  'Under the naive assumption of zero along-track wind we estimate a typical error of 1-2 pixels, corresponding to 1-2 km in height.'
- Page 3879, lines 2. Added the text: 'This error estimate is based on the validation of the surface height estimate against topographic data (section 3.1). In addition, there are several error sources that may have a more significant contribution to the total error. These are discussed in more detail below.'
- Page 3879, line 12. Added the text: '(By 'correlation coefficient of a pixel' we mean the maximum cross correlation coefficient over all possible shifts for the CW centered at the said pixel.)'.
- Page 3883, line 26. Added the text: 'A useful tool for analyzing the plume properties using MISR data, the MISR INteractive eXplorer (MINX), is available as open-source software (Nelson et al., 2013). MINX offers better resolution than the operational MISR product, but requires manual detection of the ash plumes. Plume top heights obtained with MINX have been compared with thermal height estimates and ground based radar results by Ekstrand et al. (2013).'
- Page 3885, line 18. Added the text: 'Further work, including wind corrections and the use of visible wavelength for ACM, is needed in order to understand the remaining differences between ACM and MPHP results, but this is beyond the scope of this paper. It is also possible to adapt the ACM algorithm for use with MISR data, which would allow a more detailed comparison.'
- Page 3887, line 7. Added the text: 'Ash identification and retrieval of ash properties using MISR are described by Kahn and Limbacher (2012).'
- Page 3891, line 22. Added reference: 'Ekstrand, A. L., Webley, P. W., Garay, M. J., Dehn, J., Prakash, A., Nelson, D. L., Dean, K. G., Steensen, T., A multi-sensor plume height analysis of the 2009 Redoubt eruption, J. Volcanology Geothermal Res. 259, 170-184, doi:10.1016/j.jvolgeores.2012.09.008, 2013.
- Page 3891, line 26. Added reference: 'Grainger, R. G., Peters, D. M, Thomas, G. E., Smith, A. J. A., Siddans, R., Carboni, E., and Dudhia, A., Measuring volcanic plume and ash properties from space, in: Remote Sensing of Volcanoes and Volcanic Processes: Integrating Observation and Modelling, Pyle, D. M., Mather, T. A., and Biggs, J. (eds), Geological Society, London, Special Publications, 380, doi:10.1144/SP380.7, 2013.'
- Page 3892, line 1. Added reference: 'Kahn, R. A., Limbacher, J. A: Eyjafjalljökull Volcano Plume Particle-Type Characterization from Space-Based Multi-angle Imaging. Atmosph. Chem. Phys. 12, 9459-9477, doi:10.5194/acp-12-9459-2012, 2012.'
- Page 3892, line 18. Added the reference: 'Nelson, D. L., Garay, M. J., Kahn, R. A., and Dunst, B. A. Stereoscopic Height and Wind Retrievals for Aerosol Plumes with the MISR INteractive eXplorer (MINX). Remt. Sensing 5, 4593-4628; doi:10.3390/rs5094593, 2013.'

Note that other changes are made based on the comments of Referee #2 (not listed here).