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Atmospheric Measurement Techniques Discussions

Interactive comment on "CALIPSO Level 3 Stratospheric Aerosol Product: Version 1.00 Algorithm Description and Initial Assessment" *by* Jayanta Kar et al.

Andrew Prata (Referee)

andrew.prata@bsc.es

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General comments

In this contribution, Kar et al. present the new level 3 stratospheric aerosol product for the CALIPSO mission. The details of the science algorithm used to construct the level 3 product are presented. In addition, a preliminary quantitative assessment of the product is made through an inter-comparison of the CALIPSO and SAGE-III (ISS) extinction coefficient retrievals. Some nice observations of volcanic and wildfire smoke aerosols are also described. The paper is well structured and well written and the

assumptions used in the retrieval are clearly articulated. This contribution is important because the level 3 aerosol product could potentially be used in radiative forcing studies that consider the impacts of aerosol loading in the stratosphere. I recommend publication after addressing some minor revisions suggested below.

Specific comments

When describing the time-series of stratospheric perturbations due to major volcanic eruptions and wildfires shown in Figure 6, I think it's important to stress in the text (and Abstract) that this analysis is representative of aerosols in the tropical (25°S-25°N) stratosphere. Kasatochi and Sarychev were high latitude eruptions and so most of their sulfates were confined to mid-high latitudes. In addition, Kelud and Nabro are located within tropical latitudes and so their signatures are exaggerated relative to Kasatochi and Sarychev in the figure. Figure 6 would be much more illuminating if panels representing mid-high latitude bands were added.

The discussion on the high bias of the CALIPSO retrievals relative to the SAGE-III retrievals is very interesting. Figure 13 shows that this is largely due to the assumption of a constant lidar ratio set to 50 sr in the CALIPSO product. The authors point out that there were 'probably no significant injections of ash from volcanoes' during their analysis period (June 2017 - August 2018); however, there was a significant ($\sim$0.15 Tg SO2) eruption of Ambae (15.389°S, 167.835°E) in Vanuatu in April 2018 (Global Volcanism Program, 2018). This event may have affected the analysis and should be noted in the discussion section. Another point that could be mentioned is the effect of averaging the data over 15 months. Wouldn't this 'smooth out' the influence of volcanic/smoke aerosols on the derived lidar ratios shown in Figure 13?

Another factor that would impact the new aerosol product is the choice of the color ratio threshold. The authors use a color ratio threshold of 0.5 to remove clouds and retain volcanic ash clouds. However, several authors (Winker et al. 2012; Vernier et

al. 2013; Prata et al., 2017) have shown that volcanic ash colour ratios can be as high as 0.80. Setting this threshold too low may therefore remove volcanic ash from the 'all aerosol' product. This point should be addressed when introducing the choice of their selected threshold.

Specific comments about figures

In a lot of the figures the axes and colorbar labels are missing. Also some of the labels are not written clearly. For example, the authors use underscores and abbreviations. I think using proper label names with appropriate variable symbol definitions and units would make the figures clearer. Also latitude/longitude units should use the degree symbol (not the abbreviated 'deg'). At the very least, the labelling should be consistent throughout the paper.

Technical corrections/suggestions

P1L28-30: There is also large disagreement ($>$100%) between CALIPSO and SAGE-III at altitudes below 20 km (Figure 11b). This should be stated in the abstract.

P3L26: I see two Kar et al. (2018)s in the references section. Please use 'a' and 'b' to differentiate between them.

P4L10-11: 'The consequences of this change...' - I suggest adding the V3 zonally and vertically averaged attenuated scattering ratio (for the same time period) to Fig. 1. This would make the change from V3 to V4 very clear.

P4L17: Change 'over this latitude' to 'over each latitude'.

P5L17: 'accurate to about 1%' - do you have a reference for this?

P5L28: Delete 'going'.

P6L8: Replace 'i.e.' with 'such as'.

P6L11: 'Vaughan et al. (2009)' - Is there a new reference for the V4 level two layer detection algorithm that you could add?

P6L14: Replace 'but' with 'however'.

P6L18: Change 'product' to 'level 3 stratospheric aerosol product'.

P6L21: Change 'the primary input files used for this product' to 'the primary input file used for the present product'.

P7, Figure 2: For consistency, should use small 'b' in the 'Write results to Background component' box.

P7L7: Please define the 'local tropopause'. E.g. is this taken from GMAO?

P8L4: Change 'Antarctica' to 'Antarctic'. Change 'both the hemispheres' to 'both hemispheres'.

P9L24: Shouldn't this be 'Vernier et al. 2013'?

P9L25: The Puyehue ash did not reach 17 km. Maximum heights observed by CALIOP were $\sim$13 km (Vernier et al., 2013; Prata et al., 2017).

P9L26: Threshold of 0.5 seems too low. Vernier et al. (2013) use a threshold

of 0.8 to discriminate between clouds and volcanic ash. I think the impact of this threshold should be mentioned (see specific comments above).

P10L11: Change 'threshold' to 'threshold of the level 2 layer detection algorithm'.

P11, Figure 4: Can you comment on what's causing the high scattering ratios just above 10 km at $\sim$50°N?

P12L3: What does this look like for a threshold of 0.75-0.80? You may get more of a signal for the Puyehue event.

P12L4: Change 'Nabro' to 'Nabro (near 30°N)'.

P12, Figure 5: I think the labels are wrong here i.e. Figure 5b looks like 'background' and Figure 5a looks like 'all aerosol'.

P12L19-21: I don't see a high number of samples over North America in Figure 5b (see above Figure 5 comment).

P13L27: Change 'significant ash' to 'significant ash and sulfate'.

P14L22: Change 'image' to 'figure'.

P14L23: Change '(Kasatochi, Nabro etc.) to '(e.g. Kasatochi and Nabro)'.

P15L10: 'quite clearly seen' - I'm not sure it is that clear. There are several other features in the figure that are more apparent than the Black Saturday bushfires, which aren't commented on. I suggest changing to 'can be identified'.

P15, Figure 6: I think you could add panels representing middle and high latitude bands to better represent the major stratospheric perturbations on a global scale (see specific comments above). Also, there's a significant feature around December 2010 that's not mentioned. This was probably due to the Merapi (7.54°S, 110.446°E) eruption in Indonesia in November 2010. Surono et al. (2012) estimate 0.44 Tg of SO2 in the upper troposphere and the plume reached heights of 16-17 km. Another feature that's not explained is the one around July 2015. It seems quite significant. Do you know what's causing it?

P16, Figure 7d: Please fix the cropping at the bottom of the figure - some text has been cropped.

P16L15-16: 'irregular shapes' - could this also be due to ice particles?

P17L6: 'smoke spreads globally' - I don't see this in the figure. It looks like the smoke spreads throughout the Northern Hemisphere but the Southern Hemisphere scattering ratio remains unchanged.

P17, Figure 8: What is the cause of the high scattering ratio from 25-30 km over the equator?

P17L17: Kelud erupted in February 2014 not April 2014 (see Kristiansen et al., 2015).

P18L1: 'The gradual lofting of the plume from around 17 km over the tropics to nearly 24 km over several months...'. This seems to imply a rise of 7 km, which I think is misleading. Measuring from the top of the aerosol feature it looks like it rises from 21 to 24 km from March-December 2014 (a rise of 3 km). Please clarify this in the text.

P19L7-9: The Calbuco volcanic cloud actually went almost directly through the SAA (see http://nicarnicaaviation.com/calbuco-eruption-april-2015). Eventually it spread through the Southern Hemisphere but due to the rejection of data in the SAA region a large proportion of the Calbuco signal may not be captured in the CALIPSO level 3 stratospheric aerosol product. I think this is worth mentioning here.

P20L18: Change 'essentially same' to 'essentially the same'.

P20, Equation (4): I got slightly confused here with the notation. What's the difference between $\alpha_p(r)$ (defined at P13L24) and $\sigma(z)_{CALIPSO}$? And which variable is the one that corresponds to the 'all aerosol' profile product?

P22, Figure 11 caption: 'the mean 532 nm extinction coefficient' is this what $\sigma(z)_{CALIPSO}$ is? In Eq. (4) the definition is the 'extinction coefficient at altitude z'. I would use the same wording to avoid confusion or put the symbols ($\sigma(z)_{CALIPSO}$ and $\sigma(z)_{SAGE}$) in parentheses in the figure caption.

P22L18: 'the presence of clouds which may impact the retrievals' - Please provide a little more information on how clouds impact the retrieval. If some clouds weren't removed, wouldn't this bias SAGE-III aerosol extinction high? Thus compensating for the difference seen in the comparison with CALIPSO below 20 km?

P22L23: Change '2.0' to '2'.

P22L24: On my first read through, I immediately thought the assumption of constant lidar ratio was the issue. You go on to discuss this but it's not mentioned here. Perhaps it's worth adding a sentence and referencing the discussion that comes later.

P23L15: Change 'Discussion:' to 'Discussion'.

P24L3-5: Change 'tropical latitudes' to 'tropical latitudes (30°S–30°N)'.

P24L5: Change 'higher latitudes' to 'higher latitudes and lower altitudes'.

P24L10: 'smoke, marine aerosols etc' - please list all the aerosol types considered by references cited.

P24, Eq. (5): In Eq. (3), the two-way particulate transmittance is range-dependent. I assume it would be range-dependent ($T_p^2(r)$) here too?

P25L16: 'substantially lower' - Could you put a number to this? E.g. what's the mean lidar ratio in the lowermost stratosphere? I think it is important to give a number or range given the discussion that follows.

P27L3: 'no significant injections of ash from volcanoes' - this is probably true, but there were significant injections of SO2 and therefore sulfate. For example, Ambae (Vanuatu) in April 2018 underwent a significant SO2-rich eruption (see specific comments above).

P27L12: Change 'volcanic eruptions' to 'volcanic eruptions and wildfires'.

P27L16: Change 'mid-to-high latitudes' to 'mid-to-high latitudes (30°S–60°S and 30°N–60°N)'

P27L16: Change 'high altitudes' to 'high altitudes (10–20 km)'

References

Global Volcanism Program, 2018. Report on Ambae (Vanuatu). In: Sennert, S K (ed.), Weekly Volcanic Activity Report, 4 April-10 April 2018. Smithsonian Institution and US Geological Survey.

Kristiansen, N. I., Prata, A. J., Stohl, A. and Carn, S. A.: Stratospheric volcanic ash emissions from the 13 February 2014 Kelut eruption, Geophysical Research Letters, 42(2), 588–596, doi:10.1002/2014GL062307, 2015.

Nicarnica Aviation, “Cabulco eruption, April 2015: AIRS Satellite Measurements," 24 April 2015; http://nicarnicaaviation.com/calbuco-eruption-april-2015.

Prata, A. T., Young, S. A., Siems, S. T. and Manton, M. J.: Lidar ratios of stratospheric volcanic ash and sulfate aerosols retrieved from CALIOP measurements, Atmospheric Chemistry and Physics, 17(13), 8599–8618, doi:10.5194/acp-17-8599-2017, 2017.

Surono, Jousset, P., Pallister, J., Boichu, M., Buongiorno, M. F., Budisantoso, A., Costa, F., Andreastuti, S., Prata, F., Schneider, D., Clarisse, L., Humaida, H., Sumarti, S., Bignami, C., Griswold, J., Carn, S., Oppenheimer, C. and Lavigne, F.: The 2010 explosive eruption of Java’s Merapi volcano—A ‘100-year’ event, Journal of Volcanology and Geothermal Research, 241–242, 121–135, doi:10.1016/j.jvolgeores.2012.06.018, 2012.

Vernier, J.-P., Fairlie, T. D., Murray, J. J., Tupper, A., Trepte, C., Winker, D., Pelon, J., Garnier, A., Jumelet, J., Pavolonis, M., Omar, A. H. and Powell, K. A.: An Advanced System to Monitor the 3D Structure of Diffuse Volcanic Ash Clouds, Journal of Applied Meteorology and Climatology, 52(9), 2125–2138, doi:10.1175/JAMC-D-12-0279.1, 2013.

Winker, D. M., Liu, Z., Omar, A., Tackett, J. and Fairlie, D.: CALIOP observations of the transport of ash from the Eyjafjallajökull volcano in April 2010, Journal of Geophysical Research: Atmospheres, 117(D20), doi:10.1029/2011JD016499, 2012.

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