Stratospheric Aerosol Particle Size Explains Divergent Limb and Solar Occultation Measurements After the Hunga Eruption

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Hunga Eruption

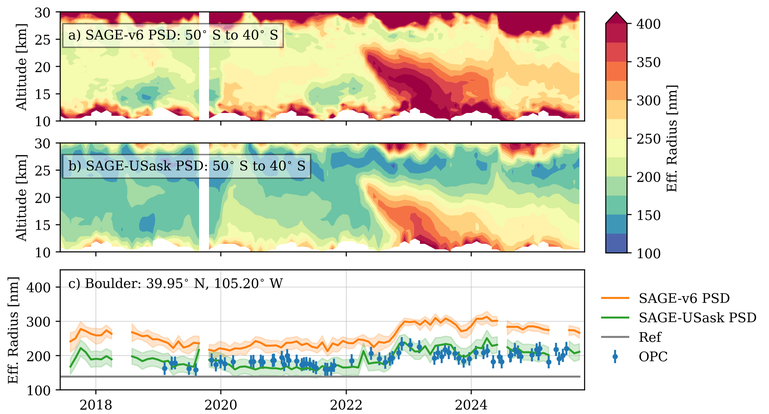
The 2022 Hunga eruption resulted in a massive unprecedented injection of water vapour into the stratosphere, and showed a large increase in stratospheric aerosol optical depth (AOD). Measurements of aerosol extinction after the Hunga eruption show large levels of disagreement between different instruments including:

- **SAGE III/ISS**, a solar occultation instrument onboard the International Space Station that provides high resolution measurements with wide latitudinal coverage.
- **OMPS-LP**, a limb scattering instrument that provides near-global daily coverage.
- **OSIRIS**, a limb scattering instrument that provides measurements with a spectral resolution of 1 nm.

Particle size

Comparisons are shown between three datasets containing aerosol particle size distribution information:

- **SAGE III/ISS version 6.0** ("SAGE-v6 PSD"), which retrieves profiles of median radius and width for a single mode log-normal size distribution from SAGE III/ISS data.
- **"SAGE-USask PSD"**, an alternate SAGE III/ISS retrieval developed by the University of Saskatchewan.
- In-situ measurements of particle size using **Optical Particle Counters** (OPCs) as part of the Balloon Baseline Stratospheric Aerosol Profiles project.



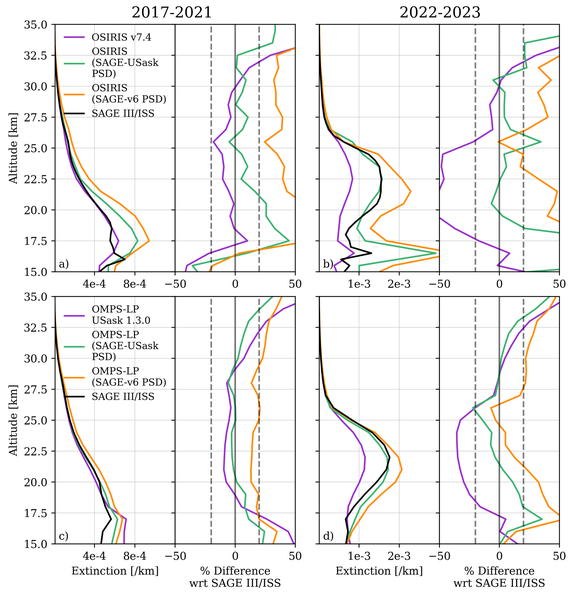
The OPC effective radius has similar variability and is generally quite close in magnitude to the SAGE-USask PSD, while the SAGE-v6 PSD is systematically higher than the other datasets.

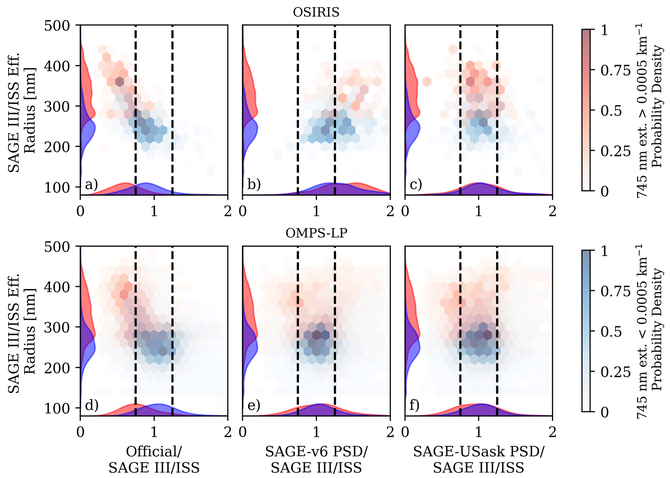
Limb scatter retrieval method

It is theorized that the differences in retrieved extinctions from the Hunga period are due to assumptions made about particle size. To explore this, a retrieval algorithm is used that explicitly sets the particle size distribution parameters to those derived from coincident SAGE III/ISS aerosol extinction spectra. This was done for both the OSIRIS and OMPS-LP USask retrieval codes, resulting in six cases to compare against the **SAGE III/ISS** occultation data:

- The **official OSIRIS v7.4** retrieval (80 nm and 1.6 lognormal distribution)
- The modified **OSIRIS** retrieval using the **SAGE-USask** PSD parameters
- The modified **OSIRIS** retrieval using the **SAGE-v6** PSD parameters
- The **official OMPS-LP USask 1.3.0** retrieval (80 nm and 1.6 lognormal distribution)
- The modified **OMPS-LP** retrieval using the **SAGE-USask** PSD parameters
- The modified **OMPS-LP** retrieval using the **SAGE-v6** PSD parameters

Results





Aerosol extinction

The four paneled figure in the previous column shows the results of these modified retrievals, separated by instrument and into pre- and post-Hunga time periods. Taking the SAGE III/ISS extinction profile to be the bias-free measurement for comparison, it can be seen that:

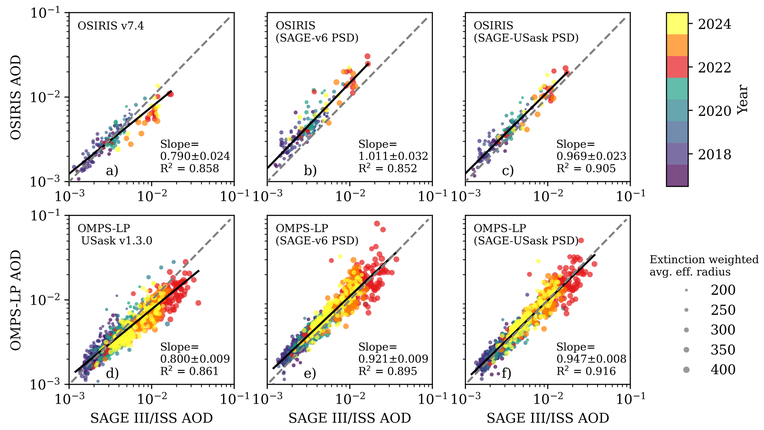
- In the pre-Hunga period (2017-2021), the SAGE-USask PSD retrievals and official products have comparable agreement with SAGE III/ISS.
- The largest increases in aerosol extinction after the Hunga eruption appear in the 18-25 km altitude range, and is also where the most difference between the different retrieval methods is observed.
- In the post-Hunga period, the low bias is dramatically affected by the changed particle size parameters, and is best corrected with the retrieval using SAGE-USask PSD.

The six paneled figure takes the data in the 18-25 km range post-Hunga, and shows the extinctions ratios of the instrument retrieved extinctions to the SAGE III/ISS extinctions as a function of effective radius. Points in blue indicate low extinction values, while points in red indicate high extinction values, showing that:

- Lower extinction values have reasonable agreement between data products.
- Higher extinction values generally correspond to larger effective radii, which drive the low bias.

Aerosol Optical Depth

The following figure shows the AOD from each of the instrument retrievals compared to that from SAGE III/ISS.



- Larger biases occur in the official retrievals at high AOD values.
- Both retrievals with injected particle sizes significantly improve the dependence of AOD bias on extinction.
- The best correlations come from cases using the USask PSD values.

Conclusions

- An alternative particle size data set using the SAGE III/ISS extinction spectra was developed by the University of Saskatchewan, which shows good agreement with OPC measurements and SAGE III/ISS occultation measurements.
- Using these particle size parameters in OSIRIS and OMPS-LP retrievals produced results more consistent with SAGE III/ISS than previously seen.
- Disagreement in limb scatter and solar occultation data records from the 2022 Hunga eruption can be attributed primarily to differences in particle size assumptions.