Revisiting GloSSAC using Space based Measurements

Mahesh Kovilakam[1,2] **(mahesh.kovilakam@nasa.gov), Larry Thomason** [2] **(l.w.thomason@nasa.gov), and Travis Knepp**[2] **(travis.n.knepp@nasa.gov),**

[1]SSAI, Hampton, [2]NASA Langley Research Center, Hampton, VA 23681

1. Introduction

We revisit Global Space-based stratospheric aerosol climatology (GloSSAC) and extend the dataset through 2021 in the latest version (version 2.2). Several space-based measurements have been used to construct GloSSAC. For version 2.2, important changes include implementation of a revised aerosol/cloud categorization for The Stratospheric Aerosol and Gas Experiment (SAGE III/ISS). SAGE III/ISS began its mission in June 2017. While SAGEIII/ISS makes reliable and robust solar occultation measurements in stratosphere–similar to its predecessors, interpreting aerosol extinction measurements in the vicinity of tropopause and in the troposphere have been a challenge for all SAGE measurements. Here, we study the challenges associated with the discrimination of aerosols and clouds from the extinction measurements. Here, we describe the methods implemented to categorize Clouds and aerosols using available SAGEIII/ISS aerosol measurements. The current algorithm now classifies standard (background) and non-standard (enhanced) aerosols in the stratosphere and identify enhanced aerosols and aerosol/cloud mixture in the tropopause region. Extinction coefficient measurements from SAGE series of observations make an important contribution in the GloSSAC data base and therefore, the impact of cloud-filtered aerosol extinction coefficient measurements on the latest version of GloSSAC (version 2.2) is also discussed. Additionally, we discuss minor version changes occurred in other space-based measurements that include Optical Spectrograph and InfraRed Imaging System(OSIRIS) and Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation(CALIPSO). We also plan on evaluating and using aerosol extinction profiles from other satellite data sets such as Ozone Mapping Profiler Suite (OMPS) in a future version.

2. SAGE III/ISS Aerosol Cloud Categorization

- Cloud screening algorithm is developed based on a method proposed by *[Thomason and Vernier, 2013]* (hereafter TV13). TV13 is modified to account for frequent volcanic/PyroCb events during SAGE III/ISS.
- Initial screening to check the quality of extinction profiles is done before cloud screening algorithm. A sample profile below shows how the initial screening affects the extinction profile.

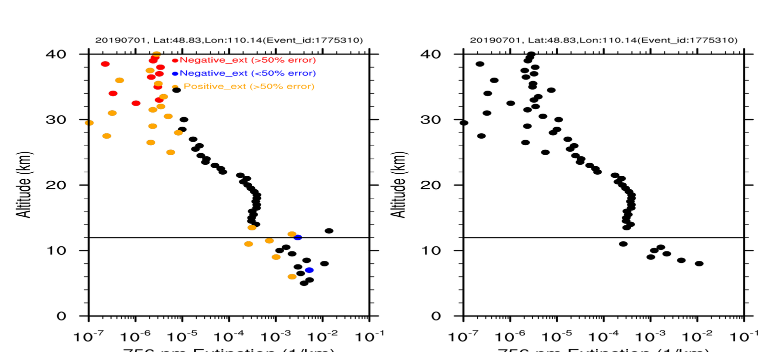

Figure 1: *A sample extinction profile at 756 nm that shows how negative extinction values in the lower stratosphere as well as in the troposphere (Left). The right panel shows the extinction profile after filtering negative values. Red (blue) symbols in the left panel shows absolute values of negative extinction with uncertainty* $>$ *50% (* $<$ *50%) respectively, while orange symbols represent positive extinction with* $>$ *50% uncertainty.*

- We use a wavelength combination of 756 and 1544 nm in all our analysis here.
- Several volcanic and PyroCb events occurred during SAGE III/ISS measurements, which are listed below.

Table 1: *Volcanic and PyroCb events used in this study*

Event Name	Event Date	Latitude
Canadian Wildfire (Cw)	17 July 2017	51^0N
Ambae Eruption (Am)	28 July 2018	15^0S
Ulawun Eruption (Ul)	22 June 2019	5^0S
Raikoke Eruption (Ra)	03 August 2019	48^0N
Australian Wildfire (Aw)	06 January 2020	34^0S
California Creek Fire (Cc)	01 September 2020	37^0N
La Soufriere (La)	22 April 2021	13^0N
McKay Creek Fire (Mc)	29 June 2021	54^0N
Hunga Tonga Eruption (Ht)	15 January 2022	20^0S

- Median absolute deviation statistics (k_0 = k_a + 3.5*MAD, where k_a is the median extinction coefficient of the distribution and MAD is the median absolute deviation) is used to identify enhanced extinction values.
- Based on k_0 time series, the extent of volcanic/PyroCb influence on the data is determined.

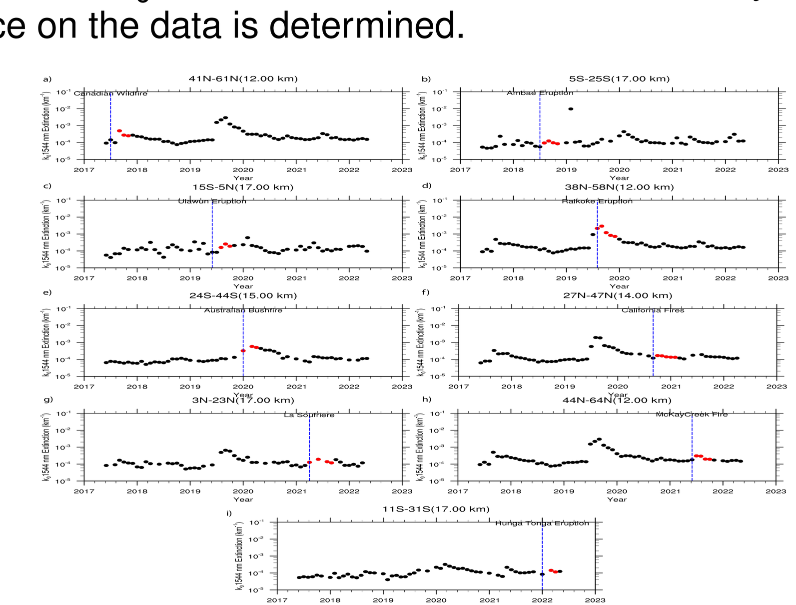

Figure 2: *Time series of k_0 1544 nm extinction for different latitude bands. Red symbols show the time line of enhanced aerosol extinction coefficient and the time it takes to get back to the background aerosol level following each event. The panels show events listed in Table 1.*

- Inter-hemispheric differences in the extinction coefficient data following volcanic/PyroCb event.

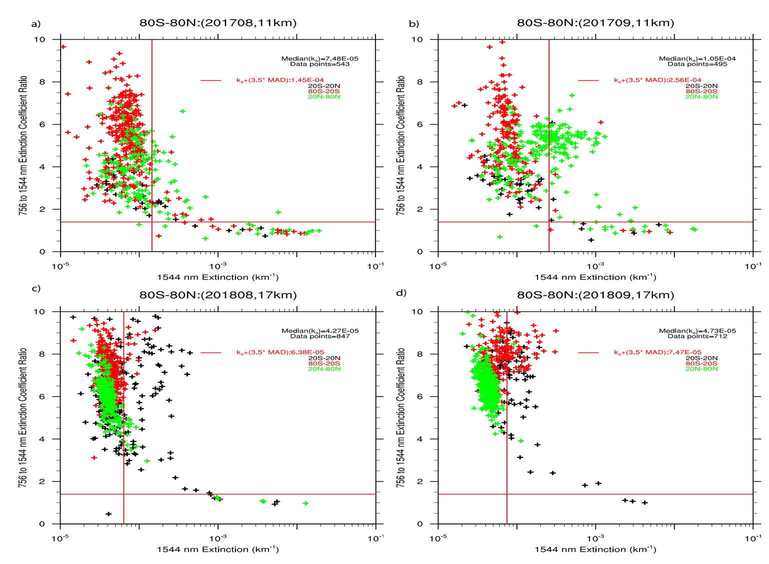

Figure 3: *Scatter plots of 756 to 1544 nm extinction ratio versus 1544 nm extinction following Canadian Wildfire event in 201708 and Ambae eruption in 201807.*

- Monthly data is divided into two latitude bands (80S-20N, 20N- 80N). Due to lack of tropical data for the statistical analyses, we decided to add tropical latitude band (20S-20N) to the southern hemispheric latitude band (80S-20S).
- We use different flags for Standard (background), Perturbed, Enhanced Aerosol/Tropopause cloud, and Aerosol/Cloud mixture.

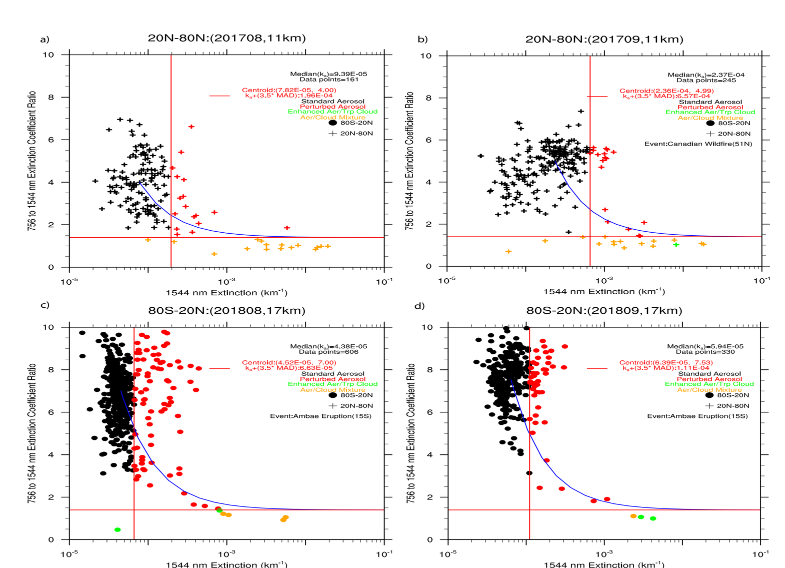

Figure 4: *Scatter plots of 756 to 1544 nm extinction ratio versus 1544 nm extinction following Canadian Wildfire event in 201708 (a,b) and Ambae eruption in 201807 (c,d), after applying cloud/aerosol categorization.*

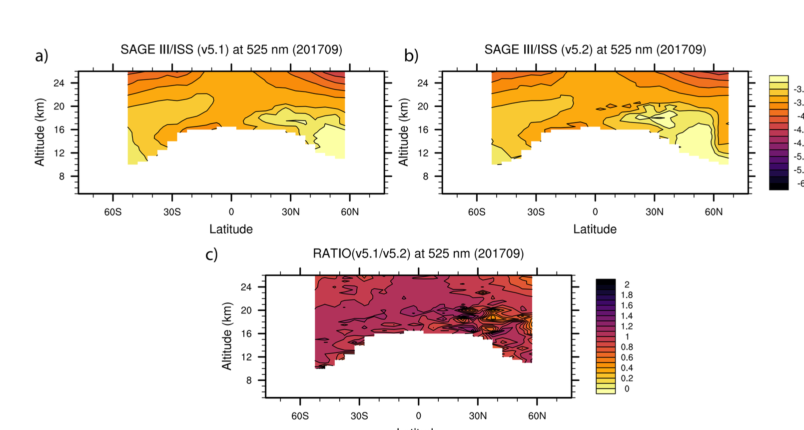

Figure 5: *Zonally averaged SAGE III/ISS altitude versus latitude extinction coefficient plot for September 2017 following Canadian wildfire event. (a) version 5.1 (b) for version 5.2 and (c) ratio between version 5.2 and 5.1. Extinction coefficient values are shown in the log base to the 10.*

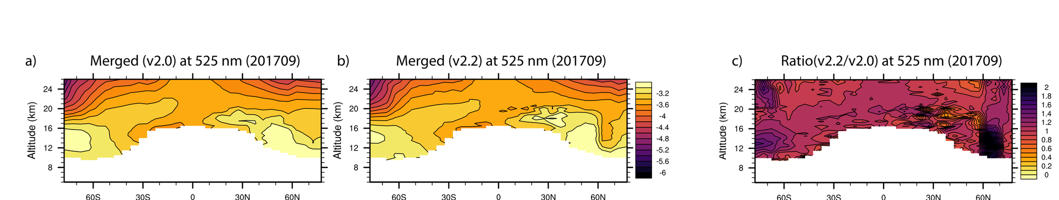

Figure 6: *Altitude versus latitude dependence of 525 nm extinction for September 2017 and August 2018. (a) for GloSSAC version 2.0, (b) for GloSSAC version 2.2, and (c) ratio between version 2.2 and 2.0.*

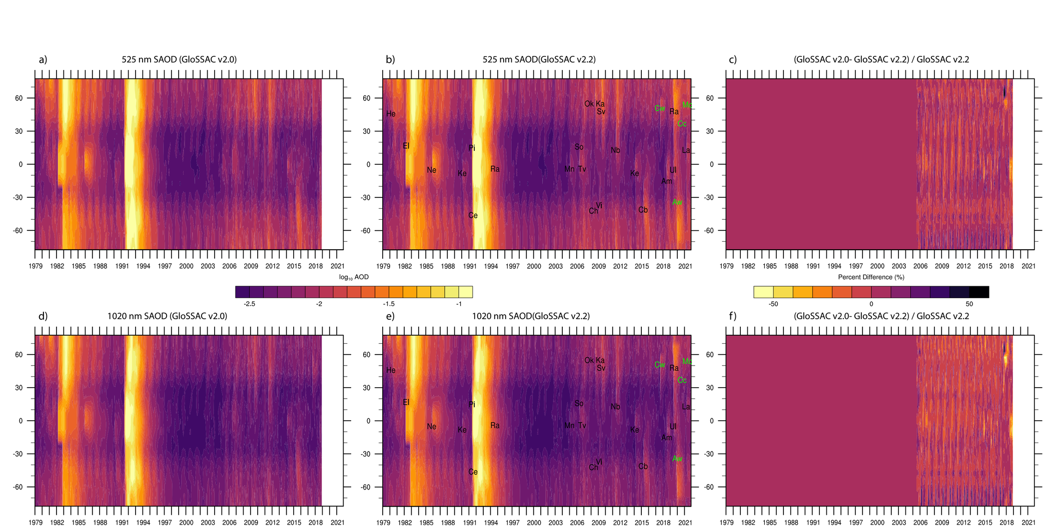

Figure 7: *Latitude versus time dependence of SAOD for 525 and 1020 nm. (a,b,c) SAOD for 525 nm for GloSSAC version 2.0, version 2.2, and percent difference between (a) and (b). (d,e,f) Same as in (a,b,c) but for 1020 nm. (b, e) show major volcanic eruptions (black) and wild fire events (green) with abbreviated two letter code with their respective latitude and time of occurrence that are listed here. The event names shown in figures are: St. Helens (He), El Chichon (El), Nevado del Ruiz (Ne), Kelut (Ke), Pinatubo (Pi), Mt. Hudson (Ce),Rabaul (Ra), Manam (Mn), Soufriere Hills (So), Tavurvur (Tv), Chaiten (Ch), Okmok (Ok), Kasatochi (Ka), Sarychev (Sv), Nabro (Nb), Kelut (Ke), Calbuco (Cb), Canadian Wildfires (Cw), Ambae (Am), Ulawun (Ul), Australian Wildfire (Aw), California Creek Fire (Cc), La Soufriere (La), McKay Creek Fire (Mc).*

3. OMPS Aerosol Extinction Measurements

- OMPS version 2.1 extinction coefficient (Taha et al., 2021) is compared against SAGE III/ISS (v 5.2), OSIRIS(v 7.2) and OMPS-SASK (v 1.2 developed by University of Saskatchewan group) for possible inclusion into GloSSAC data set.

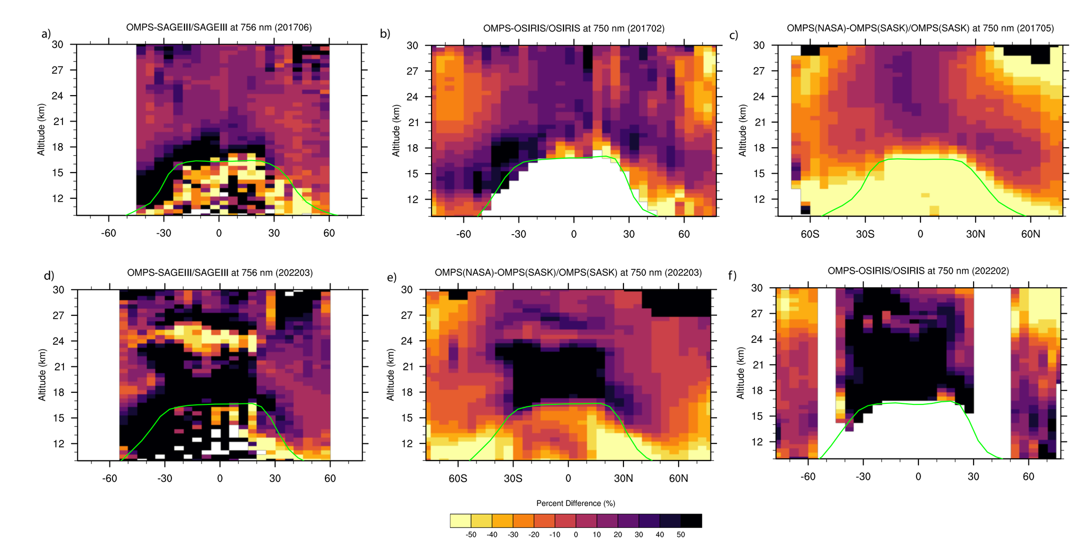

Figure 8: *Altitude versus Latitude percent difference of extinction coefficient for relatively unperturbed stratosphere (a-c) and following Hunga Tonga volcanic eruption (d-f). Percent difference of extinction coefficients between OMPS-NASA (745 nm) and (a) SAGE III/ISS (756 nm), (b) OSIRIS (750 nm) , and (c) OMPS-SASK (750 nm) . (d-f) same as in (a-c) but showing differences following Hunga Tonga volcanic eruption. Green line shows the tropopause height.*

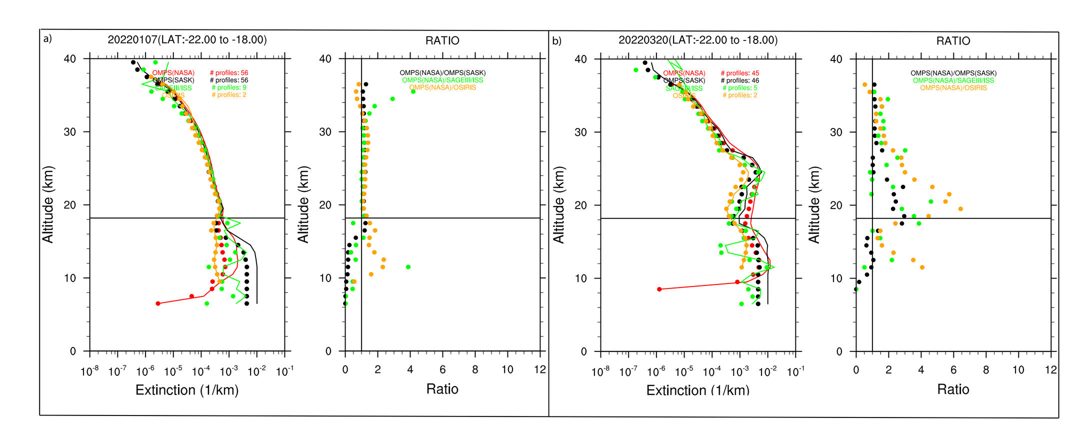

Figure 9: *Daily zonally averaged extinction coefficient profiles of SAGE III/ISS (756 nm) and OMPS-NASA (745 nm), OMPS-SASK (750 nm) and OSIRIS (750 nm) for the latitude band between 22^0S and 18^0S for (a) pre-eruption (7 January 2022) and (b) post-eruption (20 March 2022) respectively. Averaged profiles are shown as red filled circles (OMPS-NASA), green filled circles (SAGE III/ISS), black filled circles (OMPS-SASK) and orange filled circles (OSIRIS), whereas the respective solid lines represent average plus 1 standard deviation. The ratio plot shows OMPS-NASA to OMPS-SASK (black filled circles), OMPS-NASA to SAGE III/ISS (green filled circles) , and OMPS-NASA to OSIRIS (orange filled circles) Horizontal solid line is the averaged tropopause altitude, whereas vertical solid line in the ratio plot represents the ratio of 1.*

4. Summary and Conclusions

- Revised SAGE III/ISS cloud screening algorithm work reasonably well for the periods during and following perturbed events.
- The revised version is incorporated into the latest GloSSAC (v 2.2). Results show an enhancement in extinction coefficient in the lower stratospheric data following such events when compared against v 2.0 of GloSSAC. The difference between v 2.0 and 2.2 of GloSSAC is attributable to version differences of individual data sets, and improved cloud screening of SAGE III/ISS data.
- OMPS-NASA data is studied for possible inclusion into the GloSSAC data set. While the agreement between OMPS and other available space based measurements (SAGE III/ISS, OSIRIS, and OMPS-SASK) is reasonably good during benign situations, we note large differences during perturbed conditions (smoke and volcanic) often in excess of a factor of two.

6. Acknowledgements

We thank OSIRIS science team for providing us with level 2 of OSIRIS and version 1.2 of OMPS-SASK data. We also thank SAGEII and SAGEIII/ISS team for the SAGE measurements.

7. References

- Kovilakam, M., Thomason, L. W., Ernest, N., Rieger, L., Bourassa, A., and Millan, L.: The Global Space-based Stratospheric Aerosol Climatology (version 2.0): 1979?2018, Earth Syst. Sci. Data, 12, 2607?2634, https://doi.org/10.5194/essd-12-2607-2020, 2020.
- Taha, G., Loughman, R., Zhu, T., Thomason, L., Kar, J., Rieger, L., and Bourassa, A.: OMPS LP Version 2.0 multi-wavelength aerosol extinction coefficient retrieval algorithm, Atmos. Meas. Tech., 14, 1015?1036, https://doi.org/10.5194/amt-14-1015-2021, 2021.
- Thomason, L. W., and J.-P. Vernier (2013), Improved sage II cloud/aerosol categorization and observations of the asian tropopause aerosol layer: 1989?2005, Atmos. Chem. Phys., 13 (9), 4605? 4616, doi:10.5194/acp-13-4605-2013.