Stratospheric Aerosol Data Set (SADS Version 2) Prospectus

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Basic description of the contents of the final data product

The stratospheric aerosol data set (SADS) that we propose will strongly mimic the product that was produced for CCMI a few years ago (and now referenced as SADS Version 1). That data set spanned the period 1960 to 2010 and was broken into essentially 3 time periods for what is essentially an aerosol extinction record that is unified through the use of the ETH 4-λ aerosol derived product methodology. The first period consisted of a model-based representation for the period for 1960 through 1978; in the new version this will be extended to span 1850 to 1978. Optical depths will *mostly* follow those in the GISS stratospheric aerosol optical depth record. The second period is the early space-based record that in Version 1 primarily relied on the SAM II/SAGE series of instruments and built on the 'gap-free' data set produced as a part of ASAP (SPARC, 2006). This data set also used some airborne lidar data from the 1981 to 1984 period and lidar data from Mauna Loa, USA and Camaguey, Cuba in the post-Pinatubo period June 1991 through 1993. In the latter period, SAGE II data in the lower stratospheric is missing entirely or in part (depending on latitude and date within this period). In the new version, we will incorporate CLAES and HALOE aerosol data in the 1991 to 1995 period to reduce the influence of missing data. This will be somewhat empirical since these data sets are not entirely consistent with the SAGE II observations and some scaling is required to prevent discontinuities. The third period spans from the end of the SAGE II mission in August 2005 to the present and Version 1 was primarily dependent on CALIPSO. In the new version, we will attempt to incorporate data from GOMOS and OSIRIS. Some effort to make the transition and qualitative features of this portion of the data set fit in well with the SAGE-based portion of the record. We recognize that there is a requirement for producing both the data set and a supporting publication by the end of 2015. We expect to complete our work on time following this approximate schedule:

- January to July, create new base data sets
- August-September, create ETH extended data sets
- October-December, QA on the data products and write supporting manuscript

Critiques of Version 1 would be helpful at an early stage would be helpful and appreciated.

Some further details and changes from SADS Version 1

Spatial/temporal resolution

While there was some variability in the data set we produced for Version 1, we propose to create a uniform spatial-temporal data set for the updated version. This will be monthly, 5 degree latitude, 0.5 km bins for the entire period. Clearly, not all of the datasets are conducive to this resolution and significant interpolation will be required. Documentation produced at the end of the development will indicate the native resolution for each data set employed as well as the methodology used in expanding it to fit the uniform grid. The nearly 2000 monthly grids will span 80S to 80N and 5.0 to 40.0 km though the fraction of this grid that has data in it will be highly variable. At a minimum, we expect to fill all grid boxes between the tropopause and 30 km.

Data parameters

At a minimum, in all grid boxes the native measurements whatever the source will be included in the data set, for some parameters like CLAES IR extinction, they are converted to extinction at another wavelength which will likewise be retained. Detailed flagging will indicate the source of the data and whether it is interpolated from adjacent temporal points. Data will be reported for all times and periods from the tropopause (or lower) upward to where the data is no longer considered robust. In most circumstances this will mean that little data will be available above 30 km except following major volcanic events particularly the June 1991 eruption of Pinatubo where useful data extends as high as 35 km. Bulk data parameters will be reported in the gird including any native data source (such as the SAGE II 2008 approach) and the 4-λ method including all (size distribution) parameters necessary to produce other aerosol properties. It should be noted that all approaches assume sulfate-only aerosol and any departure from this will not be reflected in the analyses. Most polar stratospheric clouds will be removed but it is likely that some influence from STS PSCs will remain in the data set.

Every effort to produce a gap free data product will be made for the entire period. However, the base measurements from which aerosol size distribution parameters are derived will only be filled in as much as they are necessary to producing the bulk aerosol product parameters. Given that many periods will have minimal data from which to infer these parameters, the inferences of aerosol parameters will be made from statistical correlations derived from periods in which sufficient measurements are available to derive them. At this junction, this is solely the SAGE II period. While we recognize the limitations of indirect inferences of bulk properties based on SAGE II, we don't see any viable alternative to proceeding along this course. Recent comparisons with The University of Wyoming OPC suggests that the 2008 approach is in much better agreement than earlier approaches. Aerosol radiative input data sets that were produced for some models in the Version 1 (extinction, single scattering albedo and asymmetry factor for model-dependent spectral bands) may be produced request based on the Version 2 analyses.

Files were produced in ASCII in the last version but can easily be saved in IDL save files if that is desired. If other formats (e.g., netCDF) are desired, it should be requested as soon as possible by CCMI and we will attempt to accommodate a single additional format.

Standard data products: Aerosol extinction at 525 and 1020 nm, surface area density, volume density, mass density, and size distribution parameters (native, as available, and 4-λ). Given current interests, sulfur mass may be included as well.

Description of changes to the data product

Pre SAGE (1850-1978)

With the exception of adopting the uniform gridding and the expansion of the data set to match the standard grid this product will be produced in the same manner as for Version 1. The period will also be extended back to 1850.

SAGE Era (1979-2005)

The analysis in the 1979 to 1984 period will remain essentially unchanged except the grid will be expanded to 0.5-km vertical resolution from the 1-km resolution in the previous version. For 1979 to

1981, the data used in primarily SAGE I 1000-nm data with SAM II 1000-nm data at high latitudes (NH and SH). Between 1982 and the start of the SAGE II mission, the analysis is primarily dependent on SAM II data at high latitudes, LaRC 48-inch lidar data in northern mid-latitudes, and a series of NASA airborne lidar missions between 1981 and 1984.

For the SAGE II product will be produced in a manner consistent with earlier versions. Some changes have been made to improve quality at high latitudes and in the immediate aftermath of the Pinatubo eruption. In particular, CLAES data is used between October 1991 and the end of its mission in April 1983. This data is qualitatively consistent with SAGE II data but requires some scaling to produce compatible data for this analysis. Its inclusion in the October 1991 to the end of 1992 changes the tropical analysis substantially (much more aerosol near 20 km). HALOE has a lesser impact but is 'value added' for a few years following the eruption once the data has been treated using the process suggested in Thomason (2012). The period between the eruption in mid-June until October remains a period in which filling the grid is as much a matter of 'art' as science as observations to fill the low latitudes in particularly are scarce and the inhomogeneity of the aerosol field are so high that it is difficult to imagine ever producing a meaningful monthly mean grid. Since there are NO low latitude SAGE II measurements in June. ***We propose to essentially move the eruption data from mid-June (where the grid is an interpolation of May to July observations supplemented with some subtropical lidar data) to July 1 where far more observations are available***. The period for July to September remains a work in progress but it will be a challenge to produce something substantially more meaningful than what we have produced in the past given the dearth of data and the highly stratified nature of the aerosol layers in this period (e.g., see the figure appended below).

A solution for a long standing issue of how to produce meaningful analyses at high latitudes in winter has been developed. The method assumes that aerosol properties are reasonably homogeneous on an equivalent latitude. Aerosol statistics are compiled in an equivalent latitude/time grid (as the function $k(q_e,z,t)$). This has been done before including as a part of CCMI Version 1 and is straightforward. Since SAGE II uses MERRA data meteorological data, this will be used throughout this analysis. Using the full MERRA product (not just that associated with SAGE II observations) the density of equivalent latitudes as a function of latitude for winter hemispheres is computed as the function is $p(q|q_e,z,t)$. This would be like for latitudes of 60 to 65N, 8% of the time the equivalent latitude is between 50 and 55N, 17% of the time it is between 55 and 60N, 43% of the time it is between 60 and 65N, and so on. The reconstructed distribution of aerosol properties on a latitude grid, k', is computed using $k'(q_{j,},z,t) = \Sigma k(q_{je},z,t)$ $p(q_j|q_{ei},z,t)$ where the j subscript is for latitude bin 'j', and the 'i' subscript is for equivalent latitude bin i. Gloria Manney has agreed to help produce values for the p function. We expect substantially better high latitude data fields.

Post SAGE (2005-2014)

We expect the post-SAGE 2005-2014 period to be heavily to be constructed primarily from a combination of space-based observations by CALIPSO, GOMOS, and OSIRIS. These instruments employ fundamentally different measurement techniques than solar occultation (e.g., SAGE) and even between each other. Therefore maintaining data continuity will be a challenge for Version 2. In Version 1, this period was primarily filled with empirically-scaled CALIPSO data. Recently, there has been a successful effort to combine SAGE II, GOMOS and CALIPSO to construct a stratospheric aerosol optical depth dataset during the period 1984-2014 (Vernier et al., 2011). Results showed that the overlapping satellite data correlated well after stratospheric aerosol enhancement following several small volcanic eruptions (e.g. Manam in 2005 Soufriere Hills in 2006), which strongly suggests that these datasets are coherent with each other. In order to improve the continuity of a composite aerosol record, an empirical scaling technique to facilitate the construction of a long-term stratospheric aerosol optical depth record. This dataset was used in several simulations to include the climate impacts of small volcanic eruptions since the mid-2000's (Solomon et al., 2011, Fyfe et al., 2012) and identify the signals of those eruptions on climate variables (Santer et al., 2013,2014). For SADS Version 2, we plan to build on this effort also incorporate data from OSIRIS (Bourassa et al.,2012; Landon et al., 2015). And we expect a smoother transition from the SAGE period and generally superior aerosol data set for this time period compared to version 1.

Recommendations for 'background' aerosol

We will produce a recommended background aerosol annual cycles if this is desired. This would most likely be based on detrended 1999 to 2001 composite.

The ETH additions to the above data sets

No changes to the methodology to produce aerosol size parameters (ETH 4-λ) are anticipated. Some changes can be expected due to changes in the input files. At the end of this process, new QA will be performed to ensure that the final product is robust and that we have minimized anomalies in the final products. Aerosol radiative properties such as extinction, single scattering albedo and asymmetry factor parameters for model-dependent spectral bands, will be produced on a by-request basis as for Version 2.

Airborne lidar data from July 1991 (Winker et al., 1991)

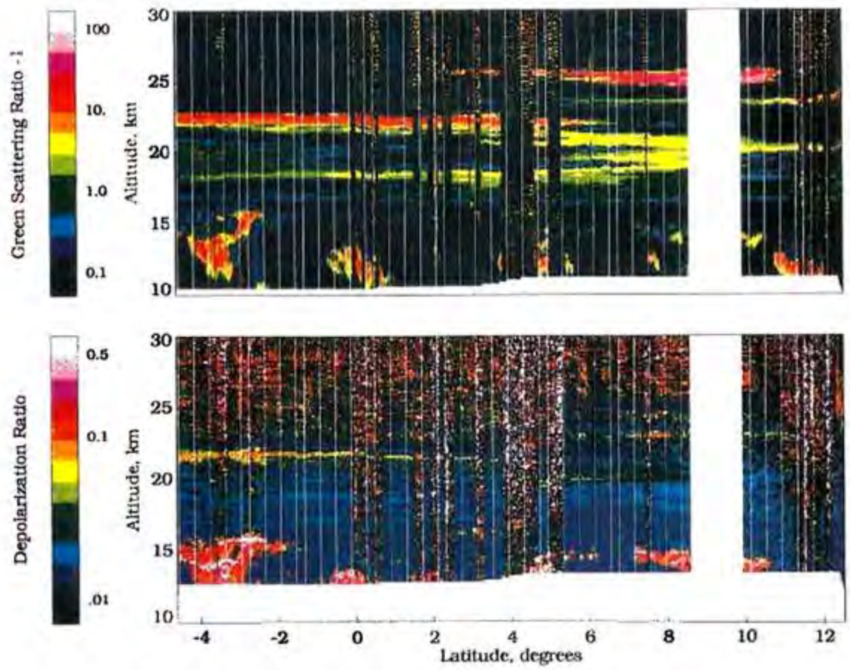


Fig. 2. Lidar observations of R-1 and depolarization from 4.5°S to 12.5°N on July 12-13, 1991.

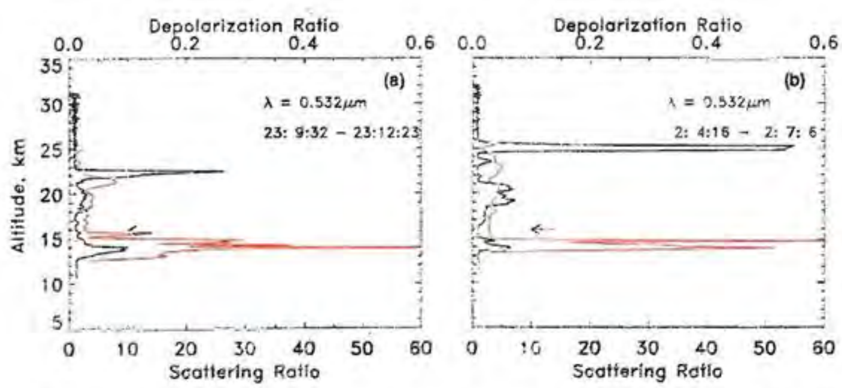
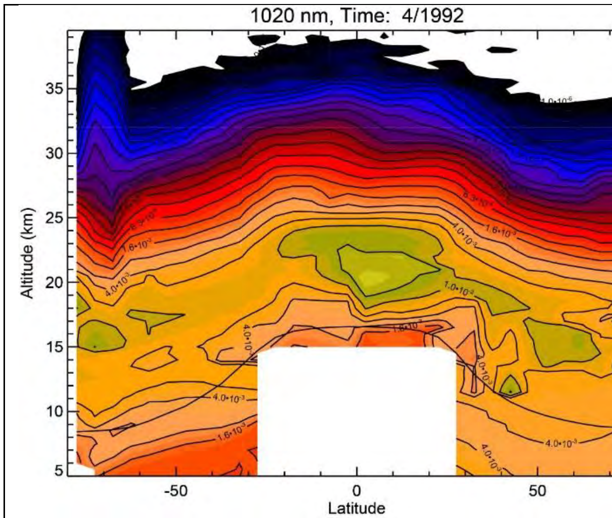
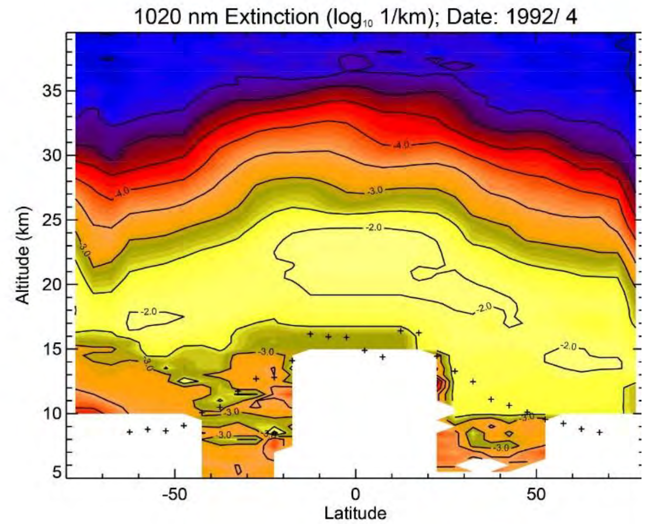


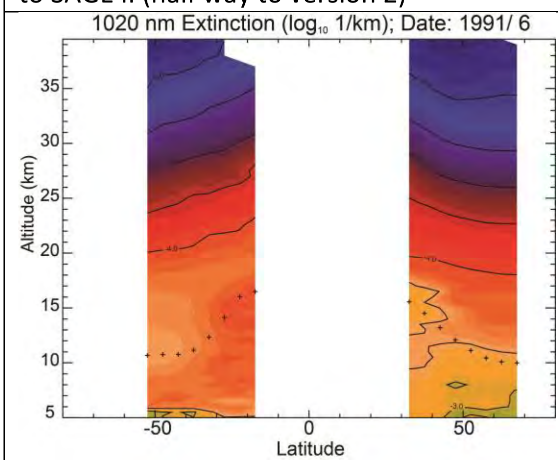
Fig. 3. Profiles of scattering ratio (black) and depolarization (red) from July 12-13 at (a) 4.2°S, 53.6°W; (b) 8.5°N, 55.6°W.



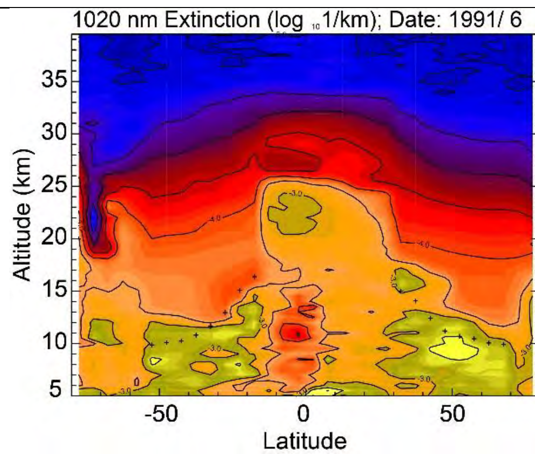
Version 1 with CLAES/HALOE data in addition to SAGE II (half way to version 2)



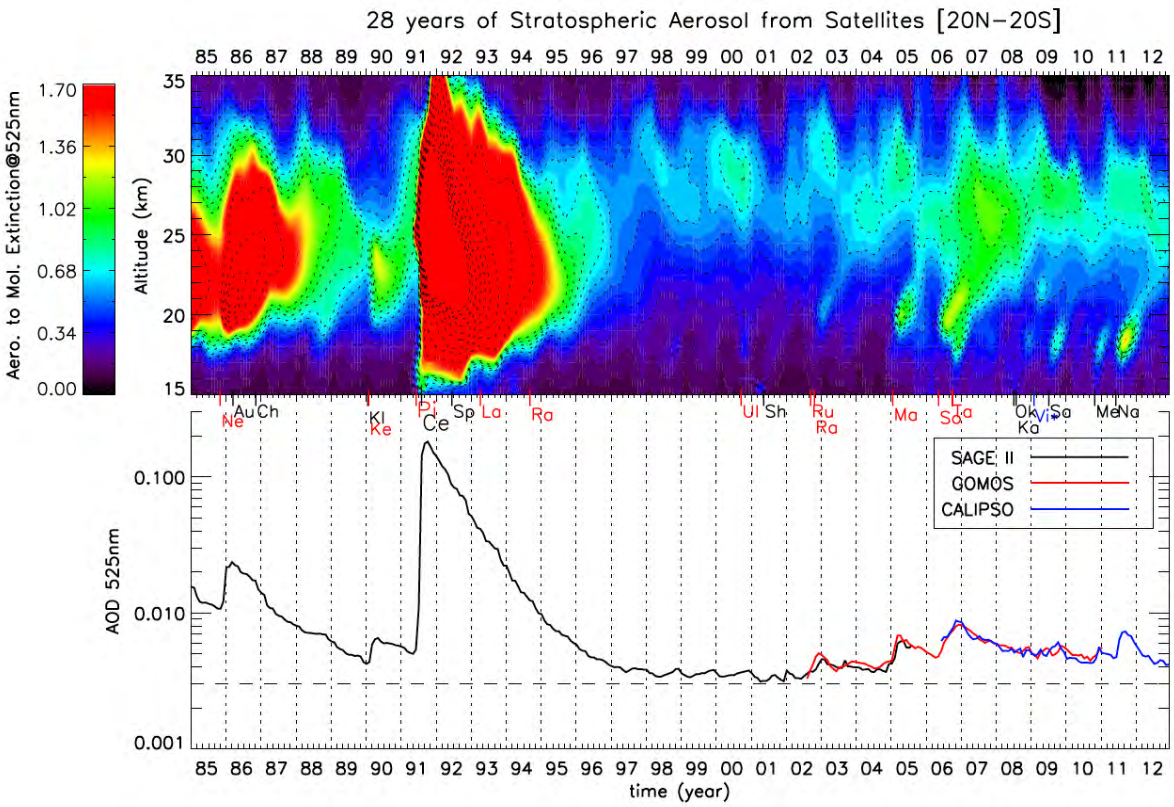
Version 1 analysis



SAGE II data in June 1991 with No Interpolation or Filling



Version 1



28 years of Stratospheric Aerosol from Satellites [20N–20S]
Aero. to Mol. Extinction@525nm
1.70
1.36
1.02
0.68
0.34
0.00
Altitude (km)
35
30
25
20
15
85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12
Ne Au Ch Kl Ke Pi Ce Sp La Ra Ul Sh Ru Ra Ma So Ta Ok Ka Vi Sa Me Na
SAGE II
GOMOS
CALIPSO
AOD 525nm
0.100
0.010
0.001
time (year)