SAGE II V7.00 Release Notes

The series of Stratospheric Aerosol and Gas Experiments (SAGE I, II, and III) are satellite-based solar occultation instruments spanning over 26 years that have been a cornerstone in studies of stratospheric change and have played a key role in numerous international assessments. Given the importance of the data, it is imperative that the data sets, and the processing codes that produce them, be maintained and, when necessary, updated and improved upon. In addition, it is extremely useful to maintain consistency in processing methodology (when applicable) and fundamental assumptions made for data reduction between the three instruments. For this reason, we have begun the implementation of a consistent algorithm across SAGE missions, adopting the best algorithms and data sources from all previous SAGE versions. Hence forth, the algorithm through which SAGE data is processed will be indicated by the integer version number, while subsequent changes that are instrument specific will be indicated by the decimal part of the version number. The first release in this series, the version 7 series, is SAGE II v7.00 and is described here.

The following list of data sources or algorithm changes were made for version 7.00:

- Adopted cross-section databases from the (2003) Bogumil/Bremen (SCIAMACHY) O_3 and NO_2 temperature-dependent cross-sections, which were used in SAGE III v4.00
- Adopted the meteorological data MERRA for consistent data to higher altitudes over the lifetime of all SAGE instruments
- Replaced the use of Twomey-Chahine with a simple onion-peeling technique for inversion of slant-path optical depths
- Adopted the EOS Toolkit routines for ephemeris calculations for more consistent pointing information
- Adopted a number of new transmission algorithms from SAGE III v4.00
- Ceased removal of the water vapor extinction in the 600nm channel due to uncertainty in the H_2O spectroscopy in this spectral band
- Updated our estimation of the SAGE II water vapor channel filter location drift resulting in better agreement with more modern datasets (i.e. MLS and SAGE III versus HALOE)
- Fixed various bugs

The MERRA met data reduces the neutral density at the higher altitude reducing the extinction contributions from Rayleigh scattering.

The EOS Toolkit corrects a long standing error in the solar ephemeris which resulted in a quasi-random error in the altitude registration of individual occultation events. This error could be as large as a couple of hundred meters.

Twomey-Chahine was found to have several of undesirable behaviors. It would not allow negative values and therefore introduced a positive bias in regions of the density (extinction) profile where the signal to noise ratio was small, typically at the higher altitude end of the retrieved profile. It also systematically approached the solution from one direction and stopped once the tolerance criterion was met, producing another form of bias as a result. Lastly, its use introduced discontinuities in the profile when the slant path extinction fell below a preset value and vertical smoothing was activated.

One of the several transmission algorithm changes resulted in the slant path extinction profiles having a uniform 1km vertical resolution. Previous version tended towards higher vertical resolution and created the possibility of aliasing effects in the 0.5km gridded data. This 1km resolution is now consistent with the 0.5km gridding of the retrieved species profiles.

Over the long 21-year mission, the spacecraft experienced episodic anomalies in the power system. These anomalies are usually followed by a period where the occultation events are of limited duration. These so called short events may have an insufficient number of exoatmospheric scans of the solar disk precluding an accurate determination of the solar limb darkening curve and the scan mirror relative reflectivity. In version 7.00, these events, 4900 in all, are now dropped and the user no longer needs to filter these out. Approximately 150 events that did not complete processing in earlier versions are now being successfully processed. The net result is that there are actually more usable profiles in v7.00 than in previous versions.

Species specific comments

Ozone

The new spectral data results in slightly decreased ozone densities typically on the order of 1-2%.

There are some important things to note when using SAGE II v7.00 ozone data. First and foremost is that strict adherence to the traditionally used Wang et. al. method of filtering SAGE II data should be followed with one modification. The traditional (Wang et. al.) filtering of SAGE II includes the following:

- Exclusion of all data points with an uncertainty estimate of 300% or greater
- Exclusion of all profiles with an uncertainty greater than 10% between 30 and 50 km
- Exclusion of all data points at altitude and below the occurrence of an aerosol extinction value of greater than 0.006 km^-1
- Exclusion of all data points at altitude and below the occurrence of both the 525nm aerosol extinction value exceeding 0.001 km^-1 and the 525/1020 extinction ratio falling below 1.4

We recommend modifying this by adding the following:

- Exclusion of all data points below 35km an 200% or larger uncertainty estimate

The reason for the reduction from 300% to 200% is that switching from Twomey-Chahine to onion-peeling for inversion allows for both negative optical depths and for inherent variability in the data to be represented in the profile. As such, it is possible for larger variances at higher altitudes where extinction values are near detection limits in addition to larger variances at lower altitudes where extinctions are high and signal acquisition is near detection limits. We introduced the 200% uncertainty value in version 7 to allow the user added flexibility in filtering data. It is assigned to negative retrieved density values below 35 km originally with abnormally small retrieved errors. It is intended as a means to differentiate between negative retrieved values with high variance and retrieved values with low variance but which are not believable. Negative retrieved density values and their associated errors remain intact at higher altitudes, as this is more often a result of noise in the data rather than a deleterious effect on the retrieval algorithm from high aerosol extinctions or clouds.

Aerosol Extinction

Aerosol extinction products in this version have minor changes within the main aerosol layer generally reflecting excellent quality in previous versions. There is some minor decrease in extinction at short wavelengths due to changes in the ozone cross-sections. In addition, the use of the onion peel prevents some nonphysical relaxation of the profile above the main aerosol layer associated with the Twomey-Chahine peeling process and profile extinctions above 30 km decrease more rapidly than in previous versions. As with previous versions, we do not recommend the use of the 386 nm aerosol channel due to some unexplained behavior that can be substantial (approaching 30%) at low extinction levels.

Nitrogen Dioxide

The v7.00 NO_2 profiles are generally smaller than those in v6.2 by approximately 5% at the peak density. This decrease reduces the long-standing high bias in SAGE II NO_2. Because of the weak NO_2 signal, the vertical resolution of the slant path extinction profile was degraded to 2km via a 1-2-1 smoothing on the gridded profile prior to inversion.

Water Vapor

The change in ozone spectroscopy required a retuning of the characteristics of the water vapor channel. This channel clearly drifted beginning in early 1985 and was apparently complete by 1987. The filter position was inferred following the same approach used in Thomason et al. (2004) except that the climatological values used to estimate the channel response was changed to SAGE III as opposed to HALOE. The original location is used through the end of 1985 and moved in one step to the new location in 1986 and does not change through the end of the mission. Generally, we find that the product is improved relative to the V6.2 version particularly above 40 km. While this product is useful in many applications, given the uncertainty surrounding the channel location, we do not recommend this data set for trend studies.

Derived Aerosol Properties

As with Version 6.2, we report aerosol surface area density (SAD) and effective radius in the data files. In Version 6.2, this was computed using a method developed by Thomason et al. (1997) and further detailed in the Assessment of Stratospheric Aerosol Properties (SPARC, 2006). In this version, SAD and effective radius values are based on the method developed in Thomason et al. (2008). Changes in the Pinatubo period are small but SAD is approximately 50% higher in the clean years, particularly after 1998 where effective radius is also ~10% smaller. Unlike any previous version, uncertainties associated with these products are realistic assessments of the uncertainties associated with these retrievals.

References

Thomason, Larry W., Sharon P. Burton, Nina Iyer, Joseph M. Zawodny, John Anderson, "A revised water vapor product for the Stratospheric Aerosol and Gas Experiment (SAGE) II version 6.2 data set", *J. Geophys. Res.*, **109**, 6312, doi:10.1029/2003JD004465, 2004.

Thomason, L. W., L. R. Poole, and T. R. Deshler, "A global climatology of stratospheric aerosol surface area density as deduced from SAGE II: 1984-1994", J. Geophys. Res., 102, 8967-8976, 1997. SPARC. 2006, Assessment of Stratospheric Aerosol Properties (ASAP), SPARC Report No. 4, WCRP-124, WMO/TD-No. 1295, Feb. 2006, L. Thomason and Th. Peter, Eds.

Thomason, L. W., S. P. Burton, B.-P. Luo, and T. Peter, "SAGE II measurements of stratospheric aerosol properties at non-volcanic levels", *Atmos. Chem. Phys.*, **8**, 983-995, 2008, www.atmos-chem-phys.net/8/983/2008/

Wang, H. J., D. M. Cunnold, L. W. Thomason, J. M. Zawodny, and G. E. Bodeker, "Assessment of SAGE version 6.1 ozone data quality", *J. Geophys. Res.*, **107(D23)**, 4691, doi:10.1029/2002JD002418, 2002.