

Stratospheric Aerosol and Gas Experiment I (SAGE I) Aerosol Extinction Profiles Langley DAAC Data Set Document



Summary:

The Stratospheric Aerosol and Gas Experiment I (SAGE I) instrument was launched February 18, 1979, aboard the Applications Explorer Mission-B (AEM-B) satellite (McCormick et al., 1979). The SAGE I instrument had four spectral channels centered at wavelengths of 1000, 600, 450, and 385 nanometers for nearly global measurement of aerosol extinction profiles and ozone and nitrogen dioxide concentration profiles. The AEM-B satellite was placed in an orbit of approximately 600 kilometers at an inclination of 56 degrees to extend the latitudinal coverage for the solar occultation measurements from 79 degrees South to 79 degrees North. The (SAGE I) instrument collected data for almost three years until the (AEM-B) satellite power subsystem failed.

The SAGE I instrument was a sun photometer that measured the attenuation of solar radiation through the Earth's atmosphere during spacecraft sunrise and sunset in the four spectral regions mentioned above. The solar radiance data were combined with spacecraft ephemeris and NOAA meteorological data and then numerically inverted to yield altitude profiles of aerosol extinction at wavelengths of 1000 and 450 nanometers and altitude profiles of ozone and nitrogen dioxide concentration.

The SAGE I aerosol data were validated by comparison with correlative lidar and dustsonde in situ measurements; the ozone data were validated by comparison with balloon ECC ozonesonde and rocket measurements; and the nitrogen dioxide measurements were compared with climatology.

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1. Data Set Overview:

Data Set Identification:

SAGE1_AERO_PRF:

Stratospheric Aerosol and Gas Experiment I Aerosol Extinction Profiles



Data Set Introduction:

See Summary (above).

Objective/Purpose:

See Summary (above).

Summary of Parameters:

This data set includes aerosol extinction coefficients in units of 1/km at wavelengths of 1000 and 450 nanometers over the altitudes from .5 km or cloud top to 40.5 km.

Discussion:

For each event, the data set contains the event date, time, and location, the type of the event (sunrise or sunset), meteorological data, processing information, ground distance that the event covers, quality factors for each aerosol wavelength, and arrays of Rayleigh and of aerosol extinction.

Except for data gaps due to lost data from transmission difficulties, processing filtering, and periods when the instrument was in full sunlight conditions, the data consist of about 15 sunrises and 15 sunsets per day for the period from launch until June 1979. After that time, only sunset measurements are available.

This data set is currently available from the Langley DAAC in its native format as well as in HDF.

Related Data Sets:

SAM II:	Aerosol Extinction Profile.
SAGE II:	Aerosol Profiles.

2. Investigator(s):

Investigator(s) Name and Title:

Dr. M. Patrick McCormick, Principal Investigator and Science Team leader

Michael W. Rowland
Aerosol Research Branch, MS 475
Atmospheric Sciences Division
NASA Langley Research Center
Hampton, VA 23681

Title of Investigation:

Aerosol Extinction Profiles at 1000 and 450 nanometers (Level 2)

3. Theory of Measurements:

The measurement technique was solar occultation. The spectrometer was activated to take solar irradiance measurements during the periods when the line-of-sight from the SAGE I instrument to the Sun had tangent altitudes between sea level and 150 km. It was self-calibrating in that an exoatmospheric measurement was made before a sunset or after a sunrise measurement. Attenuation of sunlight by aerosol at two specific wavelengths given above was measured and processed to produce aerosol extinction profile data.

4. Equipment:



Sensor/Instrument Description:

Collection Environment:

The instrument is spaceborne.

Source/Platform:

The platform for SAGE I was the Applications Explorer Mission-B (AEM-B). Nominal orbit parameters for AEM-B are listed below:

- Launch Date: February 18, 1979
- Planned Duration: 1 year
- Actual Duration: 3 years
- Orbit: non-sun synchronous, circular at 600 kilometers
- Inclination: 56 degrees
- Nodal Period: 96.8 minutes

Source/Platform Mission Objectives:

The scientific objective of SAGE I was to develop a global stratospheric aerosol, ozone, and nitrogen dioxide data base that could be used for the investigation of the spatial and temporal variations of these species caused by seasonal and short-term meteorological variations, atmospheric chemistry and microphysics, and transient phenomena such as volcanic eruptions. The data base could also be used for the study of trends, atmospheric dynamics and transport, and potential climatic effects.

Key Variables:

Not applicable.

Principles of Operation:

The SAGE I instrument was a four channel Sun photometer using a Cassegrainian-configured telescope, holographic grating, and four silicon photodiodes to define the four spectral channel bandpasses. Solar radiation was reflected off a pitch mirror into the telescope with an image of the Sun formed at the focal plane. The instrument's instantaneous field-of-view, defined by the aperture on the focal plane was a 30 arc-second circle that produced a vertical resolution at the tangent point of about 0.5 km. Radiation passing through the aperture was transferred to the spectrometer section of the instrument containing the holographic grating and four separate detector systems. The holographic grating dispersed the incoming radiation into four spectral regions centered at 1000, 600, 450, and 385 nanometer wavelengths. Slits on the Rowland circle of the grating defined the spectral bandpass of the four spectral channels. The bandpasses were 50, 30, 20, and 10 nanometers, respectively, for the above mentioned wavelengths. The entire imaging and spectrometer system was inside the azimuth gimbal to allow the instrument to be pointed at the Sun without image rotation. The azimuth gimbal could be rotated over 360 degrees so that measurements could be made at any azimuth angle.

The operation of the instrument, during each sunrise and sunset measurement, was totally automatic. Prior to each sunrise or sunset, the instrument was rotated in azimuth to its predicted solar acquisition position. When the Sun entered the instrument's field of view, the instrument adjusted its azimuth position to lock onto the radiometric center of the Sun to within +/- 45 arc-seconds and then acquired the Sun by rotating its scan mirror to the proper elevation angle. As the Sun traversed between the horizon and the tangent height of 150 kilometers, the elevation mirror scanned vertically across the solar disc. The radiometric channel data were sampled at a rate of 64 samples per second per channel, digitized to 12-bit resolution, and recorded for later transmission back to Earth. Additional SAGE I instrument information can be found in McCormick et al. (1979).

Sensor/Instrument Measurement Geometry:

The SAGE I instrument used the solar occultation technique. The instrument made measurements when the line-of-sight between the instrument and the Sun crossed the atmosphere from sea level to 150 km height. The measurement opportunity was twice per orbit for satellite sunrise and sunset events.

Manufacturer of Sensor/Instrument:

Ball Aerospace Company in Boulder, Colorado built the SAGE I instrument.

Calibration:

Specifications:

Calibration consisted of solar scans performed exoatmosphere when tangent altitudes were greater than 150 km and no atmospheric attenuation was occurring.



Tolerance:

Not applicable.

Frequency of Calibration:

Calibration Sun scans were performed during every event.

Other Calibration Information:

Not applicable.

5. Data Acquisition Methods:

Data were acquired by the instrument as it performed solar scans during solar occultation.

6. Observations:**Data Notes:**

See [Theory of Measurements](#).

Field Notes:

None.

7. Data Description:**Spatial Characteristics:****Spatial Coverage:**

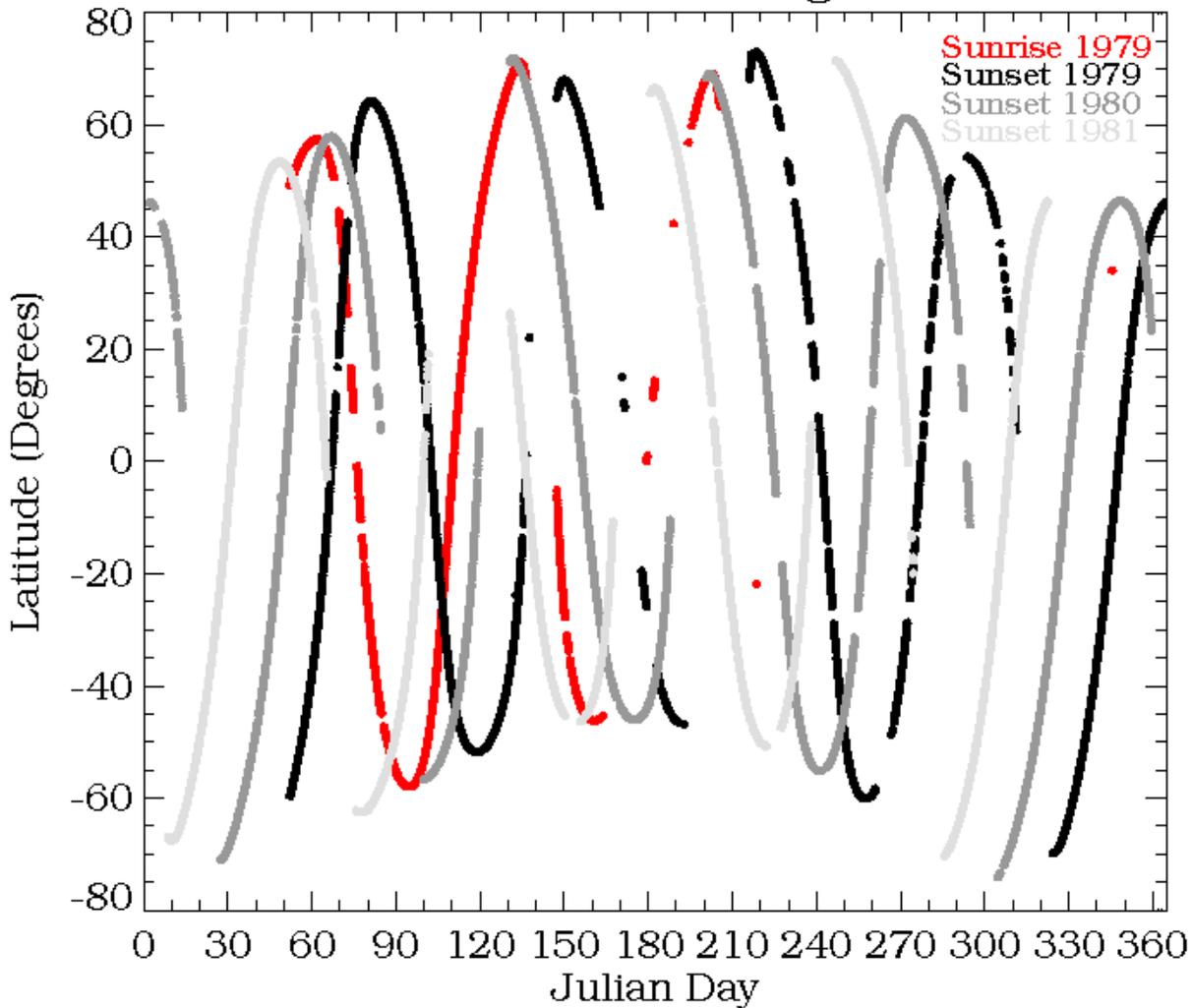
The latitude range for SAGE I varied with season. Overall coverage ranged from about 75 degrees North to 75 degrees South.

Spatial Coverage Map:

On a given day, the latitude coverage was from hundredths of a degree at the highest latitudes to 10 degrees near the equator. The longitudinal coverage was 360 degrees where the interval for consecutive sunrises or consecutive sunsets was about 24 degrees.



SAGE I Coverage



Spatial Resolution:

The aerosol profiles at the two wavelengths, 1000 and 450 nanometers, have a vertical resolution of 1 km, from .5 km or cloud top to 40.5 km. The region where the extinction falls below $2.0E-05 \text{ km}^{-1}$ (from approximately 25 to 40 km) was smoothed over 5 kilometer intervals during processing.

Projection:

Not applicable.

Grid Description:

Not applicable.

Temporal Characteristics:

Temporal Coverage:

SAGE I data collection began February 1979 and ended November 1981.

Temporal Coverage Map:

The latitude region covered by SAGE I varied with the season of the year, thus affecting the coverage cycle. At any one time during the year, full latitude range coverage was achieved in approximately 2-1/2 weeks. An entire latitude cycle was about 120 degrees and took about five weeks to complete. See [coverage map](#).

Temporal Resolution:



Sampling occurred twice per orbit for durations varying from three to ten minutes each, depending on the angle between the orbit plane of the spacecraft and the Earth-Sun vector (beta angle).

Data Characteristics:

Parameter/Variable:

The data is written in record format where each record contains one event. Every record in a data granule contains thirty-eight parameters.

Variable Description/Definition:

The thirty-eight parameters are as follows:

- Event Date
- Event Time
- Subtangent Latitude
- Subtangent Longitude
- Event Type
- Earth Referenced Event Type
- Spacecraft Beta Angle
- Coded Time of Year
- NMC Temperature
- NMC Temperature Error
- NMC Altitude
- NMC Air Density
- NMC Air Density Error
- NMC Temperature correction for 5.0mb Level
- NMC Temperature correction for 2.0mb Level
- NMC Temperature correction for 1.0mb Level
- NMC Temperature correction for 0.4mb Level
- Meteorological data not complete Flag
- Start of Model Meteorological Data Array Index Pointer
- Model Meteorological Data Selection Code
- LaRC Processing Date
- LaRC Processing Time
- Mean Subtangent Altitude for event Limb
- Subtangent Altitude
- Latitude corresponding to Altitude
- Longitude corresponding to Altitude
- Time span of data from Level 1 through 70
- Geometric Altitude
- Corresponding Pressure
- Corresponding Temperature
- 1000nm wavelength quality factor
- 450nm wavelength quality factor
- Extinction 1000nm
- Extinction Error 1000nm
- Extinction 450nm
- Extinction Error 450nm
- Extinction Ratio 1000nm
- Extinction Ratio Error 1000nm

Unit of Measurement:

Atmospheric transmittance values at the measured wavelengths are obtained by ratioing the measured solar irradiance during occultation in the atmosphere to the corresponding out-of-atmosphere measurements, and therefore, they are dimensionless. The solar irradiance measurements are expressed in units of digital counts from the instrument's ADC.

Aerosol measurements are given in extinction (units of 1/km).

Data Source:

The SAGE I flew aboard the AEM-B satellite.



Data Range:

Aerosol extinction values range from on the order of 1.0E-07 to 1.0E-02.

The minimum and maximum values for a particular parameter may vary from month to month. Each data file contains the minimum and maximum values for every parameter as well as the format of the data values.

Sample Data Record:

See data file.

8. Data Organization:

Data Granularity:

A general description of data granularity as it applies to the IMS appears in the [EOSDIS Glossary](#).

Each data granule contains one month of events, 30 per day, for a maximum of 930 events.

Data Format:

The data are written in HDF.

9. Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

The Level 2 data products of aerosols, ozone, and nitrogen dioxide were produced at LaRC using the techniques described in the references listed in this document. Briefly, the following three steps were followed:

1. The measured irradiance data were reduced, with the AEM-B ephemeris data, atmospheric refraction calculations, and the solar scan data, into profiles of limb optical thickness as a function of tangent height in the atmosphere for each channel, centered at its wavelength. The high altitude solar scan profiles for each channel were used as unattenuated, undistorted baseline measurements for normalization of the in-atmosphere solar scans.
2. The estimated Rayleigh contribution was subtracted from each channel yielding profiles of aerosol optical thickness at 1000 and 450 nanometers, ozone optical thickness at 600 nanometers and nitrogen dioxide optical thickness at 448 nanometers.
3. The species optical thickness profiles were inverted into extinction profiles by dividing the atmosphere into n-layers (an onion skin model) and applying Twomey's modification of Chahine's nonlinear relaxation algorithm. Vertical profiles of aerosol extinction at 1000 and 450 nanometers, ozone concentration and nitrogen dioxide concentration were obtained.

Data Processing Sequence:

Processing Steps:

The SAGE I science and engineering data, along with time, positional, and housekeeping data, were stored aboard the spacecraft and were downlinked to NASA GSFC through a ground station. GSFC then forwarded these data on tape to LaRC for processing and scientific analysis. GSFC also sent spacecraft and solar ephemeris data to LaRC on separate weekly tapes.

LaRC combined three data sources to produce the SAGE I MERDAT files: (1) the SAGE I instrument data, (2) the spacecraft and solar ephemeris data, and (3) NOAA NMC temperature and density interpolations from the standard NMC spatial gridded analyses at the 18 pressure levels and at the tropopause for each tangent event location.

The MERDAT files were used as data input to the inversion process explained in the previous section. At the completion of the data processing, four Level 2 SAGE I products were produced: aerosol extinction profiles at two wavelengths, ozone concentration profiles, and nitrogen dioxide concentration profiles.

The SAGE I aerosol data have been screened to delete data that have been determined unreliable or outside a useful altitude range.



Processing Changes:

The SAGE I products are Version 6.1.

Calculations:**Special Corrections/Adjustments:**

Derivation of atmospheric parameters from the telemetry data required corrections to be made for solar limb darkening, sunspot interference, atmospheric refraction, and Rayleigh scattering. No cloud filtering was done. However, the instrument measurements did not normally penetrate below the tops of clouds unless their thickness was minimal, so event profiles that appeared to stop at altitudes above the horizon were normally truncated because of clouds. Information about these procedures is referenced in another section of this document and in the listed references. Meteorological temperature data should be corrected at 5, 2, 1, and 0.4 millibars per NOAA/NMC procedures.

Calculated Variables:

See Chu and McCormick (1979).

Graphs and Plots:

There are no Level 2 aerosol graphs or plots available.

10. Errors:**Sources of Error:**

Error sources for the profile data consist of measurement error, temperature error, altitude error, and error from other species. See Chu and McCormick (1979).

Quality Assessment:**Data Validation by Source:**

Meteorological data provided by NOAA / NMC contained error estimates for both temperature and density at each of the pressure levels. Spacecraft position and velocity data were calculated from definitive measurements made by communication links with the TDRSS on a daily schedule.

Before being archived, the SAGE I Level 2 data were validated through an extensive correlative measurements program. See Russell et al. (1983), Russell et al. (1984), Yue et al. (1984), McCormick et al. (1984), and Reiter and McCormick (1982). The correlative aerosol measurements were performed with the closest coincidence in space and time. The correlative aerosol data consisted of previously validated aerosol profiles measured by SAM II, aerosol backscatter data obtained by airborne lidar, balloon-borne optical particle counter (dustsonde) data, and other in situ particle counter measurements. These correlative aerosol measurements were collected and converted into aerosol extinction for comparison with the SAGE I aerosol data.

The comparisons between SAGE I aerosol measurements and the correlative data demonstrate that SAGE I measurements agree with the correlative data to within their measurement and conversion uncertainties. The results of these comparisons clearly support the validity of the SAGE I products.

Confidence Level/Accuracy Judgement:

The error contributions for all Level 2 products of SAGE I are errors from random measurement and inversion noise, NOAA temperature uncertainties, and altitude uncertainties. Below an altitude of 25 kilometers, where aerosol extinction exceeds molecular extinction by 50 percent, the total error in the retrieved aerosol extinction coefficient is typically less than 10 percent. Therefore, even under most background or non-volcanic conditions, the extinction resulting from stratospheric aerosol is measured to within 10 percent accuracy.

Measurement Error for Parameters:

See Chu and McCormick (1979).

Additional Quality Assessments:

None.

Data Verification by Data Center:

The Langley DAAC performs an inspection process on this data received by the data producer via ftp. The DAAC checks to see if the transfer



of the data completed and were delivered in their entirety. An inspection software was developed by the DAAC to see if the code was able to read every granule. The code also checks to see if every parameter of data falls within the ranges which are included in the granule. This same code extracts the metadata required for ingesting the data into the IMS. If any discrepancies are found, the data producer is contacted. The discrepancies are corrected before the data are archived at the DAAC.

11. Notes:

Limitations of the Data:

Not applicable.

Known Problems with the Data:

None.

Usage Guidance:

The Level 2 data can be used for investigation of the spatial and temporal variation of aerosol, ozone, and nitrogen dioxide caused by seasonal and short-term meteorological variations, atmospheric chemistry and aerosol microphysics, and transient phenomena, such as volcanic eruptions. These data can also be used for the study of trends and atmospheric dynamics, radiation, and transport.

Because the SAGE I observations do not penetrate into the troposphere in cloud-free regions, studies of the aerosol in the upper troposphere can be performed to study seasonal variabilities. These tropospheric data may also be useful in generating a climatology for cirrus clouds.

Other solar occultation data sets that closely follow the SAGE I methods are the SAM II and the SAGE II data sets. SAM II coverage began on October 29, 1978 and extended through December 18, 1993 and produced data sets of aerosol at 1000 nanometers. SAGE II coverage begins October 1984 and is ongoing. It has produced data sets of aerosol, ozone, nitrogen dioxide, and water vapor. Refer to catalog entries on each of these experiments for complete details.

Any Other Relevant Information about the Study:

See [References](#).

12. Application of the Data Set:

See [Usage Guidance](#) and [References](#).

13. Future Modifications and Plans:

The SAGE I data set is currently being evaluated for possible further improvements in the data quality and expansion of the data set.

14. Software:

Software Description:

A program called read_sage.c is provided to read the SAGE I profiles. This program uses HDF subroutines.

Software Access:

Instructions for software access are given to the user when a data order has been submitted. The software is available through the Langley DAAC.

15. Data Access:

Data Center Identification and Contact Information:

Langley DAAC User and Data Services Office
NASA Langley Research Center
Mail Stop 157D
Hampton, Virginia 23681-2199
USA
Telephone: (757) 864-8656
FAX: (757) 864-8807
E-mail: support-asdc@earthdata.nasa.gov



Procedures for Obtaining Data:

The Langley DAAC IMS is an on-line system that features a GUI and a Character User Interface (ChUI) that allow users to query the Langley DAAC data set holdings, to view pre-generated browse products, and to order specific data products.

The Langley DAAC User Services staff provides technical and operational support for users ordering data.

Data Center Status/Plans:

To be updated.

16. Output Products and Availability:

There are no output products available that were generated by the SAGE I Aerosol Profiles data set.

17. References:

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3. Kent, G. S., U. O. Farrukh, P.-H. Wang, and A. Deepak, March 1988. SAGE I and SAM II Measurements of 1 Micrometer Aerosol Extinction in the Free Troposphere, *Journal of Applied Met.*, Vol. 27.
4. McCormick, M. P., 1983. Aerosol Measurements from Earth Orbiting Spacecraft, *Adv. Space Res.*, Vol. 2, No. 5, 73-86.
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11. Yue, G. K., M. P. McCormick, and W. P. Chu, June 30, 1984. A Comparative Study of Aerosol Extinction Measurements Made by the SAM II and SAGE Satellite Experiments, *Journal of Geophys. Res.*, Vol. 89, No. D4, 5321-5327.

18. Glossary of Terms:

[EOSDIS Glossary](#).

19. List of Acronyms:

[EOSDIS Acronyms](#)

ADC - Analog-to-digital converter



AEM-B - Applications Explorer Mission-B
DAAC - Distributed Active Archive Center
ECC - Electrochemical Concentration Cell
EOSDIS - Earth Observing System Data and Information System
GSFC - Goddard Space Flight Center
GUI - Graphical User Interface
HDF - Hierarchical Data Format
IMS - Information Management System
LaRC - Langley Research Center
MERDAT - Meteorological data
NASA - National Aeronautics and Space Administration
NMC - National Meteorological Center
NOAA - National Oceanic and Atmospheric Administration
SAGE I - Stratospheric Aerosol and Gas Experiment I
SAGE II - Stratospheric Aerosol and Gas Experiment II
SAM II - Stratospheric Aerosol Measurement II
TDRSS - Tracking and Data Relay Satellite System
UDS - User and Data Services
URL - Uniform Resource Locator

20. Document Information:

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