Stratospheric Aerosol Measurement II (SAM II) Aerosol Extinction Profiles Langley DAAC Data Set Guide

Summary:

The Stratospheric Aerosol Measurement II (SAM II) experiment flew aboard the Nimbus-7 spacecraft and provided vertical profiles of aerosol extinction in both the Arctic and Antarctic polar regions. The SAM II data coverage began on October 29, 1978 and extended through December 18, 1993 until SAM II was no longer able to acquire the Sun. The data coverage for the Arctic region extends through January 7, 1991, and contains data gaps beginning in 1988 that increase in size each year. The data coverage for the Antarctic region is continuous through December 18, 1993 except for a time period from mid-January 1993 through October 1993. The data gaps for both the Arctic and Antarctic regions are due to an orbit degradation associated with the Nimbus-7 spacecraft.

Table of Contents:

1. Data Set Overview:

Data Set Identification:

Stratospheric Aerosol Measurement II, SAM II

Data Set Introduction:

See Summary above.

Objective/Purpose:

The SAM II instrument, aboard the Earth-orbiting Nimbus-7 spacecraft, was designed to measure solar irradiance attenuated by aerosol particles in the Arctic and Antarctic stratosphere. The scientific objective of the SAM II experiment was to develop a stratospheric aerosol data base for the polar regions by measuring and mapping vertical profiles of the atmospheric extinction due to aerosols. This data base allows for studies of aerosol changes due to seasonal and short-term meteorological variations, atmospheric chemistry, cloud microphysics, volcanic activity and other perturbations. The results obtained are useful in a number of applications, particularly the evaluation of any potential climatic effect caused by stratospheric aerosols.

Summary of Parameters:

Each record contains eight parameters: vertical profiles of extinction km-1, extinction km-1 uncertainty, extinction ratio, extinction ratio uncertainty, NMC temperature, temperature uncertainty, and pressure as a function of altitude.

Discussion:

The SAM II data along with coincident meteorological (MET) data provided by NOAA were generated at Langley Research Center, Hampton, Virginia, on CDC Cyber (series) computers. This data set is currently available from the Langley DAAC in its native format.

Related Data Sets:

SAGE I, 1 micron aerosol measurements
SAGE II, 1 micron aerosol measurements

2. Investigator(s):

Investigator(s) Name and Title:

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Title of Investigation:

Stratospheric Aerosol Measurement II (SAM II)

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3. Theory of Measurements:

This information is not available.

4. Equipment:

Sensor/Instrument Description:

Collection Environment:

The SAM II data were digitized on the SAM II instrument, transferred to the Nimbus-7 data recorder, and telemetered to Goddard Space Flight Center (GSFC).

Source/Platform:

Nominal orbit parameters for Nimbus-7 are listed below:

- Launch Date: October 1978

- Planned Duration: 1 year
- Actual Duration: 15 years
- Orbit: Sun-synchronous, at 955 km
- Nodal Period: 104 minutes

Source/Platform Mission Objectives:

The mission objective of the SAM II experiment is to develop a stratospheric aerosol data base for the polar regions by measuring and mapping vertical profiles of the atmospheric extinction due to aerosols. Specific objectives are:

1. To investigate the spatial and temporal variations of aerosols due to seasonal and shorter-term meteorological variations, atmospheric chemistry and microphysics, and transient phenomena such as volcanic eruptions.
2. To utilize these measurements to study atmospheric dynamics and transport and potential climatic effects.

Key Variables:

Stratospheric aerosol extinction and solar irradiance.

Principles of Operation:

The SAM II instrument is a single-channel Sun photometer employing a cassegrainian telescope and interference filter to define the spectral passband. Solar radiation is reflected off a scan mirror into the telescope with an image of the Sun formed at the slot plate. The instrument's instantaneous field of view, defined by the aperture on the slot plate, is a 30-arc-second circle which produces a vertical resolution on the horizon of approximately 0.5 km. Radiation passing through the aperture is collected with a field lens, passes through an interference filter, and is measured by a silicon photodiode detector. The spectral passband, defined by the interference filter, has a 0.038 micron bandwidth centered at a wavelength of 1.0 micron.

The entire optical and detector system is contained in the azimuth gimbal to allow the instrument to be pointed at the Sun. Prior to spacecraft sunrise or sunset, the instrument is moved (i.e., pointed to the predicted solar acquisition angle). When the Sun enters the instrument field of view, the instrument locks onto the radiometric center of the Sun within +- 1 arc minute in azimuth and then acquires the Sun in elevation by rotating the scan mirror.

As the Sun sets or rises relative to the Earth's horizon, the elevation mirror scans vertically across the solar disk at a nominal rate of 15 arc minutes per second. The radiometric data are then sampled at a rate of 50 samples per second, digitized to 10-bit resolution, and recorded for later transmission back to Earth for data reduction.

Sensor/Instrument Measurement Geometry:

The SAM II instrument uses the Sun as a constant irradiance source (thus is self-calibrating before each sunset or after each sunrise) and measures the radiation that passes through the Earth's atmosphere during a sunrise or sunset.

The photometer assembly scans the Sun at a nominal rate of 15 arc minutes per second. The photometric data are sampled at a rate of 50 samples-per-second and digitized to 10-bit resolution.

The SAM II instrument, along with a number of other sensors, is mounted on the Earth-orbiting spacecraft. The orbital characteristics of this spacecraft determine the frequency and geographic locations of the SAM II measurements. The mode of operation of the SAM II instrument is such that it takes data during each sunrise and sunset encountered. The spacecraft has an orbital period of 104 minutes, which means that it circles the Earth nearly 14 times per day. There is a measurement opportunity for the SAM II each time that the spacecraft enters into or emerges from the Earth's shadow. Consequently, the instrument takes data during approximately 14 sunrises and 14 sunsets each Earth day. The spacecraft was placed in a high-noon, Sun-synchronous orbit; that is, the spacecraft crossed the Equator during each orbit at local noon. In general terms, this means that the orbital plane of the spacecraft was fixed with respect to the Sun, and thus all sunsets occur in the Arctic region and all sunrises occur in the Antarctic region.

In the course of a single day, measurements of the stratospheric aerosol are obtained at 14 points spaced 26 degrees apart in longitude in the Arctic region and similarly for the Antarctic region. All the points obtained during 1 day in a given region are at very nearly the same latitude, but as time progresses, the latitudes of the measurements slowly change with the season by 1 to 2 degrees each week, gradually sweeping out the area from approximately 64.0 to 83.0 degrees. The lowest latitude coverage occurs at the solstices whereas the highest latitudes are measured at the equinoxes.

In the course of 1 week, therefore, the instrument makes about 98 measurements in each region, all in a band of latitude of approximately 1.0 degree. These measurements give a fairly spatially dense set of data points. When the locations of all the measurements obtained in one week are plotted on a geographic set of axes, one finds that the separation between points is only about 4.0 degrees in longitude. In a

6-month period of time, the total number of observations is on the order of 5000.

However, due to an orbit degradation associated with the spacecraft, there has been a change and disruption in the collection of SAM II data beginning in 1987. During the period of time from 1987 through 1993, orbital precession caused the spacecraft to cross the equator earlier than the planned high-noon crossing. This gradually moved the Antarctic coverage equatorward. Initially the Antarctic latitudinal coverage extended from the lowest latitude, 64.5 degrees at the solstices, to the highest latitude, 81.0 degrees at the equinoxes. By 1992 the Antarctic coverage gradually shifted to extend from 53.1 degrees at the solstices, to 69.2 degrees at the equinoxes. In the Arctic region the initial latitudinal coverage extended from the lowest latitude, 64.1 degrees at the solstices, to the highest latitude, 83.0 degrees at the equinoxes. Gradually by 1991 the highest Arctic latitudinal coverage extended to 86.2 degrees at the equinoxes.

The orbital precession also affected the spacecraft orientation and prevented the SAM II instrument from acquiring the Sun for certain periods of time. In the Arctic region many sunset events were lost because an S-band antenna blocked SAM II's view to the Sun. Sunset events were lost for the following periods of time: mid-June through mid-August 1988; mid-March through mid-September 1989; mid-January through September 1990; and from January 7, 1991, through December 1993. In the Antarctic region the SAM II instrument was not able to acquire the Sun for the period of time from mid-January through October 1993. The final 2 months of SAM II data for the Antarctic region were collected during November and December 1993.

Manufacturer of Sensor/Instrument:

This information is not available.

Calibration:

Specifications:

The SAM II instrument uses the sun as a constant irradiance source, thus the instrument is self-calibrating before each sunset or after each sunrise.

Tolerance:

This information is not available.

Frequency of Calibration:

The SAM II instrument is calibrated before each sunset or after each sunrise.

Other Calibration Information:

This information is not available.

5. Data Acquisition Methods:

The SAM II data is sampled at a rate of 50 samples per second, digitized to a 10-bit resolution, and recorded for later transmission back to GSFC.

6. Observations:

Data Notes:

None.

Field Notes:

None.

7. Data Description:

Spatial Characteristics:

Spatial Coverage:

All the points obtained during one day in a given region will be at very nearly the same latitude, but as time progresses, the latitude of the measurements will slowly change with the season by one to two degrees each week. The latitude range for SAM II varies with season. The latitude of the measurements for years 1978 through 1987 gradually moves from the lowest latitude, 64 degrees, at the solstices to the highest latitude, 83 degrees, at the equinoxes. After 1987, the Antarctic coverage gradually moved equatorward and by 1992, the latitude of measurements moved from the lowest latitude, 53.1 degrees at the solstices to the highest latitude, 69.2 degrees at the equinoxes. In the

Arctic region, the latitude of measurements by 1991 gradually moved from the lowest latitude, 64 degrees at the solstices to the hightest latitude, 86.2 degrees at the equinoxes. The longitude interval for consecutive sunrises or consecutive sunsets is about 26 degrees.

Spatial Coverage Map:

Given in the spatial coverage.

Spatial Resolution:

The altitude profiles of aerosol extinction have a 1 km vertical resolution.

Projection:

Given in the spatial coverage.

Grid Description:

Given in the spatial coverage.

Temporal Characteristics:

Temporal Coverage:

There are approximately 28 SAM II measurements per day, 98 per week, and 5096 per year.

Temporal Coverage Map:

See spacial coverage.

Temporal Resolution:

The time between each successive sunrise or sunset is approximately 1 hour and 45 minutes.

Data Characteristics:

Parameter/Variable:

Atmospheric transmittance data at 1.0 micron was obtained during solar occultation at each satellite sunrise and sunset. The irradiance data were combined with spacecraft ephemeris and NOAA meteorological data and were numerically inverted to yield altitude profiles of aerosol extinction with a 1 km vertical resolution.

Variable Description/Definition:

Extinction is attenuation per unit distance.

Unit of Measurement:

per kilometer, km-1

Data Source:

SAM II irradiance data combined with spacecraft ephemeris and NOAA meteorological data numerically inverted to yield altitude profiles of aerosol extinction with a 1 km vertical resolution.

Data Range:

Longitude range: 0-360 degrees
Latitude range: 64-83 degrees

Sample Data Record:

The first 44 lines of every monthly file consists of header information (all text). Following is the actual data. The first record appears in the file as follows (This data were extracted from the granule sam2_aer_prf_7810.):

Label	Actual Data
GMT	302.0583
YR	78.0
MN	10.0

DAY	29.0
HOUR	1.0
MIN	23.0
SEC	56.1
EVENT	0.0
ORBIT	66.0
LAT	-74.93
LON	-52.09
TROP	9999.00
TEMP	9.61

8. Data Organization:

Data Granularity:

A general description of data granularity as it applies to the IMS appears in the EOSDIS Glossary.

There are approximately 14 sunrise and 14 sunset measurements made every day. The data obtained at 14 points each day are spaced 26 degrees apart in longitude and are at nearly the same latitude. Over the course of a year the latitudinal coverage ranges from 64 degrees to 83 degrees.

Data Format:

Data are written in ASCII text format.

9. Data Manipulations:

Formulae:

Derivation Techniques and Algorithms:

The measured irradiance from the SAM II instrument is related to atmospheric optical properties through the following equation:

$$H(t) = \int F(\Theta, \Phi) S(\Theta, \Phi, t) \exp[-\tau(\Theta)] \, d\Omega \quad (1)$$

where the H(t) is the measured irradiance at time t, $S(\Theta, \Phi, t)$ is the extraterrestrial solar radiance profile within the SAM II spectral bandwidth at time t corrected for atmospheric refraction effects, $F(\Theta, \Phi)$ is the instrumental field-of-view function, $\tau(\Theta)$ is the optical thickness of the atmosphere for evaluation, Θ, Φ is the azimuthal angle, and Ω is the total solid angle. Since each elevation Θ corresponds uniquely to an atmospheric tangent height h_T, the optical thickness $\tau(h_T)$ can be related to atmospheric extinction properties through the following equation:

$$\tau(h_T) = \int [\beta_a(h) + \beta_{ND}(h)] \, d\rho(h) \quad (2)$$

where $\beta_a(h)$ is the aerosol particulate extinction versus altitude profile, $\beta_{ND}(h)$ is the neutral density versus altitude profile (Rayleigh scattering), and $\rho(h)$ is the path length through the atmosphere. The integral is evaluated from the spacecraft position to the Sun.

The retrieval of aerosol extinction profiles from SAM II data is accomplished through the following two steps. First, the measured irradiance data are reduced, together with spacecraft ephemeris, into a single profile of limb optical thickness $\tau(h_T)$ as a function of tangent height h_T in the atmosphere. The high-altitude solar-scan profiles are used as a calibrated solar-limb profile in this process. The second step is to subtract the estimated neutral density contribution along each limb path to obtain the aerosol extinction profile. The neutral density profiles are calculated from the coincident temperature profiles provided by NOAA. (The 1.0-micron region of the spectrum was selected because the absorption by atmospheric gases is negligible and, consequently, the observed extinction is caused only by aerosol and molecular scattering.) When the atmosphere is divided into N homogeneous layers, the integral equation can be reduced to a system of linear equations as follows:

$$\tau_{ai} = \sum_{j=i}^{N} \rho_{ij}\beta_{aj} \quad (3)$$

where τ_{ai} is the measured limb optical thickness at the ith layer for aerosols, ρ_{ij} is the path length of the Sun ray in the jth layer with its tangent height at the ith layer, and β_{aj} is the averaged aerosol extinction coefficient for the jth layer. Equation (3) is then inverted to determine the values of β_{aj} with the SAM II inversion algorithm. The SAM II inversion algorithm is a two-step inversion technique that utilizes the constrained smoothing methods developed by Twomey (1977). First, equation (1) is inverted with the second-difference scheme. The solution thus obtained then serves as the mean profile for the final inversion for which the minimum departure from the mean constrained method is used. A more detailed description of the data processing scheme is discussed in Chu and McCormick (1979).

Data Processing Sequence:

Processing Steps:

The SAM II satellite data are processed after being telemetered to the ground, with the data on solar intensity versus time being mathematically inverted to yield extinction coefficient versus altitude (extinction profile) for each sunrise or sunset event. The mathematical inversion used is described by Chu and McCormick (1979).

The basic data product, therefore, is the extinction profile obtained during each measurement opportunity, which can be analyzed to determine the spatial and temporal variations in the upper tropospheric and stratospheric aerosol. These extinction data are archived at the Langley DAAC, NASA Langley Research Center, Hampton, VA, after being subjected to an extensive validation program including comparisons with correlative aerosol observations.

Processing Changes:

None.

Calculations:

Special Corrections/Adjustments:

None.

Calculated Variables:

See derivation techniques and algorithms.

Graphs and Plots:

There are none.

10. Errors:

Sources of Error:

Extinction uncertainty estimates the systematic and random errors associated with the calculations of the aerosol extinction that result from both the radiometric measurement and the mathematical inversion. These errors include contributions from random measurement and inversion noise, instrument passband calibration, molecular density, and altitude determination. The error associated with calculating the molecular density depends on the temperature and pressure errors in the meteorological data provided by NOAA.

Quality Assessment:

Data Validation by Source:

Before being archived the SAM II data were validated through an extensive correlative measurements program. Initially, an empirically based model of stratospheric aerosol optical properties (size distributions and refractive indices) was generated to allow the conversion of various correlative measurements to aerosol extinction and to assess quantitatively the uncertainties in the conversion process. Two major correlative measurement experiments were then conducted - the first over Sondrestrom Air Base, Greenland, in November 1978, shortly after the Nimbus-7 launch, and the second over Poker Flat Research Range, Alaska, in July 1979. In each experiment, data from balloon-borne optical particle counters (dustsondes) and other in situ particle counters, as well as airborne lidar-measured aerosol backscatter data, were collected and converted to aerosol extinction at 1.0 micron for comparison with the SAM II data. Comparisons of the SAM II and SAGE I aerosol extinction measurements have been made.

All these comparisons demonstrate that the stratospheric aerosol extinction profiles measured by SAM II agree with those inferred from the lidar, dustsonde, and other data to within the respective measurement and conversion uncertainties of the radiometric measurement and mathematical inversion.

As part of the data validation (i.e. quality control program), the SAM II data are also routinely screened for anomalous extinction profiles. These anomalous profiles occur for a variety of reasons, including Sun spots and spacecraft attitude problems during Nimbus-7 Earth Radiation Budget (ERB) calibration and other spacecraft perturbations.

Confidence Level/Accuracy Judgement:

Below 25 km, where aerosol extinction exceeds molecular extinction by 50 percent, the total error in the retrieved aerosol extinction coefficient is typically less than or equal to 10 percent. Therefore, even under most background or nonvolcanic conditions, the extinction due to stratospheric aerosol can be measured to within 10 percent accuracy.

Measurement Error for Parameters:

Aerosol extinction profiles can be retrieved to about 10 accuracy over the full altitude range of the stratospheric aerosol layer.

Additional Quality Assessments:

None.

Data Verification by Data Center:

The SAM II data are routinely screened for anomalous extinction profiles. These anomalous profiles occur for a variety of reasons, including Sun spots and spacecraft altitude problems during Nimbus-7 Earth Radiation Budget ERB calibration and other spacecraft perturbations. These profiles are removed from the SAM II data set.

11. Notes:

Limitations of the Data:

None.

Known Problems with the Data:

None.

Usage Guidance:

Due to an orbit degradation associated with the Nimbus-7 spacecraft, there was an increasing disruption and change in the collection of SAM II data, especially after 1987. The original Nimbus-7 was in a high-noon sun-synchronous orbit. Over the years this orbit slowly changed, and by 1987 the spacecraft began crossing the equator before noon. The time before noon crossing increased each year and caused the maximum latitudinal coverage to change.

In the Southern Hemisphere, the orbital precession limited the maximum poleward collection of Antarctic (sunrise) data. The decrease in the highest latitude measurements has affected many studies, including the long-term statistics of Polar Stratospheric Clouds, PSC's.

In the Northern Hemisphere, the orbital precession caused the angle between the orbital plane and the sun vector (beta angle) to increase and the direction SAM II had to look to observe a sunset was blocked by an S-band antenna. Therefore, many sunset events beginning in year 1988 were lost.

Any Other Relevant Information about the Study:

None.

12. Application of the Data Set:

The scientific objective of the SAM II experiment was to develop a stratospheric aerosol data base for the polar regions by measuring and mapping vertical profiles of the atmospheric extinction due to aerosols. This data base allows for studies of aerosol changes due to seasonal and short-term meteorological variations, atmospheric chemistry, cloud microphysics, volcanic activity and other perturbations. The results obtained are useful in a number of applications, particularly the evaluation of any potential climatic effect caused by stratospheric aerosols.

13. Future Modifications and Plans:

The data set is archived for use. No changes are anticipated.

14. Software:

Software Description:

Read software is available for this data set. The code is written in C. The code is able to run on most platforms. The read software allows the user to select which parameters he choses to be output to a file. All records will be read. There is a "README" file to assist the user to work with the code as well as the data.

Software Access:

When ordering data from the Langley DAAC, the user has the option of receiving read software for this data. Users may contact:

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

15. Data Access:

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Procedures for Obtaining Data:

The data are available from the Langley Data Center web site.

Data Center Status/Plans:

All data granules for this experiment are archived at the Langley DAAC. The Langley DAAC will continue to support this experiment.

16. Output Products and Availability:

CD-ROM of SAM II data is available. These can be obtained from the Langley DAAC. The SAM II Cd-ROM contains over 14 years of polar Arctic and Antarctic aerosol profiles obtained with the SAM II satellite experiment. For each measurement event, vertical profiles of extinction km-1, extinction ratio, and National Meteorological Center (NMC) temperatures and pressures are provided as a function of altitude.

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18. Glossary of Terms:

EOSDIS Glossary.

19. List of Acronyms:

EOSDIS Acronyms

CDC - Control Data Corporation
DAAC - Distributed Active Archive Center
DBMS - Database Management System
EOSDIS - Earth Observing System Data and Information System
ERB - Earth Radiation Budget
GSFC - Goddard Space Flight Center
GUI - Graphical User Interface
IMS - Information Management System
LaRC - Langley Research Center
MET - Meteorological
NASA - National Aeronautics and Space Administration
NMC - National Meteorological Center
NOAA - National Oceanic and Atmospheric Administration
PSC - Polar Stratospheric Cloud
SAGE - Stratospheric Aerosol and Gas Experiment
SAGE I - Stratospheric Aerosol and Gas Experiment I
SAGE II - Stratospheric Aerosol and Gas Experiment II
SAM II - Stratospheric Aerosol Measurement II
UDS - User and Data Service
URL - Uniform Resource Locator

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