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SAM II Data User's Guide

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Preface

The data products from the Stratospheric Aerosol Measurement (SAM) II experiment flown on the Nimbus 7 spacecraft are being archived on magnetic tape at the National Space Sciences Data Center, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, and are available to researchers. The satellite was launched in October 1978 and, as of October 1987, has collected 9 years of high-quality aerosol data. This document is intended to serve as a guide to the use of this data set for scientific investigations of polar stratospheric aerosols. Included is a detailed description of the Beta and Aerosol Number Density Archive Tape (BANAT), which is the SAM II data product containing the aerosol extinction data available for these investigations. Also included are brief descriptions of the instrument operation, data collection, processing and validation, and some of the scientific analyses that have been conducted to date.

The SAM II experiment development has been guided through the years by the SAM II Nimbus Experiment Team, which is made up of the following people: M. Patrick McCormick, experiment scientist and experiment team leader, NASA Langley Research Center; G. W. Grams, Georgia Institute of Technology; B. M. Herman, University of Arizona; T. J. Pepin, University of Wyoming; and P. B. Russell, NASA Ames Research Center. The LaRC SAM II Data Processing Team, which is currently involved in the processing and screening of the data, and which provided the list of anomalous events is made up of the following people: Jack C. Larsen, Mary Osborn, Kathy Powell, and Charles Trepte of ST Systems Corporation.

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Summary

The Stratospheric Aerosol Measurement (SAM) II experiment is flying aboard the Nimbus 7 spacecraft, providing vertical profiles of extinction as a result of stratospheric aerosols in both the Arctic and Antarctic polar regions. The SAM II is a single spectral channel Sun photometer which measures the attenuation of solar radiation through the Earth's atmosphere during spacecraft sunrise and sunset. The irradiance data are combined with spacecraft ephemeris and National Oceanic and Atmospheric Administration (NOAA) meteorological data and are numerically inverted to yield altitude profiles of aerosol extinction with a 1-km vertical resolution. These data are validated by comparison with correlative lidar and in situ aerosol measurements and are archived at the National Space Sciences Data Center (NSSDC). This report describes the SAM II experiment, instrument characteristics, and mode of operation; outlines the methodology of the data inversion; and describes the format of the data products to permit others to use the data archived at NSSDC. Results of the data validation and examples of data products are also presented to demonstrate the quality of the data and its applicability to atmospheric studies.

Introduction

The SAM II experiment is the second in a series of four satellite experiments employing the solar occultation technique to monitor and study stratospheric aerosols. The Stratospheric Aerosol Measurement (SAM) I, the first instrument to use this technique from space, was flown on the Apollo/Soyuz test project in July 1975 (Pepin and McCormick 1976). It employed a single spectral channel centered at a wavelength of 0.8 μm for aerosols and collected only four profiles to test the technique and instrument design from a space platform. The SAM II instrument, which also employs a single spectral channel but is located at 1.0 μm for aerosols, was launched on the Nimbus 7 spacecraft in October 1978. SAM II, which collects data only in the polar regions because of the Nimbus 7 orbit, has collected 9 years of data and is still operating successfully (Russell 1986). The purpose of this report is to provide the necessary information for the usage of the archived SAM II data.

The Stratospheric Aerosol and Gas Experiment (SAGE) I was launched on February 18, 1979, aboard the Applications Explorer Mission 2 (AEM-2) spacecraft (McCormick et al. 1979). SAGE I had four spectral channels for measuring atmospheric extinction of aerosols, ozone, and nitrogen dioxide, and was in an orbit that allowed collection of data from 79°S to 79°N latitude. The SAGE I instrument collected data for 3 years until the AEM-2 spacecraft power subsystem failed. The most recent of these experiments, SAGE II, employs seven spectral channels for measuring the atmospheric extinction of aerosols, ozone, nitrogen dioxide, and water vapor, and is in an orbit that allows data collection from 80°S to 80°N latitude. The SAGE II instrument was launched October 1984 aboard the Earth Radiation Budget Satellite (ERBS) and, after 3 years of operation, is still operating successfully (McMaster 1986). The data from these experiments are being archived at the National Space Sciences Data Center (NSSDC), NASA Goddard Space Flight Center, Greenbelt, Maryland 20771. Separate user guides for SAGE I and SAGE II archived data are available on magnetic tape.

Nimbus 7 SAM II Mission

The scientific 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. This data base will be used for investigations of 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. These data will also be used for studies of atmospheric dynamics and transport and potential climatic effects. The SAM II sensor, along with a number of other atmospheric and oceanographic monitoring sensors, is mounted on the Nimbus 7 Earth-orbiting spacecraft. (See fig. 1.) The SAM II sensor is designed to measure the attenuation of solar radiation due to aerosols through the Earth's atmosphere during each spacecraft sunrise and sunset. (See fig. 2.) Thus, the Nimbus 7 orbital characteristics determine the geographic location of the SAM II measurements. Nimbus 7, with its 955-km-altitude high-noon Sun-synchronous orbit, provides 14 sunrise measurements in the Southern Hemisphere separated by approximately 26° longitude, and similarly 14 sunset measurements in the Northern Hemisphere separated by approximately 26° longitude each day. The latitude of the measurements remains approximately constant during any one day in a given hemisphere, but changes slowly with season (fig. 3). The latitude of the measurements gradually moves from the lowest latitude, 64°, at the solstices to the highest latitude, 80°, at the equinoxes.

Instrument Description and Operation

The SAM II instrument is a single-channel Sun photometer employing a cassegrainian telescope and

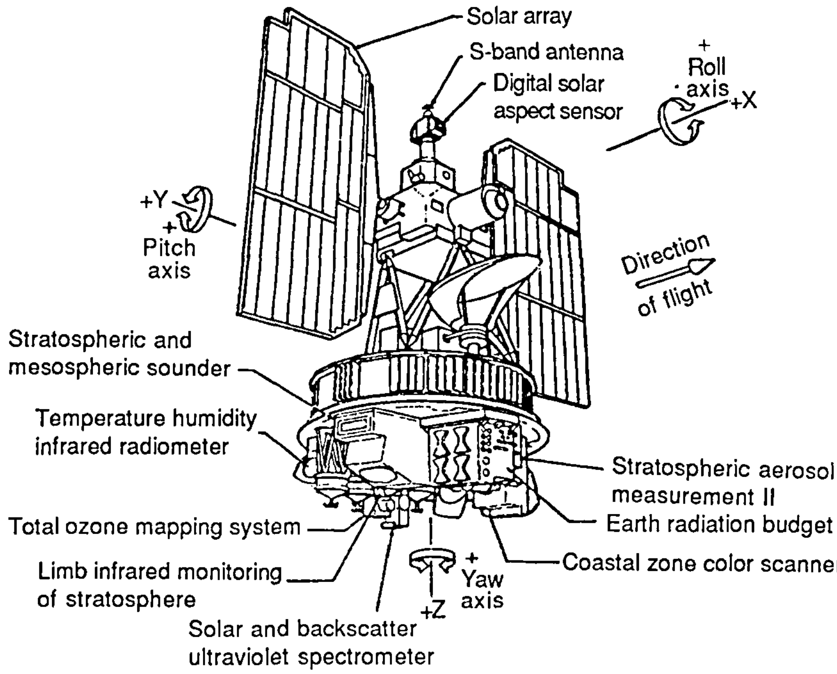


Figure 1. Nimbus 7 observatory showing various instruments. (Taken from McCormick et al. 1979.)

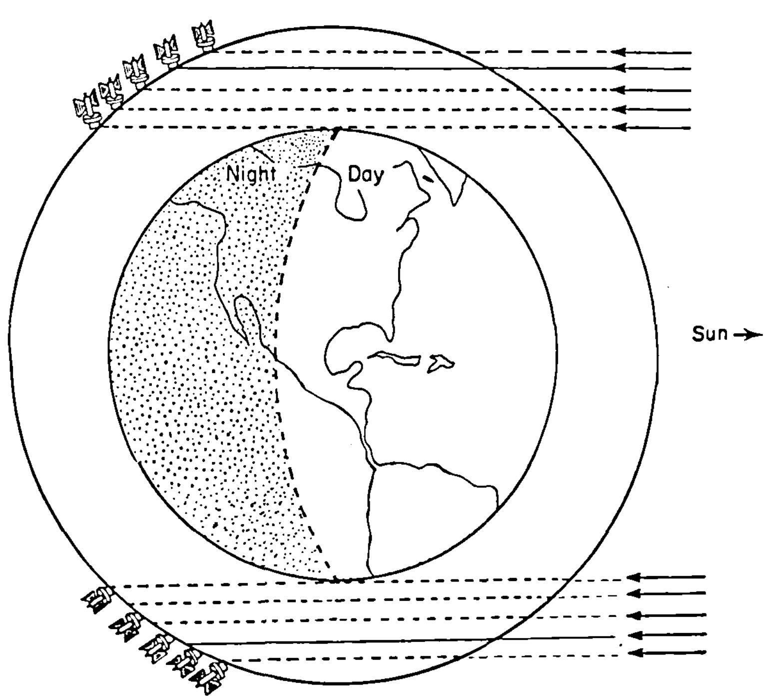


Figure 2. Occultation geometry for SAM II instrument.

interference filter to define the spectral passband. Figure 4 is a schematic of the instrument. 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-μm bandwidth centered at a wavelength of 1.0 μm.

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. (See fig. 5.) The two solid lines in the figure represent the image positions of the top and bottom edges of the solar disk during a sunset event as viewed from the spacecraft. The gradual shrinking of the vertical shape of the solar image is the result of atmospheric refraction. The dashed line represents the relative motion of the instrument elevation mirror as it scans the Sun 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. An example of the reconstructed radiance data from a sunrise observation is shown in figure 6. Additional information and technical details on the SAM II instrument can be found in McCormick et al. (1979) and Madrid (1978).

Data Processing

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

$$H(t) = \int F(\theta,\phi)S(\theta,\phi,t)\ \exp[-\tau(\theta)]\ d\Omega \qquad (1)$$

where $H(t)$ 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:

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

where $\beta_a(h)$ is the aerosol particulate extinction versus altitude profile, $\beta_{ND}(h)$ is 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-μm 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:

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

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

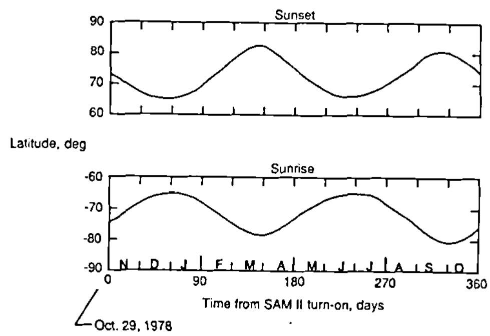


Figure 3. Geographic coverage for SAM II observations with sunset measurements in northern hemisphere and sunrise measurements in southern hemisphere.

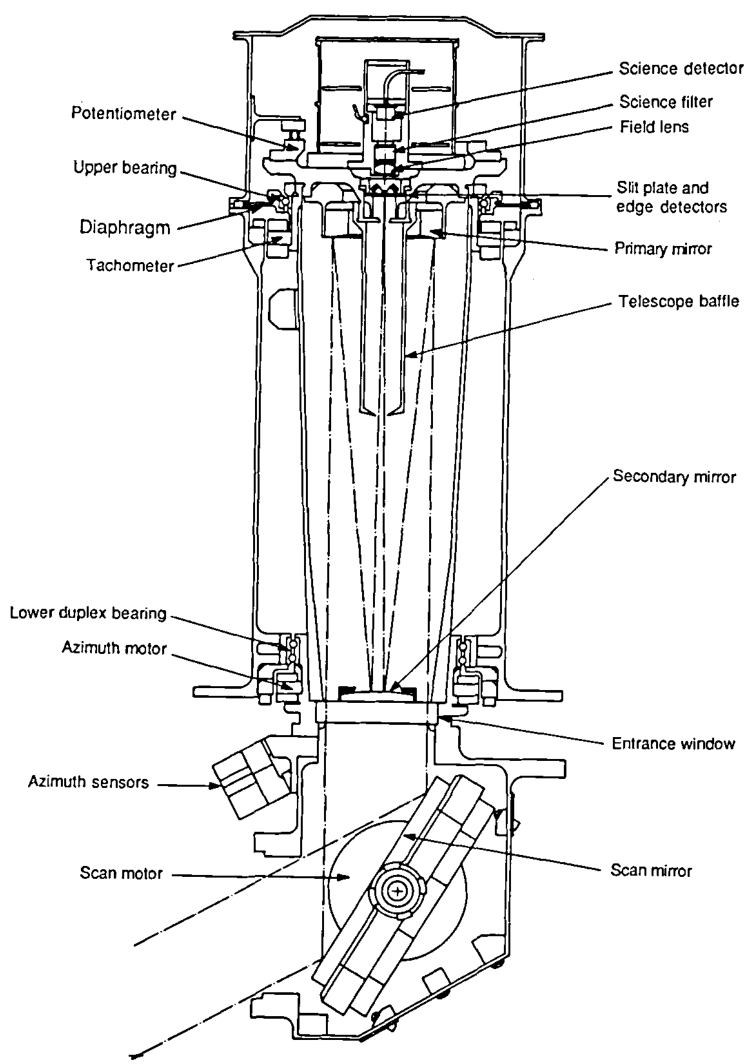


Figure 4. Schematic of SAM II instrument.

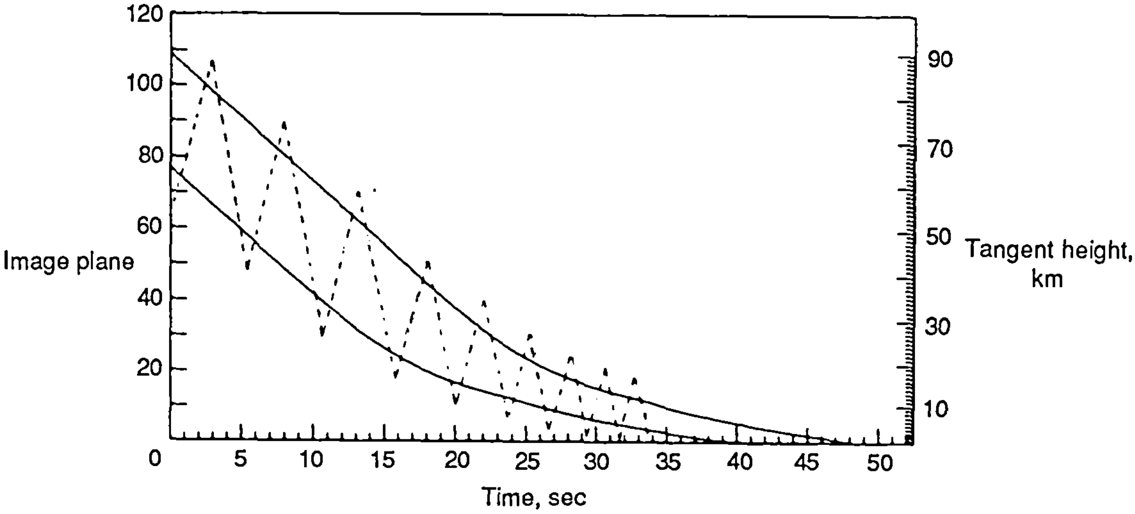


Figure 5. Data acquisition mode for typical SAM II sunset measurement. Solid lines denote top and bottom of solar disk; zig-zag dashed line shows data-taking sequence.

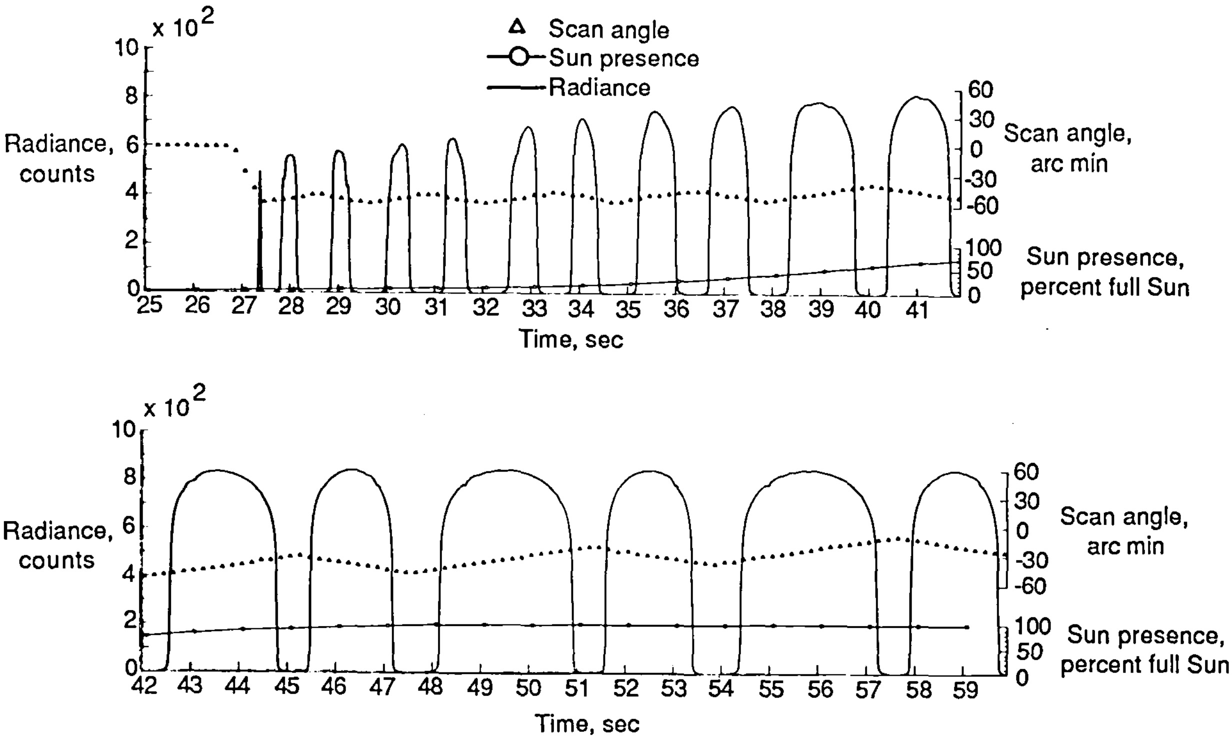


Figure 6. Typical SAM II radiometric data for a sunrise measurement. (Taken from McCormick et al. 1979.)

description of the data processing scheme is discussed in Chu and McCormick (1979).

An example of the results of the data inversion can be seen in figure 7. The aerosol extinction profiles shown are from SAM II irradiance data collected July 16, 17, and 19, 1979, and are representative of background aerosol conditions in the Arctic (McCormick et al. 1981). The error bars shown in the figure are estimates of 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. These data are interpolated to the geographical location of the SAM II observation based on their gridded analyses. Below 25 km, where aerosol extinction exceeds molecular extinction by 50 percent, the total error in the retrieved aerosol extinction coefficient is typically $\leq$10 percent. Therefore, even under most background or nonvolcanic conditions, the extinction due to the stratospheric aerosol can be measured to within 10-percent accuracy.

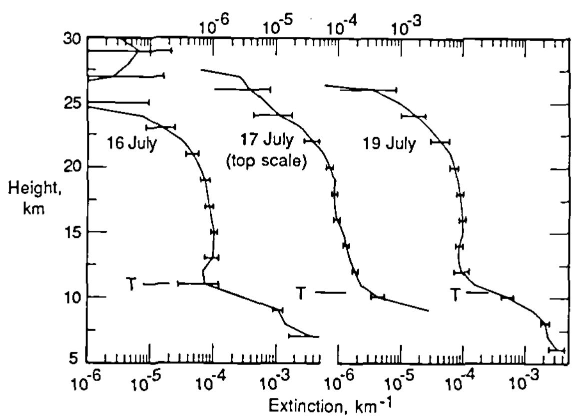


Figure 7. Typical SAM II extinction profile. (Taken from McCormick et al. 1981.)

Data Validation

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 (Russell et al. 1981b). 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 μm for comparison with the SAM II data. Figure 8 shows the results of those comparisons from the Sondrestrom experiment (Russell et al. 1981a). During the second experiment, SAGE I, 1.0-μm extinction measurements were also made. Figure 9 shows the results of the SAM II-SAGE I, 1.0-μm extinction comparisons from the Poker Flat experiment (Russell et al. 1984). Other comparisons of the SAM II and SAGE I aerosol extinction measurements have also been made (Yue, McCormick, and Chu 1984).

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. These results clearly support the validity of SAM II extinction data and the error estimates derived from the 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. A listing of these anomalous profiles and a description of the data screening process are given in appendix A.

Data Products

The basic archived products of the SAM II data processing are the Beta and Aerosol Number Density Archive Tape (BANAT), archived at NSSDC, and a series of NASA SAM II reference publications containing representative graphics of the data set (e.g., McCormick 1981). Table 1 lists the volumes and the periods covered by each report to date. It is intended that additional reports be published to include all the data collected. The BANAT contains the altitude profiles of aerosol extinction coefficient, molecular extinction coefficient, and total extinction

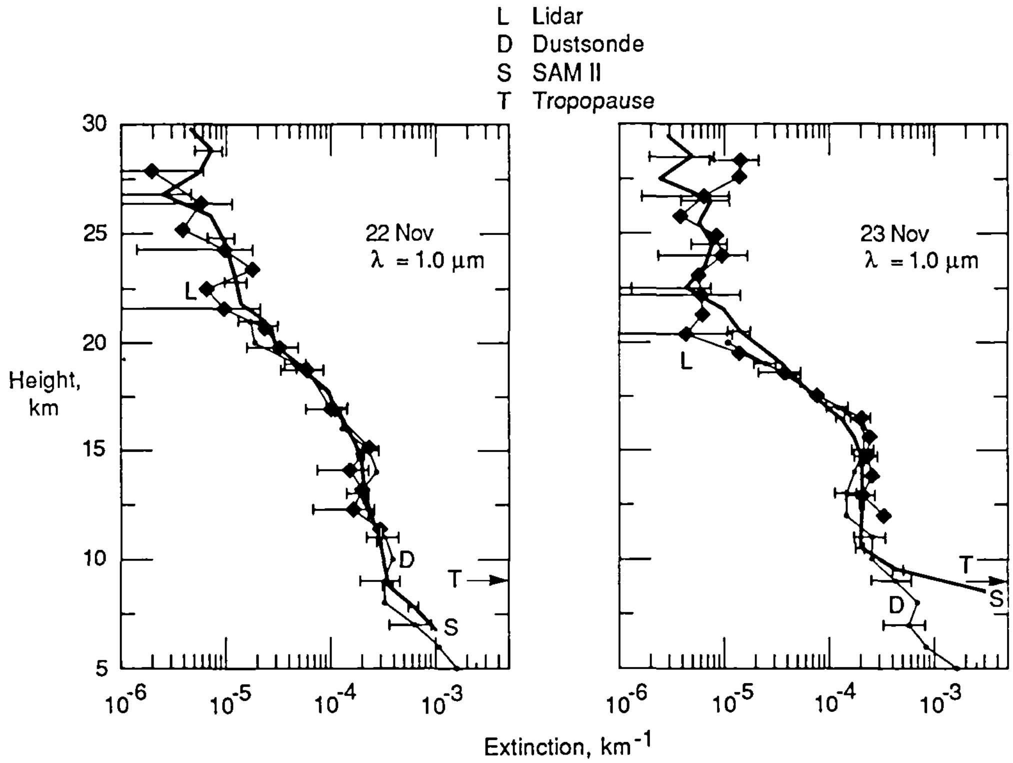


Figure 8. Comparison of SAM II measurements with dustsonde and lidar in November 1978. (Taken from Russell et al. 1981a.)

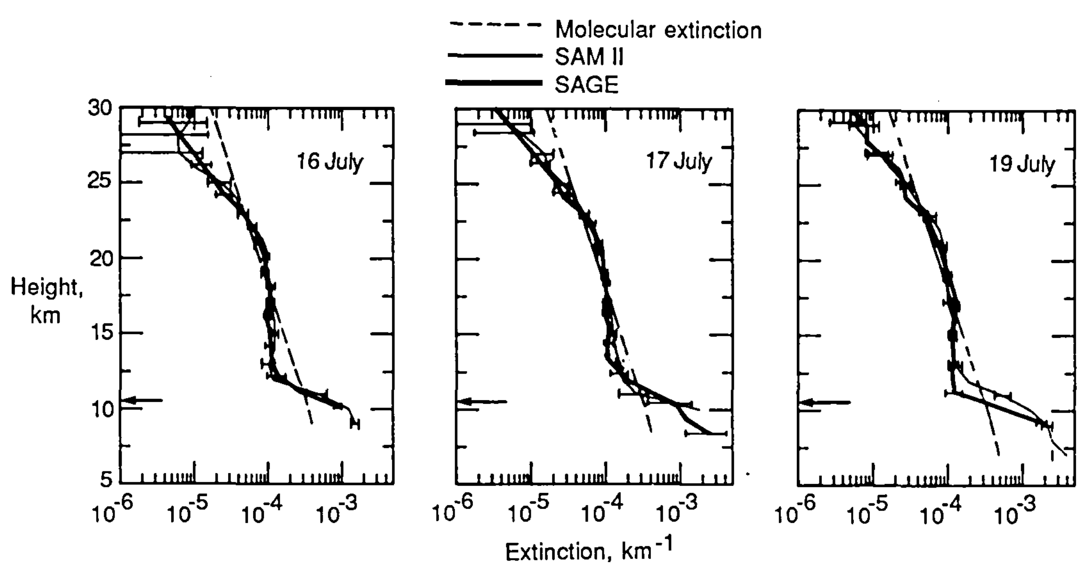


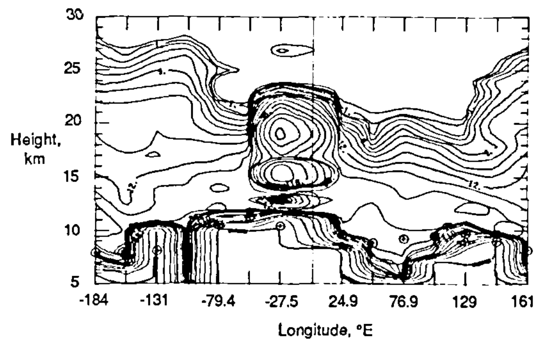
Figure 9. Comparison of SAM II with SAGE aerosol measurements in July 1979. (Taken from Russell et al. 1984.)

ratios (aerosol plus molecular divided by molecular extinction), along with the corresponding error estimates, for each sunrise and sunset event. There are 12 BANAT's per year; each covers a 1-month period and is written on a 9-track, 1600-bpi magnetic tape for archival at NSSDC. The BANAT format is described in appendix B.

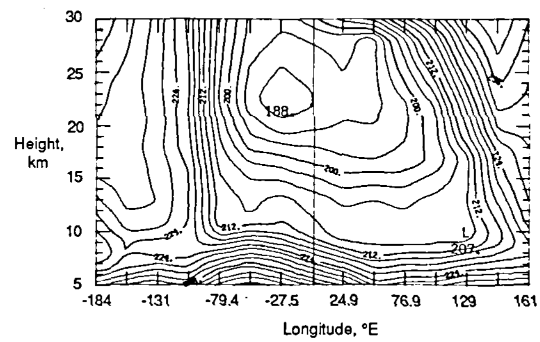
Aerosol number density profiles and the optical model used to generate the number densities from extinction coefficients are also included on the BANAT's for the first 4 years (November 1978 to October 1982). The stratospheric aerosol loading that resulted from numerous volcanic eruptions was sufficiently high in years 5 through 8 (November 1982 to October 1986) to invalidate the optical models developed for background conditions (Hofmann and Rosen 1984). The number density data for these years is thus eliminated from the BANAT's by zero filling the arrays on the tape.

Each NASA reference publication contains a description of aerosol distribution in both polar regions as well as selected graphics products for the 6-month period covered by each report. Aerosol extinction profiles, with corresponding NOAA temperature profiles, were separated by polar region and averaged over a week. Since the incremental change in latitude between successive measurement locations is small, the averages taken over a period of a week represent zonal averages within narrow latitude bands. These profiles are displayed with information about the variability of the averages depicted as horizontal error bars. Vertical cross sections of 1-μm aerosol extinction and temperature for a 1-day period are shown as a function of longitude. An example of these graphics products is illustrated in figure 10. These plots are to be used to indicate the fine structure of the aerosol distribution and to show when the zonal average is a poor representation of the observed data. A single day from each week was selected for presentation. Plots and tables of averaged weekly optical depth for both polar regions are also included in each NASA reference publication.

Polar stratospheric clouds (PSC's) or regions of enhanced extinction were observed by SAM II during both the Arctic and Antarctic local winters. The PSC'S had peak extinctions up to 10^{-2} km^{-1} or almost 2 orders of magnitude above background stratospheric aerosol. The occurrence of the PSC's also had a strong positive correlation with temperatures below 185 K (McCormick et al. 1982). Figure 10, isopleths of aerosol extinction and temperature for 1 day of SAM II observations, shows the manifestation of a PSC at 27°W longitude and its correlation with cold temperatures.



(a) Aerosol extinction isopleth in units of 10^{-5} per km as measured by SAM II.



(b) Corresponding temperature isopleth in degrees Kelvin.

Figure 10. Occurrence of polar stratospheric cloud on January 23, 1979. (Taken from McCormick 1981.)

Scientific Studies

The SAM II data have been used to develop a climatology of polar stratospheric aerosols, which allows the study of seasonal variability and trends. Numerous studies have also been conducted on atmospheric dynamics that use aerosols as conserved tracers and on stratospheric chemistry, which correlates observed aerosol variability with other atmospheric species. The following discussion briefly describes some of the results of these investigations using the SAM II observations.

This discovery has led to numerous other investigations, including studies of the annual variability of PSC's (McCormick and Trepte 1986), possible formation mechanisms (Steele et al. 1983), and possible effects on polar climate (Hamill and McMaster 1984). Most recently, the PSC's involvement in the removal of ozone and other trace gases through heterogeneous reactions in the Antarctic spring is being investigated by several researchers (Hamill, Toon, and Turco 1986; McCormick and Larsen 1986).

The SAM II data have been used to study atmospheric dynamics. Northern Hemispheric aerobreak extinction measurements are correlated with constant-pressure altitude maps and show significant differences in the profile inside and outside the Arctic cyclonic polar vortex, as shown in figure 11 (McCormick et al. 1983). It has been shown that as the polar vortex intensifies during the Northern Hemispheric winter, a gradient of aerosol extinction ratio is established across the polar-night jet stream that is associated with a subsidence within the vortex. Descent rates near 20 km at the center of the vortex are estimated to be 0.8 mm per second; these rates result in an estimated total aerosol mass of 7000 tons transferred downward through the base of the vortex for the entire season (Kent et al. 1985).

Similar studies have been conducted during Northern Hemispheric warmings; these studies correlate the variations in stratospheric aerosols with other atmospheric species (Wang and McCormick 1985).

A stratospheric aerosol polar climatology is also being devmeloped from the SAM II data for use in studies of the seasonal variability and trends in stratospheric aerosol loading. Figure 12 shows the polar stratospheric aerosol optical depth record observed by SAM II for the first 7 years of operation (McCormick and Trepte 1987). The weekly averaged data clearly show the influence of seasonal variation and volcanic perturbations. Background aerosol conditions are observed immediately following launch with optical depths of 0.001 to 0.002 in both hemispheres. Periodic enhancements in the optical depth are observed during local winter in both hemispheres, but the increase in the Antarctic is most evident (almost 1 order of magnitude). These enhancements are the result of the PSC formation discussed previously and can persist for about 3 months. The enhancement in optical depth due to PSC's is greatest in the Antarctic because of the colder temperatures in the average austral winter stratosphere.

The perturbations in stratospheric aerosol optical depth due to volcanic activity are also shown in figure 12. These perturbations can easily be seen in the Northern Hemispheric data taken following the eruptions of Mount St. Helens in 1980 and the eruptions of Alaid and Pagan in 1981. Even more obvious is the large increase in optical depth observed in both hemispheres following the 1982 eruption of El Chichon. The impact of volcanic eruption is much more apparent in the Arctic because of the greater number of eruptions that occurred in the Northern Hemisphere during this period and because of the more favorable seasonal circulation pattern following those eruptions.

Concluding Remarks

This report has presented a description of the Stratospheric Aerosol Measurement (SAM) II instrument and its data collection, processing and validation, and a description of the Beta and Aerosol Number Density Archive Tape (BANAT) data archival product for use in scientific investigations of polar stratospheric aerosols. These data products are archived and can be ordered from the National Space Sciences Data Center (NSSDC), NASA Goddard Space Flight Center, Code 601, Greenbelt, Maryland 20771. When requesting the SAM II BANAT data, the product identification number (78-098A-06B) and the time period of interest should be specified. The BANAT data products are archived at NSSDC about 6 months after the data are collected, and 8 years of data are currently archived and available for researchers.

At the time of this report, 9 years of SAM II data have been collected, and the instrument continues to operate without problems. However, the Nimbus 7 spacecraft and the complement of scientific experiments, including SAM II, were only designed for a normal 1-year lifetime; therefore, the prospect of continued long-term observations is uncertain.

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Hampton, VA 23665-5225
May 13, 1988

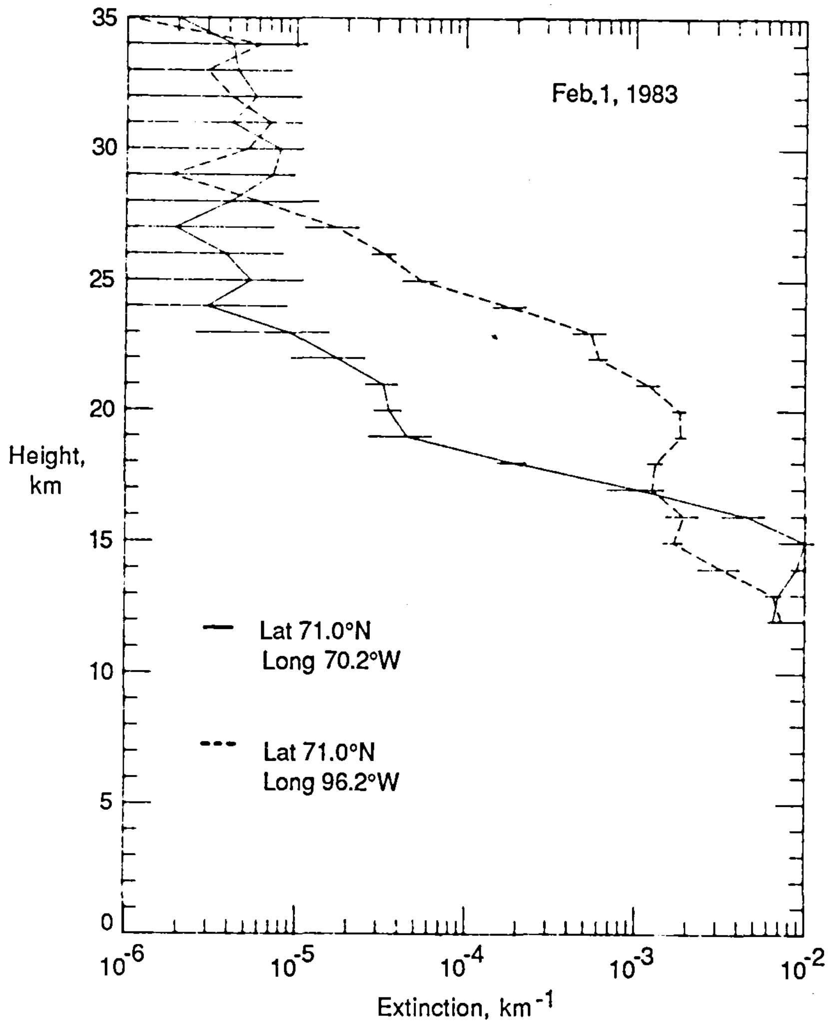

Figure 11. SAM II aerosol extinction measurements inside (solid line) and outside (dashed line) polar vortex. (Taken from McCormick et al. 1983.)

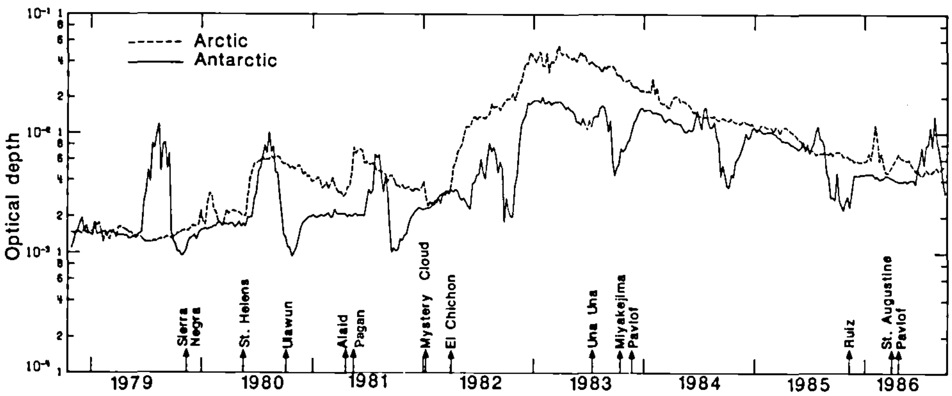

Figure 12. SAM II measured stratospheric aerosol optical-depth time histories. (Taken from McCormick and Trepte 1987.)

Appendix A

SAM II Quality Control

Anomalous extinction profiles have recently been found in the Stratospheric Aerosol Measurement (SAM) II data set covering the period from the middle of 1982 through 1983. Although some of these profiles exhibit the high extinction characteristic of Earth Radiation Budget (ERB) calibrations, the remainder of the questionable profiles appear to be related to problems in determining the correct scan altitude during periods of heavy stratospheric aerosol loading. To determine the extent of the problem, the entire SAM II data base has been screened for bad profiles by plotting extinction isopleths on a daily basis as a function of altitude and longitude. Individual profiles which are not consistent with adjacent profiles (either in time or longitude) can be easily identified when plotted in this form. Suspicious profiles are then checked against the microfiche plots of extinction and transmission. Although this visual screening process is somewhat subjective, the primary concern is with those profiles which are obviously incorrect. Instances where the profiles are questionable, but for which it was not possible to reach a definite conclusion, are also listed in the following tables. The user should inspect these profiles and decide whether or not they should be included in the particular study being undertaken. The anomalous profiles have been categorized in the tables as follows:

Cause:

- E — ERB calibration. Delete all these profiles.
- E+ — Extinction profile is similar to that for an ERB calibration, but the profile shape suggests that there are additional problems. Delete all these profiles.
- SP — Sunspots. These appear to be a problem only above 20 km. Whether or not these profiles should be deleted depends on how the SAM II data are being used. Only the worst cases have been listed in the tables. There are many more profiles remaining in the data base which show erratic high extinction values at high altitude and are probably caused by incomplete removal of sunspot perturbations.
- ADB — Altitude determination is bad. The qualifier (described subsequently) determines whether the profile should be deleted.
- ? — Cause unknown. Qualifier determines whether the profile should be deleted.

Qualifier (in parentheses):

- D — Delete profile from consideration.
- ? — End user must inspect the profile to decide what altitude range of the profile can be used.

Asterisks following the orbit numbers in the following tables indicate those profiles which have been identified previously as perturbed by an ERB calibration. Sunrise is SR(S), which always occurs in the southern hemisphere; sunset is SS(N), which always occurs in the northern hemisphere. Days for which no profiles are available are listed at the end of each yearly table. It is intended that these tables be updated as new data are processed or as old data are reprocessed.

1978

ORBIT NUMBER	MONTH/DAY	0-SR(S) 1-SS(N)	CAUSE
253	NOV/11	1	ADB(D)
490*	NOV/28	0	E
797*	DEC/20	1	E

1979

ORBIT NUMBER	MONTH/DAY	0-SR(S) 1-SS(N)	CAUSE
1073	JAN/09	0	SP
1552*	FEB/13	0	E
1766	MAR/01	1	ADB(D)
1773*	MAR/01	0	E
1987	MAR/17	1	ADB(D)
2105*	MAR/25	0	E
2105*	MAR/25	1	E
2568*	APR/28	0	E
2568*	APR/28	1	E
2836	MAY/17	0	ADB(D)
2928*	MAY/24	0	E
3259*	JUN/17	0	E
3259*	JUN/17	1	E
3591*	JUL/11	0	E
3591*	JUL/11	1	E
3923*	AUG/04	0	E
4254*	AUG/28	0	E
4586*	SEP/21	0	E
4586*	SEP/21	1	E
4691	SEP/28	0	SP
5097*	OCT/28	1	E
5130	OCT/30	1	?(?)
5249*	NOV/08	1	E
5560*	NOV/30	1	E
5581*	DEC/02	0	E
5915*	DEC/26	0	E

1980

ORBIT NUMBER	MONTH/DAY	0-SR(S) 1-SS(N)	CAUSE
6224	JAN/17	0	ADB(D)
6244*	JAN/19	0	E
6264	JAN/20	1	ADB(D)
6576*	FEB/12	0	E
6696	FEB/20	1	E
7085	MAR/19	0	ADB(D)
7239	MAR/31	0	E
7571*	APR/24	0	E
7866	MAY/15	0	ADB(D)
7903*	MAY/18	0	E
8278	JUN/14	1	SP
8340	JUN/18	1	SP
8567*	JUL/05	1	E
8567*	JUL/05	0	E
8897*	JUL/29	1	E
9280	AUG/25	1	SP
9295	AUG/26	0	SP
9561*	SEP/15	0	E
9892*	OCT/09	0	E
9954	OCT/13	0	SP
10225*	NOV/02	1	E
10887*	DEC/20	1	E

NO METEOROLOGICAL DATA FOR THE FOLLOWING DAYS:
MARCH 5, 6, 7, 8, 9
AUGUST 10, 11
DECEMBER 15, 16

1981

ORBIT NUMBER	MONTH/DAY	0-SR(S) 1-SS(N)	CAUSE
11219*	JAN/13	0	E
11549*	FEB/05	0	E
11549*	FEB/05	1	E
11882*	MAR/01	0	E
11882*	MAR/02	1	E
12214*	MAR/26	0	E
12878*	MAY/13	0	E
13210*	JUN/06	1	E
13873*	JUL/24	1	E
14205*	AUG/17	0	E
14264	AUG/21	1	SP
14291	AUG/23	1	SP
14536*	SEP/10	0	E
14868*	OCT/04	0	E
15021	OCT/15	1	SP
15200	OCT/28	0	E
15533*	NOV/21	0	E
15658	NOV/30	0	ADB(D)
15788	DEC/09	0	SP+ADB(D)
15863*	DEC/15	0	E
14291	AUG/23	0	SP

1982

ORBIT NUMBER	MONTH/DAY	0-SR(S) 1-SS(N)	CAUSE
16195*	JAN/08	0	E
16195*	JAN/08	1	E
16306	JAN/16	0	SP+ADB(D)
16858*	FEB/25	0	E
16858*	FEB/25	1	E
17156	MAR/18	0	E+ADB(D)
17190*	MAR/21	0	E
17190*	MAR/21	1	E
17521*	APR/14	1	E
17853*	MAY/08	1	E
18185*	JUN/01	0	E
18185*	JUN/01	1	E
18517*	JUN/25	0	E
18517*	JUN/25	1	E
18595	JUN/30	0	ADB(D)
18678	JUL/06	0	ADB(D)
18848*	JUL/19	0	E
18848*	JUL/19	1	E
19110	AUG/07	1	?(D)
19118	AUG/07	0	SP+ADB(?)
19512*	SEP/05	0	E
19512*	SEP/05	1	E
19649	SEP/15	1	ADB(D)
19844*	SEP/29	0	E
19844*	SEP/29	1	E
19852	SEP/29	1	ADB(D)
20553	NOV/19	0	ADB(D)
20629	NOV/24	0	ADB(D)
20643	NOV/25	1	E
20679	NOV/28	0	ADB(D)
20684	NOV/28	1	E
20753	DEC/03	1	E
20796	DEC/06	1	SP
20804	DEC/07	1	ADB(D)
20851	DEC/10	1	?(?)
20892	DEC/13	0	ADB(D)
21001	DEC/21	0	ADB(?)
21016	DEC/22	0	ADB(D)
21065	DEC/26	1	ADB(D)
21011	DEC/22	0	ADB(D)
21123	DEC/30	0	ADB(D)
21137	DEC/31	0	ADB(D)

NO METEOROLOGICAL DATA FOR THE FOLLOWING DAYS:
JANUARY 17, 18
JULY 13, 14, 27, 28, 29, 30
AUGUST 12, 13

1983

ORBIT NUMBER	MONTH/DAY	0-SR(S) 1-SS(N)	CAUSE
21178	JAN/03	0	ADB(D)
21220	JAN/06	0	ADB(D)
21245	JAN/08	0	ADB(D)
21416	JAN/20	0	ADB(D)
21417	JAN/20	0	ADB(D)
21834*	FEB/20	1	E
21918	FEB/26	0	ADB(D)
22436	APR/04	0	ADB(D)
22444	APR/05	1	ADB(D)
22757	APR/27	0	ADB(D)
22839	MAY/03	1	E
22860	MAY/05	0	ADB(D)
23037	MAY/18	1	ADB(D)
23052	MAY/19	0	ADB(?)
23298	JUN/05	0	SP
23369	JUN/11	0	SP
23516	JUN/21	1	E+?(D)
23723	JUL/06	0	ADB(D)
23831	JUL/14	1	ADB(D)
23876	JUL/17	0	ADB(?)
23985	JUL/25	0	E
24292	AUG/16	0	SP+ADB(D)
24394	AUG/24	1	ADB(D)
24695	SEP/15	1	ADB(D)
25060	OCT/11	1	ADB(D)
25712	NOV/27	0	ADB(D)
25834	DEC/06	0	ADB(D)
26176	DEC/31	0	ADB(D)

1984

ORBIT NUMBER	MONTH/DAY	O-SR(S) 1-SS(N)	CAUSE
26821	FEB/15	1	E
27152	MAR/10	1	E
27474	APR/03	1	E
27811	APR/27	1	SP
28894	JUL/14	0	ADB(D)
30064	OCT/07	1	ADB(D)
30093	OCT/09	0	ADB(D)
30257	OCT/21	0	ADB(D)
30420	NOV/02	0	E
30792	NOV/29	1	E

1985

ORBIT NUMBER	MONTH/DAY	0-SR(S) 1-SS(N)	CAUSE
31684	FEB/01	0	E
32021	FEB/25	0	E
33210	MAY/23	1	ADB(D)
33491	JUN/12	1	SP
33760	JUL/01	0	?(D)
33925	JUL/13	0	ADB(D)
33981	JUL/17	0	ADB(D)
33995	JUL/18	0	ADB(D)
34051	JUL/22	0	ADB(D)
34078	JUL/24	0	ADB(D)
34578	AUG/29	1	ADB(D)

FOLLOWING DAYS HAVE NO EVENTS:
JULY 2
MAY 27, 28, 29, 30, 31

1986

ORBIT NUMBER	MONTH/DAY	O-SR(S) 1-SS(N)	CAUSE
36512	JAN/16	0	ADB(?)
36713	JAN/31	1	E
36817	FEB/07	0	E
37032	FEB/23	0	E
37571	APR/03	0	E
37979	MAY/02	0	E
38390	JUN/01	0	ADB(?)
38525	JUN/11	0	ADB(?)

FOLLOWING DAYS HAVE SEVERAL MISSING EVENTS:
MARCH 21, 22, 23, 24, 25, 26, 27, 28
MAY 22
JUNE 8
JULY 1 THROUGH AUG 4 (MANY SUNSET EVENTS MISSING)

Appendix B

BANAT Format

The SAM II Beta and Aerosol Number Density Archive Tapes (BANAT's) each contain processed SAM II data for 1 month along with coincident meteorological (MET) data provided by the National Oceanic and Atmospheric Administration (NOAA). They are generated at Langley Research Center, Hampton, Virginia, on a Control Data Corporation Cyber series computer and written on 9-track, 1600-bpi magnetic tapes. They are then shipped to Goddard Space Flight Center for archival and distribution through the National Space Sciences Data Center (NSSDC).

The BANAT gross format is shown in figure B1. The first file contains the Nimbus Operating System (NOPS) Standard Header Record written twice in EBCDIC. The second file consists of two records defining the optical model codes for sunrise (SR) and sunset (SS) events. This is followed by a data file for each day in the month. Each daily data file contains eight data records (four each for sunrise and sunset events). The last file on the tape is the Trailer Documentation File, which provides a history of the weekly SAM II data tapes used to generate the BANAT. The Trailer Documentation File is not present on the first 2 years of BANAT's (i.e., before November 1980). The BANAT is terminated with two end-of-file marks.

Standard Header

All magnetic tapes used as interfaces within NOPS require some form of internal identification. A standardized series of records in the initial file on each tape is used and called a NOPS standard header file. Each standard header file is written in EBCDIC so that it can be easily printed for quick identification of the tape. The standard header file consists of two duplicate standard header records. The standard header record is a physical record consisting of five logical records of 126 EBCDIC characters each. A detailed description of the format of these records is contained in "NOPS Requirements Document #NG-45, Tape Specification T454051 SAM II BANAT," which is distributed with each tape.

Optical Model File

This file contains the optical model information used for converting aerosol extinction to number density. These models became invalid after the first 4 years (November 1978 to October 1982) because of the heavy aerosol loading following the eruption of El Chichon. After the first 4 years, the model in this file is zero filled. There are two records in this file; the first contains sunrise models, and the second contains sunset model codes. Both records have the same format, which is described as follows:

1. Physical record number (12 bits)—Number of this record within file number two. It starts at 1 and increases by 1 to a total of two records.
2. Type of event (4 bits)—Code word for whether the data correspond to a sunrise or sunset event: 1 = Sunrise; 2 = Sunset.
3. Record identification (8 bits)—Identification of record type and the last record written in a file. The most significant bit (MSB) is set to "1" if the record is the last one written in the file. The second MSB is set to "0". The six least significant bits (LSB's) identify the type of record being read. The identifications are as follows:

	Sunrise	Sunset
Optical model codes	5	25

4. Month (12 bits)—A number ranging from 1 to 12, which indicates the number of the month within a calendar year.
5. Day (12 bits)—The day number which starts at 1 on the first day of each month.
6. Year (12 bits)—A number which provides the entire year (i.e., 1978).
7. Spares (24 bits)
8. Spares (24 bits)
9. Number of data values (12 bits)—Number of applicable elements in the altitude array and the optical model code array.
10. Origin of altitude range (12 bits)—Starting altitude, expressed in tenths of kilometers.
11. Altitude increment (12 bits)—Altitude increment, expressed in tenths of kilometers.
12. Altitude values—Altitudes corresponding to model codes, expressed in tenths of kilometers (81, 12-bit words).
13. Model scale (24 bits)—Scaling factor for data in the optical model codes array. True value = Bit value/Scaling factor
14. Model codes—Array of optical model codes which are a function of altitude and event. These values are expressed as scaled integers (81, 24-bit words).
15. Error scale (24 bits)—Scaling factor for data in optical model error array. True value = Bit value/Scaling factor

	Standard NOPS header
	End of record
	Standard NOPS header
	End of file
	Optical model codes (SR)
	End of record
	Optical model codes (SS)
	End of file
Repeat for number of days in month (maximum of 31 documentation and data files)	Documentation and data for aerosol number density (SR)
	End of record
	Documentation and data for aerosol coefficient of extinction (SR)
	End of record
	Documentation and data for molecular coefficient of extinction (SR)
	End of record
	Documentation and data for total extinction ratio (SR)
	End of record
	Documentation and data for aerosol number density (SS)
	End of record
	Documentation and data for aerosol coefficient of extinction (SS)
	End of record
	Documentation and data for molecular coefficient of extinction (SS)
	End of record
	Documentation and data for total extinction ratio (SS)
	End of file
	Trailer documentation file
	End of file
	End of file

Figure B1. BANAT gross format.

16. Error bars—Array of errors corresponding to optical model codes. These values are expressed as scaled integers (81, 24-bit words).
17. Spares (12 216 bits)
18. 1's complement check sum (12 bits)

The total length of the optical model record is as follows:

288 for 60-bit words

480 for 36-bit words

540 for 32-bit words

720 for 24-bit words

2160 for 8-bit bytes

Documentation/Data File

One documentation/data file is written for each day of the month. Each file consists of eight records, which are identical in format except for the type of data included (see 24g below). They are written in ascending record identification order (see 4 below); the first four records describe sunrise events and the next four records describe sunset events. The format for each record is shown in figure B2 and is described as follows:

1. Physical record number (12 bits)—Number of this record within a file. It starts at 1 and increases by 1 to a total of 8 per file.
2. Spares (2 bits)
3. MET code (2 bits)—Flag which defines the type of meteorological processing utilized. The codes are as follows:

   0 = Real data

   1 = Model MET data or MET data from last orbit

   2 = No MET data

4. Record identification (8 bits)—Identification of record type, last record written in a file, and records in the last data file on the tape. The MSB is set to "1" if the record is the last one written in the file. The second MSB is set on all records in the last data file on the tape. The six LSB's identify the type of record being read. The identifications are as follows:

	Sunrise	Sunset
Documentation/aerosol number density record	1	21
Documentation/aerosol coefficient of extinction record	2	22
Documentation/molecular coefficient of extinction record	3	23
Documentation/total extinction ratio record	4	24
Missing data	63	63

5. Month (12 bits)—A number ranging from 1 to 12 which indicates the number of the month within a calendar year.
6. Day (12 bits)—The day number which starts at 1 on the first day of each month.
7. Year (12 bits)—A number which provides the entire year (i.e., 1978).
8. Spares (12 bits)
9. Spares (24 bits)
10. Spares (24 bits)
11. Data scale (24 bits)—Scaling factor for the data contained within the data array. True value = Bit value/Scaling factor. Same scaling is used for error array.
12. Type of event (12 bits)—Code word for whether the data correspond to a sunrise or sunset event: 1 = Sunrise; 2 = Sunset
13. Number of altitude locations (12 bits)—Total number of altitudes to which the elements of the data array correspond.
14. Number of longitude locations (12 bits)—Total number of longitude locations per event type per day.
15. Number of latitude locations (12 bits)—Total number of latitude locations per event type per day.
16. Initial data orbit number (24 bits)—Starting orbit number for a given file (i.e., day) and type of event. A data orbit begins at a descending node.
17. Final data orbit number (24 bits)—Ending orbit number for a given file (i.e., day) and type of event.
18. Latitude bandwidth (12 bits)—Bandwidth covered by a given orbit (approximately 1 degree). This number is expressed in hundredths of a degree.
19. Spares (12 bits)
20. Array of times (GMT) (14, 32-bit words)—Times that correspond to the zero kilometer point for a

Fields	Number of bits
Physical record number (12); MET code (2); Spares (2); Record identification (8)	24
Month (12); Day (12)	48
Year (12); Spares (12)	72
Spares (24)	96
Spares (24)	120
Data scale (24)	144
Type of event (12); Number of altitudes (12)	168
Number of longitudes (12); Number of latitudes (12)	192
Initial orbit number (24)	216
Final orbit number (24)	240
Latitude bandwidth (12); Spares (12)	264
Times corresponding to 0 km point (14 × 32); Spares (8)	720
Altitude origin (12); Altitude increment (12)	744
Spares (3 × 24)	816
Altitudes corresponding to each data point (81 × 12); Spares (12)	1800
Longitudes (14 × 12)	1968
Latitudes (14 × 12)	2136
Tropopause heights (14 × 12)	2304
Spares (14 × 12)	2472
Data array stored by altitude/orbit (81 × 14 × 24)	29688
Data error array stored by altitude/orbit (81 × 14 × 24)	56904
Orbit numbers (14 × 24)	57240
Spares (348); Check sum (12)	57600

Figure B2. Documentation/data record format.

given longitude-latitude pair. Time is in integer milliseconds.

21. Spares (8 bits)
22. Two control words for altitude range—Origin (12 bits); interval between independent coordinate points (12 bits).
23. Spares (3, 24-bit words)
24. (a) Array containing altitude values corresponding to each data point (81, 12-bit words)—Altitude value for every increment from 0 to 80 km (81 values given in tenths of kilometers).

    (b) Spares (12)

    (c) Array containing longitude values corresponding to each event (14, 12-bit words)—Longitude given in tenths of degrees and output as 0 to 3599 tenths of degrees east from the Greenwich Meridian.

    (d) Array containing latitude values corresponding to each event (14, 12-bit words)—Latitude given in tenths of degrees. Zero represents the South Pole and 1800 represents the North Pole.

    (e) Array containing tropopause height value corresponding to each MET profile (14, 12-bit words)—Tropopause given in tenths of kilometers.

    (f) Spares (14, 12-bit words)

    (g) AEROSOL NUMBER DENSITY ARRAY (number of particles/cm^3) (81 × 14, 24-bit words)—Cumulative number of particulates, for every orbit, with radii greater than or equal to 0.15 μm for each altitude value given in 24(a),

    or

    AEROSOL COEFFICIENT OF EXTINCTION DATA, km^{-1}

    or

    [1]MOLECULAR COEFFICIENT OF EXTINCTION DATA, km^{-1}

    or

    TOTAL EXTINCTION RATIO DATA, nondimensional

    (h) AEROSOL NUMBER DENSITY ERROR ARRAY (81 × 14, 24-bit words)—One value for each data value given in 24(g),

    or

    AEROSOL COEFFICIENT OF EXTINCTION ERROR ARRAY

    or

    [2]MOLECULAR COEFFICIENT OF EXTINCTION ERROR ARRAY

    or

    TOTAL EXTINCTION RATIO ERROR ARRAY

25. Array containing orbit numbers corresponding to each event (14, 24-bit words)—Orbit numbers for each event.
26. Spares (348 bits)
27. 1's complement check sum (12 bits)—Last 12 bits of the physical record. Each 24-bit word output to the tape is divided into two, 12-bit words. The 12-bit words are added together, and any overflow over 12 bits is added into the LSB side of the summation word. The final summation word is placed as the last word of the record as the check sum.

Trailer Documentation File

If there is a trailer documentation file, it is the last file on the tape and consists of all NOPS standard header records from the weekly SAM II data tapes that went into the making of the BANAT. The first 2 years of BANAT's did not have trailer documentation files. A detailed description of the format of this file is contained in "NOPS Requirements Document #NG-45, Tape Specification T454051 SAM II BANAT," which is distributed with each tape.

[1]MET temperatures (19, 24-bit words)—Temperatures, in degrees Kelvin, for each event are contained in words 42–60 of the molecular coefficient of extinction array. Each profile contains 18 temperatures that correspond to 18 standard pressure levels in millibars as follows: 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 10, 5, 2, 1, and 0.4. The 19th temperature corresponds to the variable tropopause pressure. MET altitude (19, 24-bit words)—Altitudes, in tenths of kilometers, that correspond to the pressures described above are contained in words 62–80 of the molecular coefficient of extinction array.

[2]MET temperature errors (19, 24-bit words)—Temperature errors, in degrees Kelvin, that correspond to the MET temperatures described above, are contained in words 42–60 of the molecular coefficient of extinction error array.

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Table 1. SAM II Reference Publications

Reference publication	Volume	Coverage
RP-1081 (December 1981)	I	October 1978–April 1979
RP-1088 (March 1982)	II	April 1979–October 1979
RP-1106 (June 1983)	III	October 1979–April 1980
RP-1107 (June 1983)	IV	April 1980–October 1980
RP-1140 (May 1985)	V	October 1980–April 1981
RP-1141 (May 1985)	VI	April 1981–October 1981
RP-1164 (August 1986)	VII	October 1981–April 1982
RP-1165 (August 1986)	VIII	April 1982–October 1982

NASA National Aeronautics and Space Administration	Report Documentation Page	
1. Report No. NASA RP-1200	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SAM II Data User's Guide		5. Report Date July 1988
		6. Performing Organization Code
7. Author(s) W. P. Chu, M. T. Osborn, and L. R. McMaster		8. Performing Organization Report No. L-16377
9. Performing Organization Name and Address NASA Langley Research Center Hampton, VA 23665-5225		10. Work Unit No. 665-10-40-04
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, DC 20546-0001		13. Type of Report and Period Covered Reference Publication
		14. Sponsoring Agency Code

15. Supplementary Notes
W. P. Chu and L. R. McMaster: Langley Research Center, Hampton, Virginia.
M. T. Osborn: ST Systems Corporation (STX), Hampton, Virginia.

16. Abstract
This document is intended to serve as a guide to the use of the data products from the Stratospheric Aerosol Measurement (SAM) II experiment for scientific investigations of polar stratospheric aerosols. Included is a detailed description of the Beta and Aerosol Number Density Archive Tape (BANAT), which is the SAM II data product containing the aerosol extinction data available for these investigations. Also included are brief descriptions of the instrument operation, data collection, processing and validation, and some of the scientific analyses that have been conducted to date.

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