

Earth Sc.

#543

SAGE
PROFILE DATA

79-013A-01C

79-013A-01D

79-013A-01E

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1. INTRODUCTION:

The documentation for this data set was originally on paper, kept in NSSDC's Data Set Catalogs (DSCs). The paper documentation in the Data Set Catalogs have been made into digital images, and then collected into a single PDF file for each Data Set Catalog. The inventory information in these DSCs is current as of July 1, 2004. This inventory information is now no longer maintained in the DSCs, but is now managed in the inventory part of the NSSDC information system. The information existing in the DSCs is now not needed for locating the data files, but we did not remove that inventory information.

The offline tape datasets have now been migrated from the original magnetic tape to Archival Information Packages (AIP's).

A prior restoration may have been done on data sets, if a requestor of this data set has questions; they should send an inquiry to the request office to see if additional information exists.

2. ERRATA/CHANGE LOG:

NOTE: Changes are made in a text box, and will show up that way when displayed on screen with a PDF reader.

When printing, special settings may be required to make the text box appear on the printed output.

Version	Date	Person	Page	Description of Change
01				
02				

3 LINKS TO RELEVANT INFORMATION IN THE ONLINE NSSDC INFORMATION SYSTEM:

<http://nssdc.gsfc.nasa.gov/nmc/>

[NOTE: This link will take you to the main page of the NSSDC Master Catalog. There you will be able to perform searches to find additional information]

4. CATALOG MATERIALS:

- a. Associated Documents To find associated documents you will need to know the document ID number and then click here.
<http://nssdcftp.gsfc.nasa.gov/miscellaneous/documents/>

- b. Core Catalog Materials

REQ. AGENT

RAND NO.

ACQ. AGENT

SAR

CYW

SAGE

OZONE PROFILE DATA

79-013A-01C **ESAC-00035**

This data set consists of 9-track, 6250 BPI, 1 file, Binary Magnetic Tapes.

<u>D#</u>	<u>C#</u>	<u>TIME SPANS</u>
D-74290	C-26171 ✓	02/21/79 - 11/30/79
D-74291	C-26172 ✓	12/01/79 - 11/30/80
D-82245	C-27832 ✓	12/01/80 - 11/18/81

SAGE

NITROGEN DIOXIDE PROFILE DATA

79-013A-01D **ESAC-00060**

This data set consists of 9-track, 6250 BPI, 1 file, Binary Magnetic Tapes.

<u>D#</u>	<u>C#</u>	<u>TIME SPANS</u>
D-82246	C-27833	02/21/79 - 11/30/79 ✓
D-82247	C-27834	12/01/79 - 11/30/80 ✓
D-82248	C-27835	12/01/80 - 11/18/81 ✓

SAGE

AEROSOL PROFILE DATA

79-013A-01E **ESAC-00027**

This data set consist of 9-track, 6250 BPI, 1 file, Binary Magnetic Data.

<u>D#</u>	<u>C#</u>	<u>TIME SPAN</u>
D-822450 82251	C-27851 27852	02/21/79 - 11/30/79 ✓
D-822449 82250	C-27836 27851	12/01/79 - 11/30/80 ✓
D-822451 D82249	C-27852 27836	12/01/80 - 11/18/81 ✓

Langley Research Center
Hampton, Virginia
23665-5225

*not for
general dist.
CWD 4/9*

Reply to Attn of

475

September 13, 1990

Mr. Ralph Post
NSSDC-Data Repository Receiving
Goddard Space Flight Center
Code 633
Greenbelt, MD 20771

Dear Ralph:

I am sending under separate cover the reprocessed SAGE I aerosol, ozone, and nitrogen dioxide data (9 tapes) for archival. This data should replace any existing SAGE I data you now have. The data covers the entire period that the satellite was operational (February 1979 - November 1981). A revised copy of the "SAGE I User's Guide" is enclosed with the tapes, a second copy is enclosed with this letter, and a third copy has been sent to Carolyn Ng.

If you have any questions regarding the data tapes or the "SAGE I User's Guide," please call Mr. Mike Rowland at FTS 928-2691 or me at FTS 928-2674.

Sincerely,

George L. Maddrea, Jr.
SAGE II Data Validation Manager

Enclosure

DRAFT

SAGE I Data User's Guide

L. R. McMaster
Langley Research Center
Hampton, Virginia

W. P. Chu
Langley Research Center
Hampton, Virginia

M. W. Rowland
ST Systems Corporation
Hampton, Virginia

I. Preface

The data products from the Stratospheric Aerosol and Gas Experiment (SAGE I), flown on the Application Explorer Mission II (AEM-2) spacecraft, have been archived on magnetic tapes at the National Space Sciences Data Center, NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, and are now available to researchers. The AEM-2 satellite was launched on February 18, 1979, but because of the failure of the spacecraft power subsystem, the mission was terminated on November 11, 1981. Over the operational life of the spacecraft, the instrument collected 33 months of scientific data, including vertical profiles of stratospheric aerosol, ozone, and nitrogen dioxide. This document is intended to serve as a guide for using these data sets in scientific investigations of stratospheric chemistry, related to aerosol, ozone, nitrogen dioxide, dynamics and climate change. The SAGE I data products, containing the aerosol extinction data at 1000 and 450 nm, the ozone concentration data, and the nitrogen dioxide concentration data, are described in detail in Appendixes B, C, and D. Also, there are brief descriptions of the instrument operation, data collection, processing and validation, and some descriptions of the scientific analyses that have been conducted.

Over the years, the SAGE I experiment development and research have been guided by the SAGE I Science Team, made up of the following people:

M. P. McCormick, Principal Investigator, NASA Langley Research Center; R. Craig, Florida State University; D. M. Cunnold, Georgia Institute of Technology; G. W. Gram, Georgia Institute of Technology; B. M. Herman, University of Arizona; M. Hirano, Kyoto University; D. E. Miller, British Met Office; D. G. Murcray, University of Denver; T. J. Pepin, University of Wyoming; W. G. Planet, NOAA NMC; and P. B. Russell, NASA Ames Research Center.

The efforts of the LaRC SAGE I Data Processing Team is also gratefully acknowledged.

II. Summary

The Stratospheric Aerosol and Gas Experiment I (SAGE I) instrument was launched on board the Applications Explorer Mission-2 (AEM-2) spacecraft, which was dedicated to the SAGE I mission. SAGE I provided global data collection of aerosol vertical extinction profiles, ozone vertical concentration profiles, and nitrogen dioxide vertical concentration profiles. The SAGE I instrument was a Sun photometer that measured the attenuation of solar radiation in four spectral regions through the Earth's atmosphere during spacecraft sunrise and sunset. The irradiance data were combined with spacecraft ephemeris and National Oceanic and Atmospheric Administration (NOAA) meteorological data and then numerically inverted to yield altitude profiles of aerosol extinction at 1000 and 450 nm 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. These data are currently archived at the National Space Sciences Data Center (NSSDC). This publication describes the SAGE I experiment, instrument characteristics and mode of operation, outlines the method of the data inversion, and explains to potential users the format of the data products archived at NSSDC. Results of the data validation and examples of data products are also presented to demonstrate the quality of the data and some of its applications in atmospheric studies.

III. Introduction

The SAGE I experiment was the second in a series of satellite experiments using the solar occultation technique to monitor and study stratospheric trace constituents. The Stratospheric Aerosol Measurement II (SAM II), the first automatic instrument to use this technique from space, was launched October 10, 1978, on the Nimbus-7 spacecraft (McCormick et al., 1979). The SAM II instrument uses a single spectral channel centered at the 1000 nm wavelength for monitoring stratospheric aerosols. Because of the Nimbus-7 sun-synchronous orbit SAM II collects stratospheric aerosol data exclusively in the two polar regions, extending from 64°-80° North latitude and 64°-80° South latitude. SAM II is still operational and in its twelfth year of data collection, at the time of the preparation of this paper.

The Stratospheric Aerosol and Gas Experiment (SAGE I) was launched February 18, 1979, aboard the Applications Explorer Mission-2 (AEM-2) spacecraft (McCormick et al., 1979). The SAGE I instrument had four spectral channels centered at the 1000, 600, 450, and 385 nm wavelengths for measuring the atmospheric extinction due to aerosols, ozone, and nitrogen dioxide. The AEM-2 spacecraft was in a 600 km, 56° inclined orbit to extend the latitudinal coverage for the solar occultation measurements from 79° South to 79° North latitude. The SAGE I instrument collected data for 3 years until the AEM-2 spacecraft power subsystem failed. The processed SAGE I data have been archived at the National Space Sciences Data Center (NSSDC), NASA Goddard Space Flight Center, Greenbelt, Maryland 20771.

The most recent of these solar occultation experiments, SAGE II, uses seven spectral channels for measuring the atmospheric extinction of aerosols, ozone, nitrogen dioxide, and water vapor and is in an orbit similar to that of SAGE I which allows data collection from 80° South to 80° North latitude. The SAGE II instrument was launched October 5, 1984, aboard the Earth Radiation Budget Satellite (ERBS) and is still collecting data after more than 5 years of operation at the time of the preparation of this paper (McMaster, 1986). As the SAGE II experiment data are processed and validated, they are also being archived at the NSSDC.

IV. AEM-2 SAGE I Mission

The scientific objective of the SAGE I experiment was to develop a global stratospheric aerosol, ozone, and nitrogen dioxide data base which could be used for the investigation of the spatial and temporal variation of these species caused by seasonal and short-term meteorological variations, atmospheric chemistry and microphysics, and transient phenomena, such as volcanic eruptions, and for the study of trends, atmospheric dynamics and transport, and potential climatic effects. The SAGE I sensor was designed to measure the attenuation of solar radiation resulting from atmospheric aerosol, ozone, and nitrogen dioxide at four spectral regions through the Earth's atmosphere during each spacecraft sunrise and sunset (see Figure 1). The SAGE I sensor was a dedicated instrument on the AEM-2 spacecraft with its orbit tailored to maximize geographic coverage for solar occultation sampling. The AEM-2 spacecraft, with its 600 km orbit altitude and 56° inclination, provided 15 sunrise and sunset measurements each day with successive sunrise or sunset measurements occurring about 25° longitude apart. The latitude of the sunrise or sunset measurements varied slowly from day-to-day providing near global coverage every three to four weeks. As the seasons changed, the maximum latitude of the SAGE I measurements range from 79° South to 79° North. Figure 2 shows the latitudinal coverage of the SAGE I mission over the 33 months of instrument operation. Because of the spacecraft power subsystem problems that reduced the power capacity of its batteries, sunrise measurements from SAGE I were terminated after June 1979.

V. Instrument Description and Operation

The SAGE I instrument was a four-channel Sun photometer using a cassegrainian telescope, holographic grating, and four silicon photodiodes to define the four spectral channel bandpass. Figure 3 is a schematic of the SAGE I instrument. Solar radiation was reflected off a scan 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 the four spectral regions centered at the 1000, 600, 450, and 385 nm 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 30 nm,

respectively. 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° so that measurements could be made at any azimuthal angle.

The operation of the instrument, during each sunrise and sunset measurement, was totally automatic. Prior to each sunrise or sunset encounter, 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-second and then acquired the Sun by rotating its scan mirror to the proper elevation angle. As the Sun traversed between the horizon and the 150 km tangent height, the elevation mirror scanned vertically across the solar disk (see Figure 4). The two solid lines in the figure represent the instrument image positions of the top and bottom edges of the solar disk during a sunset event. The gradual shrinking of the vertical shape of the solar image at the lower altitudes is caused by increasing atmospheric refraction. The dashed line represents the relative motion of the instrument elevation mirror as it scanned the Sun at a nominal rate of 15 arc minutes per second. 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. An example of the reconstructed radiance data from a sunrise observation is shown in Figure 5. Additional SAGE I instrument information can be found in McCormick et al. (1979).

VI. Data Processing

The SAGE I measurement data are processed based on the algorithm developed by Chu and McCormick (1979) and its updated revision as discussed by Chu et al. (1989). In this section, a brief outline of the SAGE I algorithm will be presented.

The measured irradiance from the SAGE I instrument can be related to the atmospheric optical properties using the Lambert-Beer relation:

$$H_{\lambda}(t) = \int F(\theta, \phi) S(\theta, \phi, t) \exp[-\tau_{\lambda}(\theta)] d\Omega \quad (1)$$

where $H_{\lambda}(t)$ is the measured irradiance at time t for channel wavelength of λ . $S(\theta, \phi, t)$ is the extraterrestrial solar radiance profile within the SAGE I spectral bandwidth at time t corrected for atmospheric refraction effects, $F(\theta, \phi)$ is the instrumental field-of-view function, $\tau_{\lambda}(\theta)$ is the optical thickness of the atmosphere for elevation angle θ and wavelength λ , ϕ is the azimuthal angle, and Ω is the total solid angle. Each elevation angle θ corresponds uniquely to an atmospheric tangent height h_t , the optical thickness $\tau_{\lambda}(\theta)$ can be related to atmospheric extinction properties through the following equation:

$$\tau_{\lambda}(h_t) = \int [\beta_a(h) + \beta_{O_3}(h) + \beta_{NO_2}(h) + \beta_{Ray}(h)] d\rho \quad (2)$$

where $\beta_a(h)$ is the aerosol extinction versus altitude profile, $\beta_{O_3}(h)$ is the ozone extinction versus altitude profile, $\beta_{NO_2}(h)$ is the nitrogen dioxide extinction versus altitude profile, $\beta_{Ray}(h)$ is the Rayleigh extinction versus altitude profile, and $\rho(h)$ is the path length through the atmosphere. The integral is evaluated from the spacecraft position to the Sun.

The processing of the SAGE I data to generate the various species profiles is done using the following three steps. First, the measured irradiance data are reduced, with the spacecraft ephemeris, atmospheric refraction calculation, and the Sun scan data, into profiles of limb optical thickness $\tau_{\lambda}(h_t)$ as a function of tangent height h_t in the atmosphere for each channel centered at wavelength λ . The high-altitude solar-scan profiles for each channel are used as calibrated solar-limb profiles out of the atmosphere. The second step is to subtract the estimated Rayleigh contribution along each limb path for each channel, and to separate the four spectral optical thickness profiles into aerosol optical thickness profiles at 1000 and 450 nm, ozone optical thickness profile at 600 nm, and nitrogen dioxide optical thickness profile at 385 nm following the method as described by Chu et al. (1989). The Rayleigh contributions are computed from coincident temperature versus height profiles provided by NOAA.

The third step is to invert the species optical thickness profiles into extinction profiles. By dividing the atmosphere into N homogeneous layers, the integral equation can be reduced to a system of linear equations as follows:

$$\tau_{\alpha i} = \sum_j^N \rho_{ij} \beta_{\alpha j} \quad (3)$$

where $\tau_{\alpha i}$ is the measured limb optical thickness at the i th layer for species α , ρ_{ij} is the path length of the Sun ray in the j th layer with its tangent height at the i th layer, and $\beta_{\alpha j}$ is the averaged extinction coefficient for species α in the j th layer. Equation (3) is then inverted with the Twomey's modification of Chahine's nonlinear relaxation algorithm as described by Chu et al. (1989). The SAGE I inversion algorithm generates vertical aerosol extinction profiles at 1000 and 450 nm and ozone and nitrogen dioxide vertical concentration profiles.

An example of the SAGE I aerosol data inversion can be seen in Figure 6. The 1000 nm aerosol extinction profiles shown are from SAGE I irradiance data collected April 24, 1979, at 5:45 and 7:22 GMT. They illustrate the background aerosol condition versus the presence of volcanic plume from the eruption of La Soufriere volcano (McCormick et al., 1982). The error bars shown in the figures are estimates of the random errors associated with the calculations of the aerosol extinction that result from both the radiometric measurement and the mathematical inversion. These errors (also archived at NSSDC along with the constituent profiles) include contributions from random measurement and inversion noise, NOAA temperature uncertainties, and altitude uncertainties. Below an altitude of 25 km, 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 can be measured to within 10 percent accuracy.

An example of the SAGE I ozone data inversion can be seen in Figure 7. The dashed line ozone partial pressure profile shown is from SAGE I irradiance data collected on April 2, 1979. It illustrates a typical mid-latitude springtime ozone profile. The profile shown by the solid line in the figure is a coincident ECC ozonesonde profile obtained at Garmisch (Reiter et al., 1982). The error bars associated with the SAGE I ozone profile are estimates of the random errors from the calculation of the ozone concentration profile. These errors are estimated similar to the errors in the aerosol extinction profiles. Generally, the uncertainties of the ozone concentration profiles retrieved from the SAGE I measurements are within the 10 percent range from cloud top height to about 45 km.

An example of the SAGE I NO₂ data inversion using the 385 nm channel can be seen in Figure 8. Chu and McCormick, 1986, suggest that measurement noise and difficulties associated with removing the Rayleigh, ozone, and aerosol contributions based on this single wavelength retrieval lead to an accuracy of approximately 20 percent as shown by the error bars. The SAGE II instrument uses two relatively narrow bandwidth channels to make the NO₂ measurement, resulting in a significant improvement in the profile accuracy from that experiment (Cunnold et al., 1990).

SAGE I data were originally processed and archived at NSSDC in 1985 using correction to NOAA upper pressure level temperature data as tabulated by Geller et al., (1983). However, the tabulated correction factors were later determined to have sign errors (Gelman et al., 1986). The effects on the original SAGE I results were most pronounced in low latitude-high altitude regions. As part of the NASA-World Meteorological Organization (WMO) ozone trends panel activities in 1987 (Watson et al., 1989), SAGE I data were reprocessed with the corrected temperature adjustment factors. This user's guide describes the revised SAGE I data set that has replaced the old SAGE I data set at NSSDC.

VII. Data Validation

Before being archived, the SAGE I data were validated through an extensive correlative measurements program. Two major correlative measurement experiments were conducted - the first over Natal, Brazil, in April 1979, and the second over Poker Flat Research Range, Alaska, in July 1979. In each experiment, correlative aerosol and ozone measurements were performed near coincident in space and time with the SAGE I measurements. The correlative aerosol data consisted of SAM II measured aerosol extinction profiles, airborne LIDAR-measured aerosol backscatter data, balloon-borne optical particle counter (dustsonde) data, and other in situ particle counter measurements. These correlative aerosol measurements were collected and converted to aerosol extinction for comparison with SAGE I aerosol data (Russell et al., 1981a, 1981b, and Russell et al., 1984). The correlative ozone data consisted of ECC ozonesondes measurements and rocket ozone data (McCormick et al., 1984). Figure 9 shows the aerosol data from the Poker Flat experiment showing the comparisons between the SAGE I, SAM II, the dustsonde, and the Ames Wire Impactor data (Russell et al., 1984). Other comparisons of the SAGE I and SAM II aerosol extinction measurements were also made (Yue et al., 1984). Figure 10 shows the SAGE I ozone measurements compared with the ECC ozonesondes at Poker Flat and Natal. Figure 11 shows the SAGE I ozone measurements compared with the rocket measurements at Poker Flat (McCormick et al., 1984). Comparisons of the SAGE I ozone data with other ECC data were also made (Reiter et al., 1982). Due to the unavailability of any unusually accepted NO₂ monitor the SAGE I nitrogen dioxide measurements were compared to available climatological as well as non-coincident balloon soundings and ground-based measurements (Chu and McCormick, 1986).

These comparisons between SAGE I aerosol, ozone, and nitrogen dioxide measurements and correlative data demonstrate the SAGE I measurements agree with the correlative data to within their measurement and conversion uncertainties. These results clearly support the validity of the SAGE I aerosol, ozone, and nitrogen dioxide data.

VIII. Data Products

The basic archived products from the SAGE I data processing are the aerosol profile tape, the ozone profile tape, and the nitrogen dioxide profile tape. The aerosol profile tapes contain the altitude profiles of aerosol extinction coefficient at 1000 and 450 nm, Rayleigh extinction coefficients at 1000 and 450 nm, and the extinction ratio of aerosol to Rayleigh at 1000 nm, plus the corresponding error estimates, for each sunrise and sunset event. Auxiliary information that was used for the processing of the SAGE I data, such as NOAA's temperature versus altitude data, ephemeris-calculated latitude and longitude at the tangent location, beta angle of the spacecraft orbit (angle between the spacecraft orbit plane and the earth-sun direction), and the event duration, is also included on the profile tape. There is one aerosol profile tape per year that covers twelve months' data from December of one year to November of the

next year (winter through fall). The tapes are formatted as 6250-bpi, 9-track tapes and are archived at NSSDC. The aerosol profile tape record format is described in Appendix B.

The ozone profile tapes contain the sunrise and sunset altitude profiles of ozone number density and mixing ratio, plus their corresponding error estimates. They contain the same auxiliary information as in the aerosol profile tapes. There is one ozone profile tape per year that covers twelve month's data from December on one year to November of the next year. The tapes are formatted as 6250-bpi, 9-track tapes and are archived at NSSDC. The ozone profile tape format is described in Appendix C.

The nitrogen dioxide profile tapes contain SAGE I nitrogen dioxide data in the same format as the ozone profile tapes. Similarly, there is one nitrogen dioxide data tape per year that covers twelve months' data from December of one year to November of the next year. The nitrogen dioxide profile tape format is described in Appendix D.

Appendixes B, C, and D refer to Appendix A, "Meteorological Data Notes" to explain the NMC-supplied meteorological fields in the data records of the tapes. Appendix A also explains how the meteorological data were handled by the SAGE I processing team.

IX. Scientific Studies

The SAGE I data have been used to perform a variety of atmospheric studies of atmospheric chemistry and dynamics, history of volcanic perturbation, and the ozone and nitrogen dioxide long-term trends. The following discussion briefly describes some results of these investigations using the SAGE I aerosol, ozone, and nitrogen dioxide data.

SAGE I aerosol data provided the first global description of volcanic perturbation of the stratospheric dust layer during the 33 months that SAGE I was in operation (Kent and McCormick, 1984). Figure 12 shows the time history of global stratospheric aerosol optical depth from 1979 to 1981 using both SAGE I and SAM II aerosol measurements. It shows the effects on the total stratospheric aerosol loading because of the different volcanic injections. The two wavelengths of aerosol extinction coefficients obtained from the SAGE I measurements have been used to estimate the stratospheric aerosol size information, spatial distribution, and temporal evolution (Lenoble and Pruvost, 1983; Yue and Deepak, 1983; Yue and Deepak, 1984).

The primary goal of the SAGE I mission was to monitor stratospheric trace species. However, SAGE I measurements did penetrate into the troposphere at the cloud free regions. Studies of the aerosol in the free troposphere, as measured by SAGE I, have been performed to study the seasonal variabilities (Kent et al., 1988). Also, the SAGE I

tropospheric data can be used to generate a cirrus cloud climatology (Woodbury and McCormick, 1986). Figure 13 illustrates a global map showing the frequency of occurrence of the high cirrus that was developed by the SAGE I data.

SAGE I aerosol, ozone, and nitrogen dioxide data have also been used for the studies of atmospheric dynamics. For example, high latitude aerosol, ozone, and nitrogen dioxide data have been used to study the stratospheric sudden warming phenomena (Wang and McCormick, 1985; Nagatani et al., 1985; Chu and McCormick, 1986). SAGE I ozone data have been used to study the latitudinal transport in the atmosphere caused by wave activities (Wang et al., 1984).

SAGE I ozone and nitrogen dioxide data have also been used to study atmospheric chemistry anomalies related to nitrogen dioxide photochemistry (Chu and McCormick, 1986), and ozone chemistry (Wang et al., 1984).

The SAGE I ozone data have been compared with SAGE II ozone data to determine the global ozone trends over the period from 1979 to late 1980 (Watson et al., 1989; McCormick et al., 1990). It was this comparison between SAGE I and SAGE II ozone data that demonstrated stratospheric ozone at 50 km did not decrease significantly over the studied period countering the trend results of other satellite observations. The SAGE I and SAGE II ozone data have been regarded as the most accurate ozone profile data measured from space (WMO, 1990).

X. Concluding Remarks

This report has presented a description of the Stratospheric Aerosol and Gas Experiment (SAGE I) instrument, its data collection, processing and validation techniques, and a description of the aerosol, ozone, and nitrogen dioxide archival products used in scientific investigations of various atmospheric sciences. These data products are archived and can be requested on magnetic tape directly from the National Space Sciences Data Center (NSSDC), NASA Goddard Space Flight Center, Code 933, Greenbelt, Maryland 20771 (foreign requests should be sent to Code 930.2). Each request should specify the experiment data desired (aerosol, ozone, or nitrogen dioxide), the NSSDC identification number (79-013A-01C), and the time period of interest. All 33 months of SAGE I data have been archived.

XI. References

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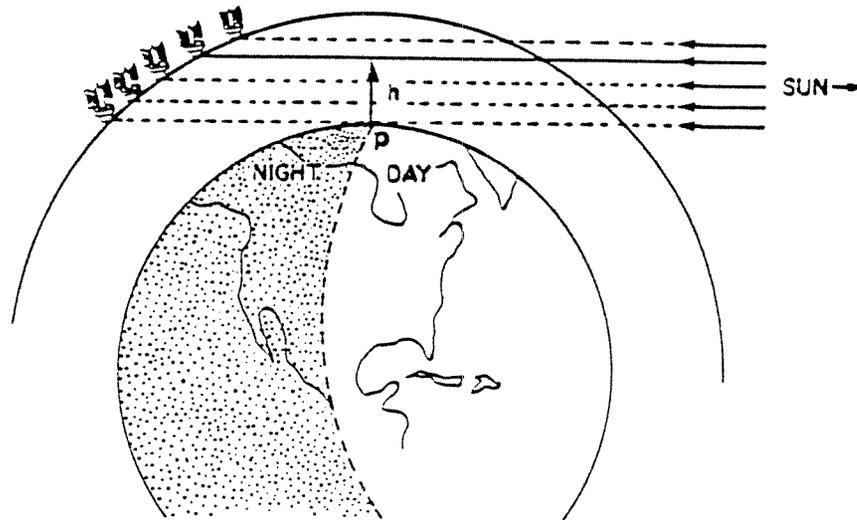


Figure 1. Solar occultation measurement geometry.

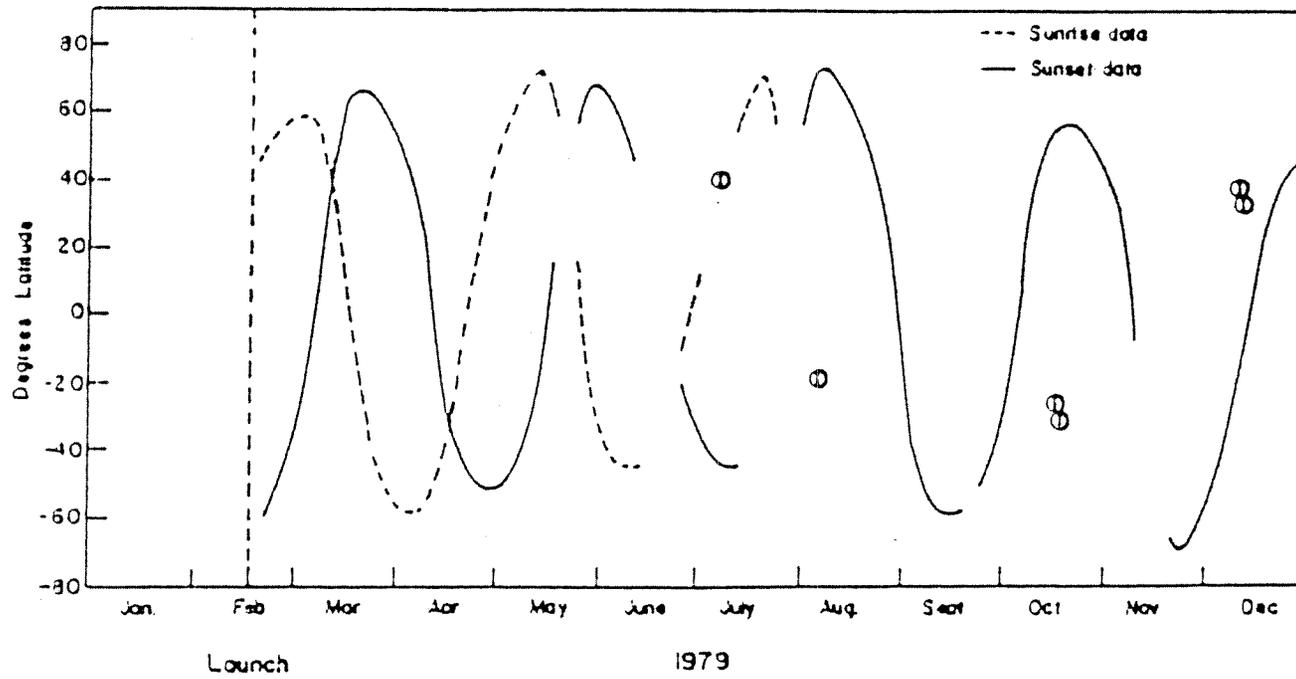


Figure 2. SAGE I measurement latitude, February 1979 to November 1981.

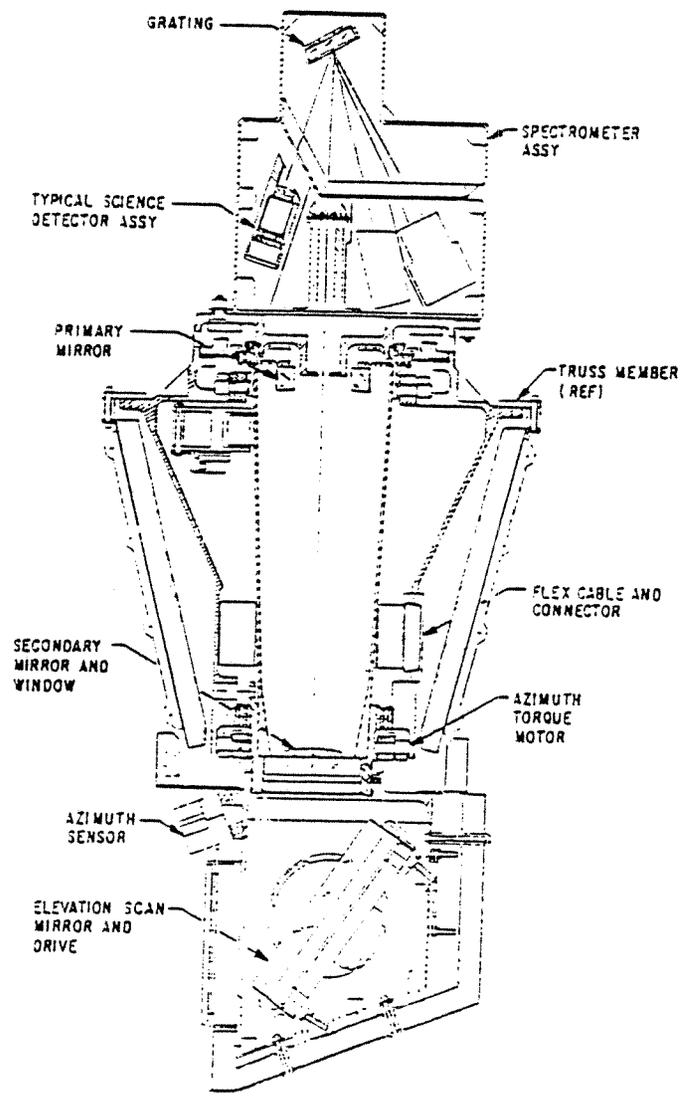


Figure 3. Schematic of SAGE I instrument.

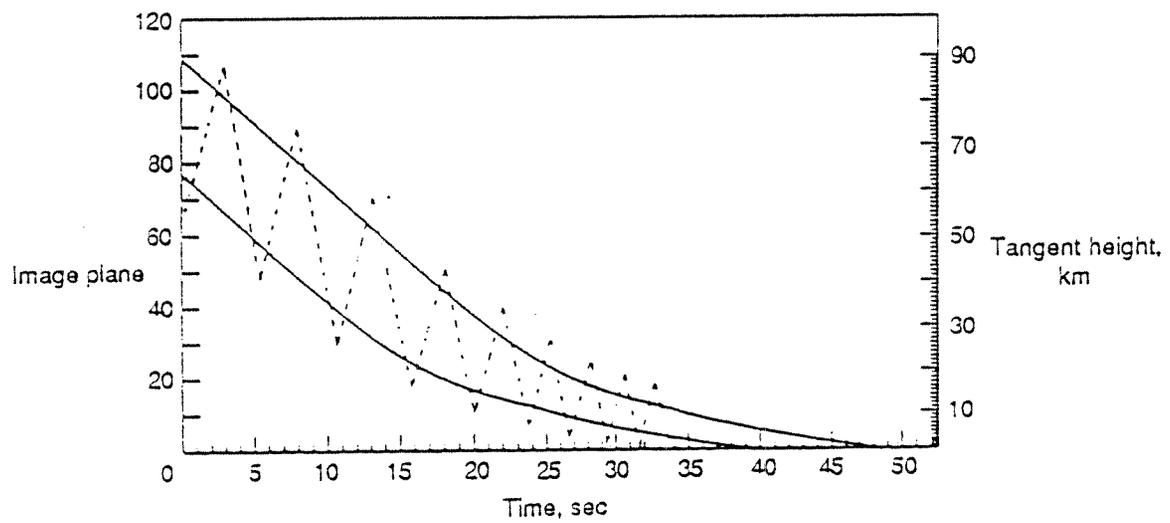


Figure 4. Typical SAGE I elevation scanning of solar disk during sunset.

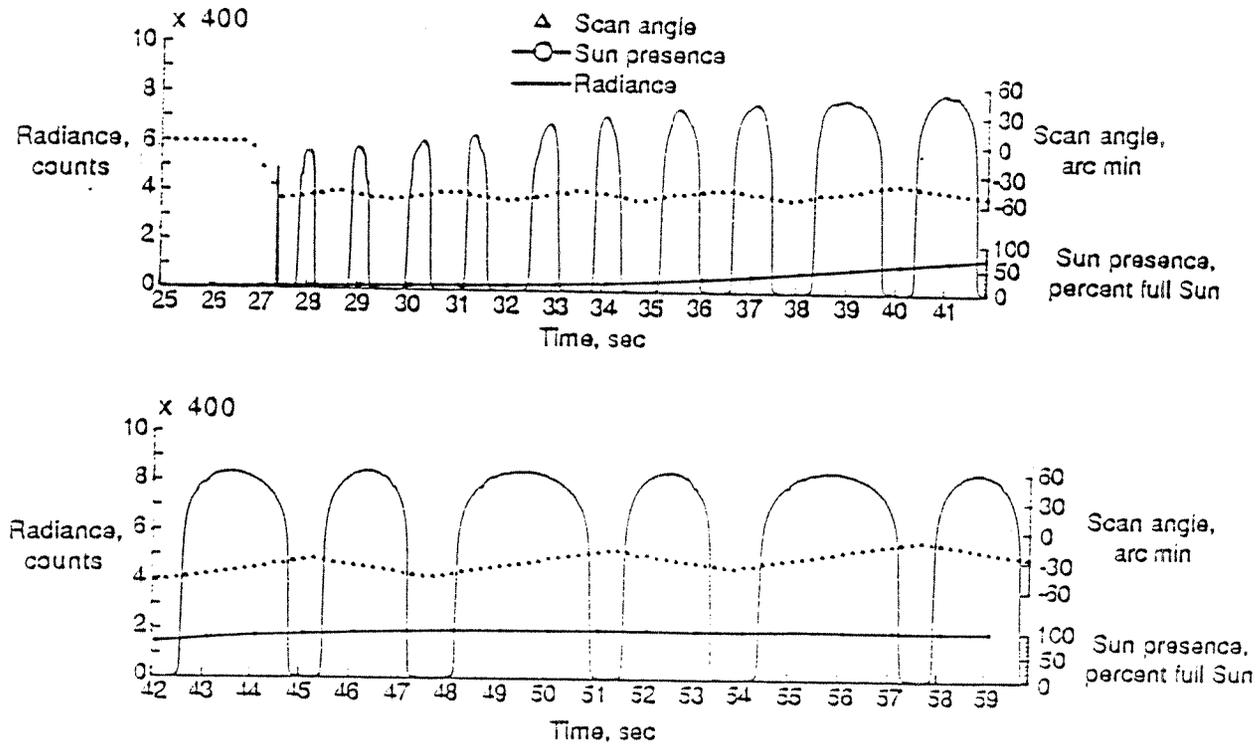


Figure 5. Typical SAGE I 1000 nm channel solar radiance during sunrise.

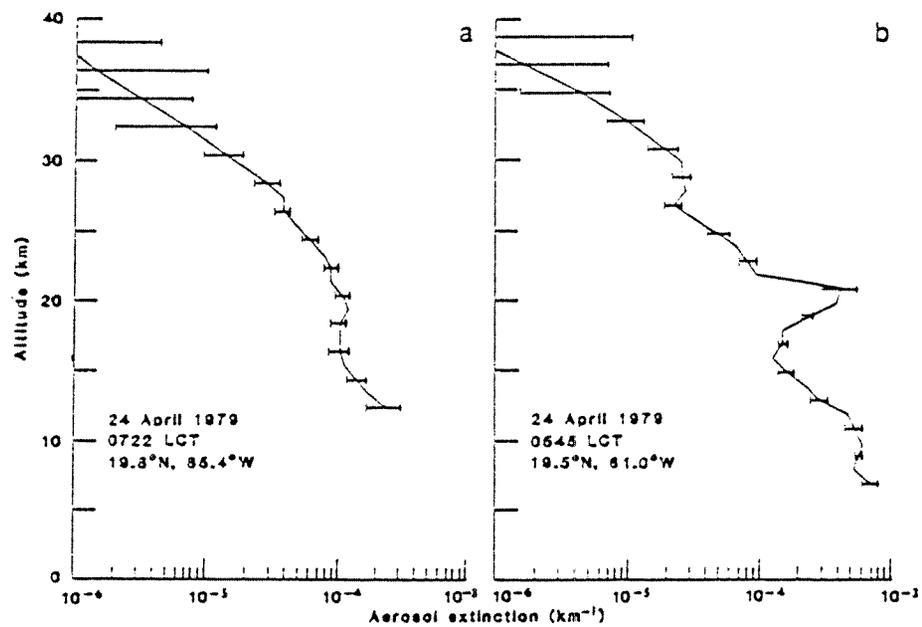


Figure 6. SAGE I aerosol extinction profile on April 24, 1979 for (a) background conditions and (b) perturbed conditions resulting from La Soufriere eruption.

SOLID LINE: GARMISCH, ECC SONDE
START 1645 GMT

----- SAGE MEASUREMENTS
AT 1743 GMT

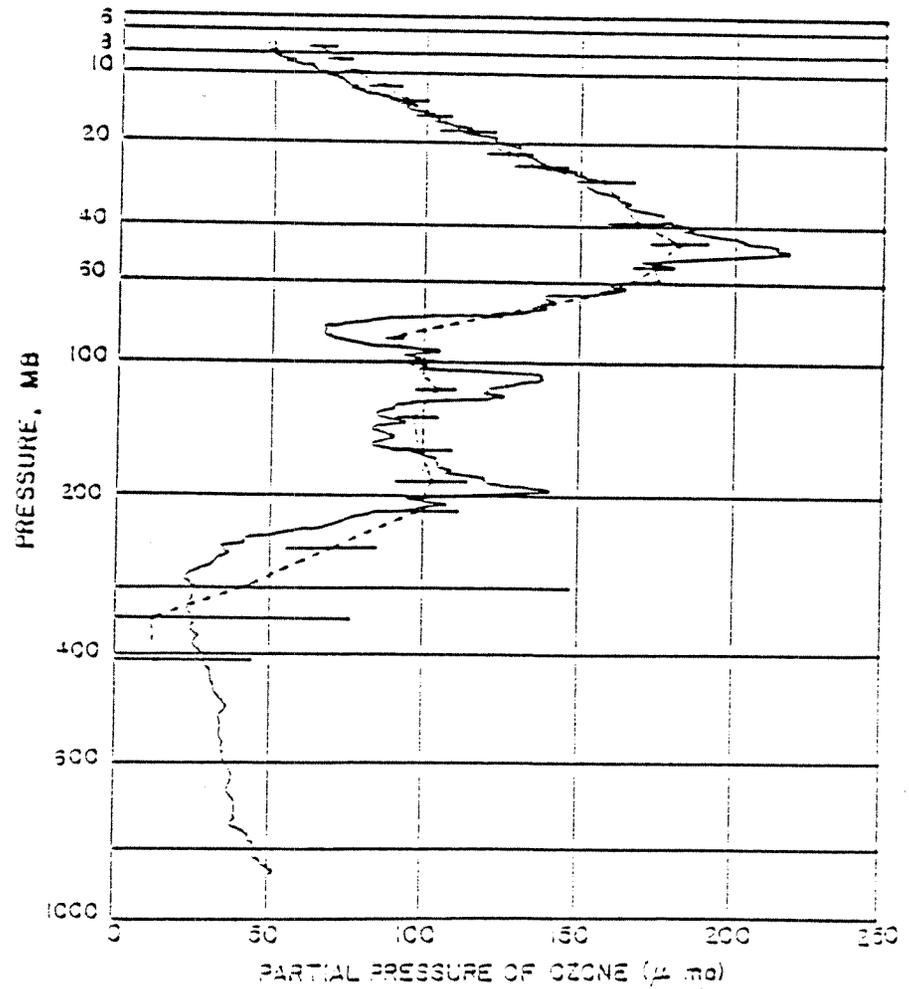


Figure 7. Comparison of SAGE I ozone retrieval with coincident Electra Chemical Call (ECC) ozonesonde.

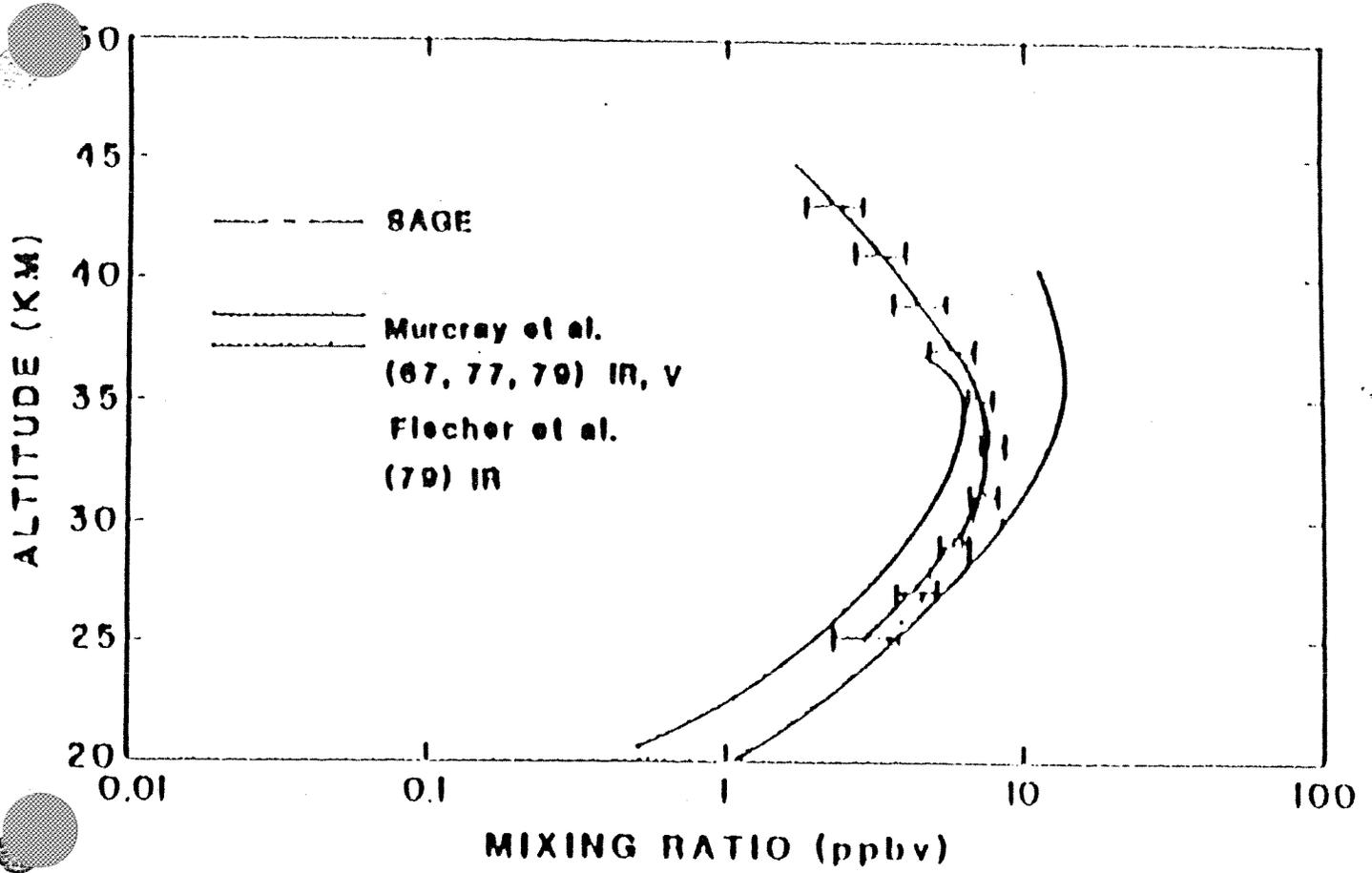


Figure 8. Comparison of SAGE I sunset NO₂ retrieval with previous balloon measurements at 32-33°N by D. Murcray and others.

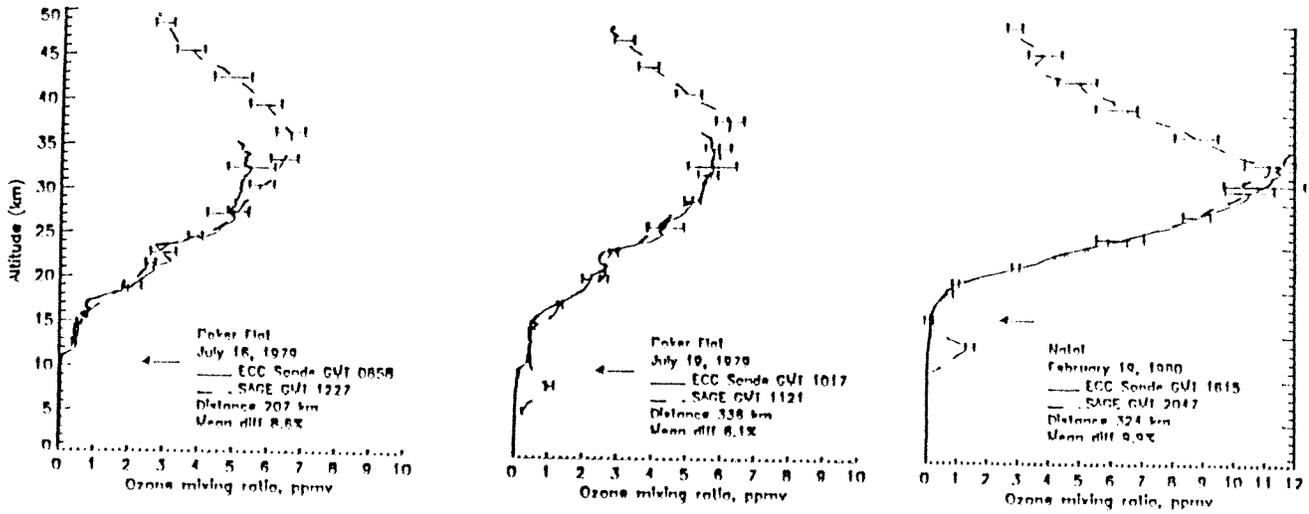


Figure 10. Comparison of SAGE I ozone mixing ratio retrieval with coincident ECC ozonesondes during validation experiments in Alaska and Brazil.

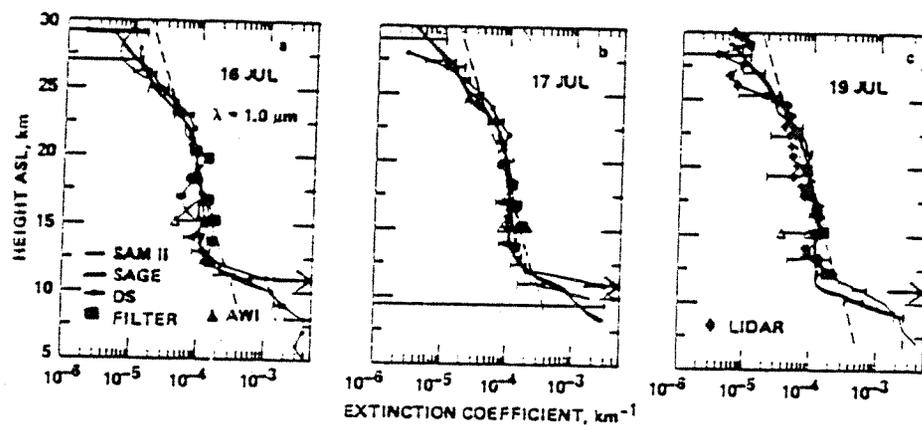


Figure 9. Comparison of SAGE I aerosol extinction coefficient retrieval with correlative aerosols measurement collected during 1979 validation experiment in Alaska.

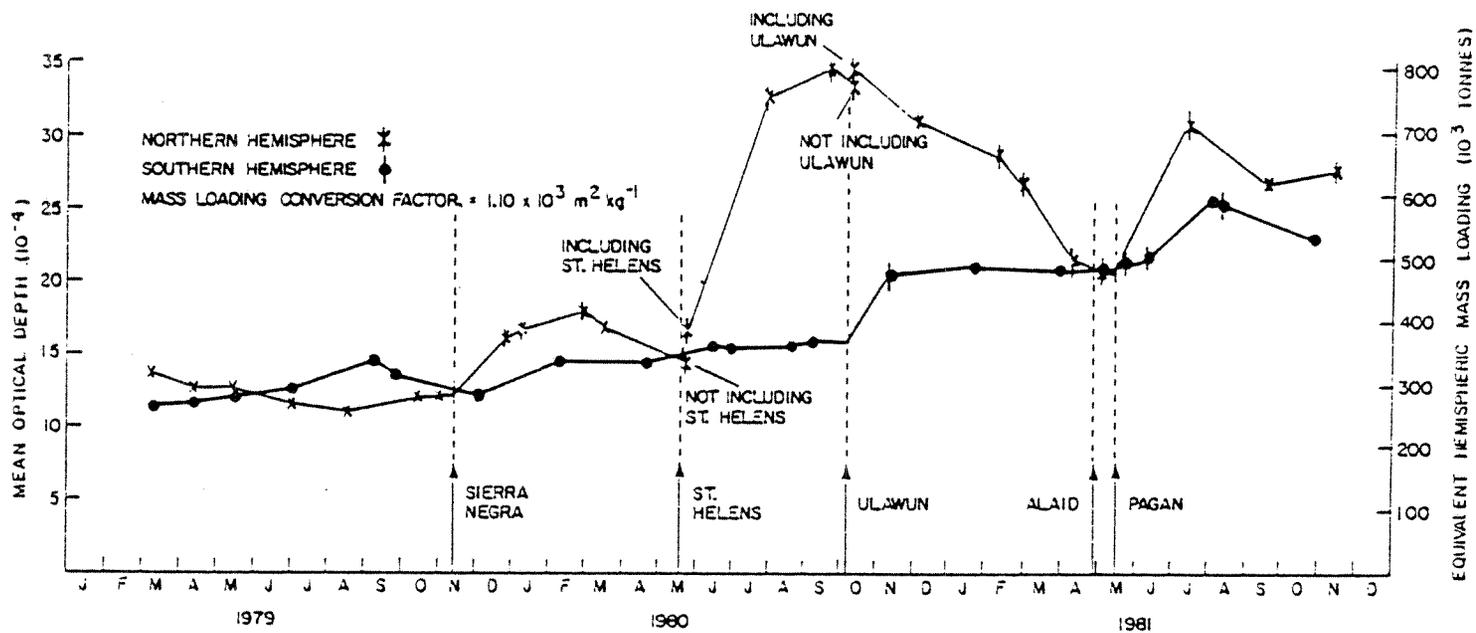


Figure 12. Time history of SAGE I and SAM II mean hemisphere optical depth measurements for 1979 to 1981.

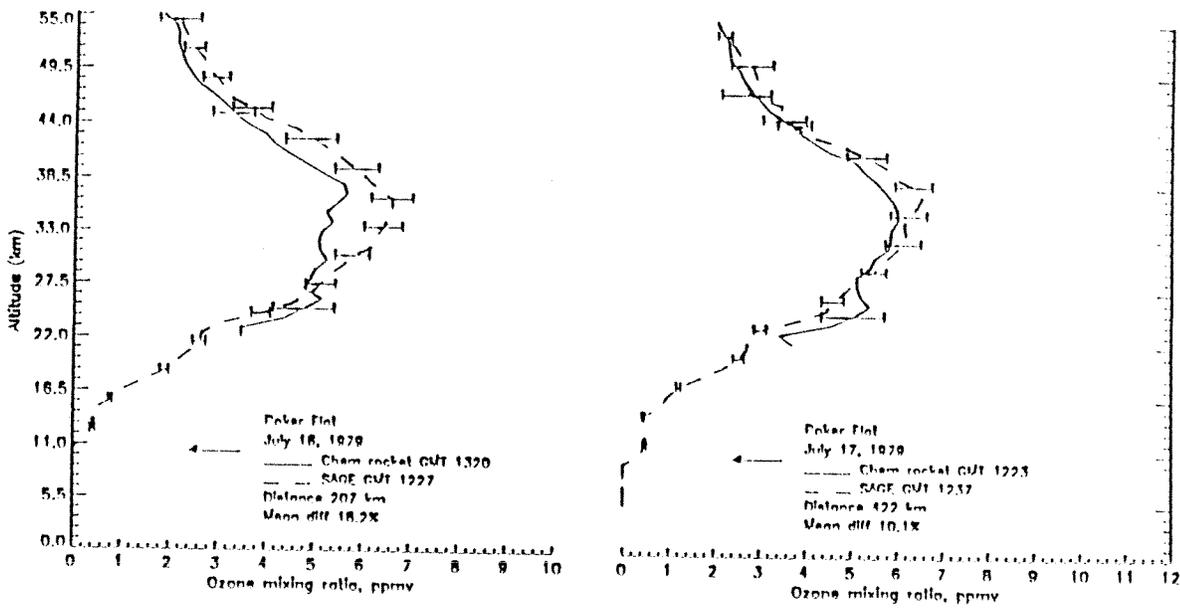


Figure 11. Comparison of SAGE I ozone mixing ratio retrieval with coincident rocket ozonesondes during 1979 validation experiment in Alaska.

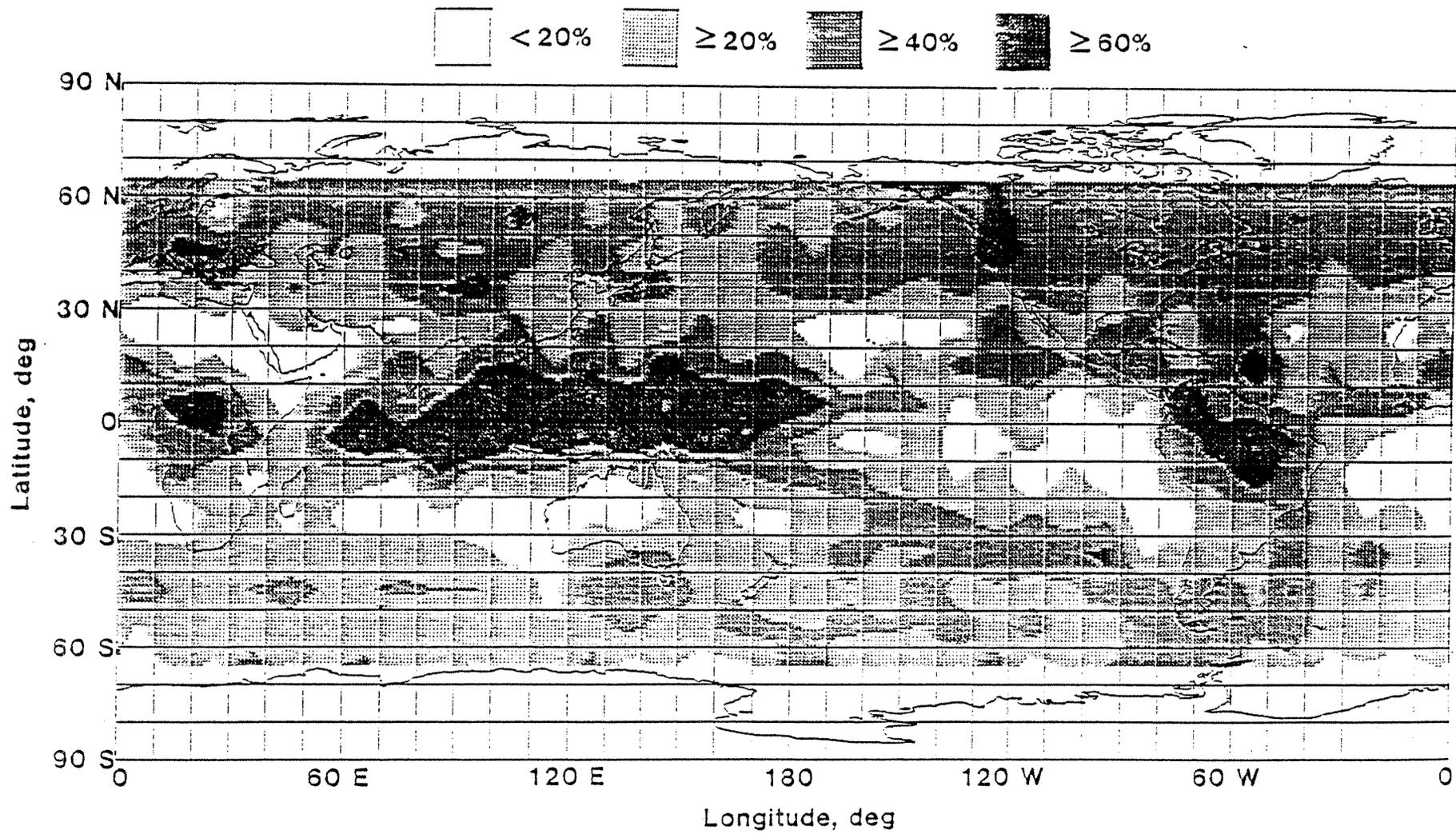


Figure 13. Average frequency of cirrus cloud occurrence from full 33 months of SAGE I operation.

Appendix A
Meteorological Data Notes

Meteorological Data Notes

Meteorological data are supplied to Langley Research Center by NOAA/National Weather Service - Climate Analysis Branch, in Washington, D.C. Data for temperature, temperature error, geometric altitude, air density, and air density error are provided for eighteen pressure levels (1000 - 0.4 mb) and at the derived tropopause pressure. The pressure levels correspond to the 25-element meteorological data arrays (1 to 25) as follows: 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 10, 5, 2, 1, 0.4, 0.04, 0.01, *spare, spare, spare, spare*, and derived tropopause pressure. Elements 19 and 20 (0.04 - 0.01 mb) contain LaRC model data for temperature and altitude only. Elements 21 through 24 contain fill values, and element 25 contains the NOAA-supplied tropopause information.

If NOAA cannot supply meteorological data as above, LaRC determines the highest pressure level for which data are supplied and then inserts model data from the next level up to the lowest pressure level of 0.01 millibars. Only temperature and altitude information are supplied using these model data: Temperature error, density, and density error will be filled for the corresponding levels that contain the LaRC-supplied data.

Meteorological correction factors for temperatures at 5, 2, 1, and 0.4 millibars are already added to the value of the temperatures in elements 15 through 18 of the temperature array. These correction factors are only included in the NOAA-supplied data: If model data are in these locations, no correction factors are applied. The correction factors are listed in Fields 134-137 of the record.

Meteorological data (Fields 245 through 384 of the event record) are interpolated from the meteorological data in Fields 9 through 133 of the record. Altitude data in Fields 175-244 increments by 1 kilometer with the center of each level at the 0.5 kilometer point of the level bin.

Other meteorological data information is contained in the following record locations:

Field 0138: 1 if NOAA-supplied data is incomplete, 0 if complete

Field 0139: The model pointer is the array index that points to the start of LaRC-supplied model data in the temperature and altitude arrays of the meteorological data.

Field 0140: Model selection code (*ssll*) where *ss* is 01 to 04 for spring through winter, and *ll* is 0 to 80 in 10 degree increments for absolute latitude.

Field 0141: date of revision of the LaRC-supplied model

Appendix B

Aerosol Profile Format

SAGE AEROSOL PROFILE RECORD FORMAT (v6.1)

Cyber Words (60-bit)	S i z e	Field Content Description	T y p e	N o t e
40 Kilometer Reference Data				
0001	1	Event Date (yymmdd.0)	(R)	1
0002	1	Event Time (hhmmss.0)	(R)	1
0003	1	Subtangent Latitude (0.0 ± 90.0 degrees)	(R)	
0004	1	Subtangent Longitude (0.0 ± 180.0 degrees)	(R)	
0005	1	Spacecraft-Referenced Event Type (0.0 = sunrise; 1.0 = sunset)	(R)	2
0006	1	Earth-Referenced Event Type (0.0 = sunrise; 1.0 = sunset)	(R)	2
0007	1	Spacecraft Beta Angle (0.0 ± 61.0 degrees)	(R)	3
0008	1	Coded Time of Year (ddd.fract)	(R)	4
NMC Meteorological Data (see Appendix A)				
0009-0033	25	Temperature (Kelvin)	(R)	
0034-0058	25	Temperature Error (Kelvin)	(R)	
0059-0083	25	Geometric Altitude (meters)	(R)	
0084-0108	25	Air Density (grams/cubic meter)	(R)	
0109-0133	25	Air Density Error (percent)	(R)	
0134	1	Temperature Correction Value for 5.0 Millibar Level (Kelvin)	(R)	
0135	1	Temperature Correction Value for 2.0 Millibar Level (Kelvin)	(R)	
0136	1	Temperature Correction Value for 1.0 Millibar Level (Kelvin)	(R)	
0137	1	Temperature Correction Value for 0.4 Millibar Level (Kelvin)	(R)	
0138	1	"Meteorological Data Not Complete" Flag (0=complete; 1=incomplete)	(R)	
0139	1	"Start of Model Meteorological Data" Array Index Pointer (1 - 19)	(R)	
0140	1	Model Meteorological Data Selection Code (ssll)	(R)	
0141	1	Revision Date of LaRC Meteorological Model (yymmdd.0)	(R)	
NASA/LaRC Processing Information				
0142	1	LaRC Driver Revision Level	(R)	
0143	1	LaRC Transmission Revision Level	(R)	
0144	1	LaRC Inversion Revision Level	(R)	
0145	1	LaRC Event Tag (yymmddhhmm.sq)	(R)	5
0146	1	LaRC Processing Date (yymmdd.0)	(R)	1
0147	1	LaRC Processing Time (hhmmss.0)	(R)	1
0148	1	Mean Subtangent Altitude for Event Limb Calibration (kilometers)	(R)	6
0149	1	Value Designated as the Data Fill Number for this Event	(R)	7
Event Ground-Track Slew Data				
0150-0157	8	Subtangent Altitude (kilometers)	(R)	
0158-0165	8	Corresponding Latitude (0.0 ± 90.0 degrees)	(R)	
0166-0173	8	Corresponding Longitude (0.0 ± 180.0 degrees)	(R)	
0174	1	Time Span of Data from Level 1 through 70 (seconds)	(R)	
Altitude and Meteorological Data for Profile Arrays				
0175-0244	70	Geometric Altitude (kilometers)	(R)	9
0245-0314	70	Corresponding Pressure (millibars)	(R)	9
0315-0384	70	Corresponding Temperature (Kelvin)	(R)	9
0385-0390	6	Spare		
(continued on the next Page)				

SAGE AEROSOL PROFILE RECORD FORMAT (v6.1)

Record Format Notes

GENERAL NOTES

- Each field of the event record contains one 60-bit CDC-Cyber floating point number.
- All time and data references are to GMT, except Fields 146 and 147 which are LaRC processing time.
- All latitudes and longitudes are given at the event subtangent point.
- If any field in the event record is considered invalid, or has missing data, a fill value will be placed in that field. For each event record, that fill value can be found in Field 149. (See Note 7, below)
- Each profile level bin is centered at the 0.5 kilometer point within a range of 1.0 kilometers.

DATA FIELD NOTES

1. The "yymmdd.0" and "hhmmss.0" fields are generated by the FORTRAN statements:
$$\text{DATE} = \text{FLOAT}(\text{IYY} * 10000 + \text{IMM} * 100 + \text{IDD}) \ \& \ \text{TIME} = \text{FLOAT}(\text{IHH} * 10000 + \text{IMM} * 100 + \text{ISS})$$
2. Spacecraft-Referenced Event Type and Earth-Referenced Event Type fields are normally the same type, but, if the absolute value of the spacecraft beta angle is close to 61 degrees, their values may be opposite. The Earth-Referenced Event Type field is based on a ground-observer's viewpoint.
3. The Spacecraft Beta Angle field is defined as the angle generated by the intersection of the Earth-Sun vector and the spacecraft orbit plane.
4. The Coded Time of Year field is the time at the beginning of the event (not the same time as Fields 1 and 2), and is generated by the FORTRAN statement:
$$\text{CODTIME} = \text{FLOAT}(\text{DOY}) + (\text{SOD}/86400.0); \quad \text{where} \ \text{DOY} = \text{day of year (1-366)} \ \text{and} \\ \text{SOD} = \text{seconds of the day (0.0-86399.99...)}$$
5. The LaRC Event Tag is generated similarly to Note 1. The ".sq" at the end of the value is the event number of the day divided by 100.
6. The Mean Subtangent Altitude for Event Limb Calibration field contains the altitude at which data for the exoatmospheric solar image was gathered for use in solar limb normalization for the event.
7. The Value Designated as the Data Fill Number for This Event field must be used to determine what data in the event record is valid. If any field, other than this one, contains this number, that field has no valid information and should not be used by the investigator.
8. The Quality Factor fields for each wavelength are equal to 1.0 minus the summation of the optical depth errors at each profile level from 20.5 to 59.5 kilometers. In cases where a 40 kilometer span cannot be realized, the quality factor is proportioned to a 40 kilometer span to allow a better comparison across wavelengths and other events.
9. The values of altitude, pressure, and temperature in their seventy-element arrays correspond to the sixty-element arrays within the record. Altitude coincidence for all these arrays is at element 1.
10. Extinction Ratio = (Extinction + Rayleigh) / Rayleigh

Appendix C

Ozone Profile Format

SAGE AEROSOL PROFILE RECORD FORMAT (v6.1)

(continued from previous page)

Cyber Words (60-bit)	S i z e	Field Content Description	T y p e	N o t e
Channel Optical Depth Profile—Quality Estimations				
391	1	1000 nm Wavelength Quality Factor	(R)	8
392	1	Spare		
393	1	Spare		
394	1	Spare		
395	1	450 nm Wavelength Quality Factor	(R)	8
396	1	Spare		
397	1	Spare		
0398-0400	3	Spare		
Rayleigh Extinction Profiles				
0401-0460	60	1000 nm Rayleigh Extinction (km ⁻¹)	(R)	9
0461-0520	60	1000 nm Rayleigh Extinction Error (km ⁻¹)	(R)	9
0521-0580	60	Spare	(R)	
0581-0640	60	Spare	(R)	
0641-0700	60	450 nm Rayleigh Extinction (km ⁻¹)	(R)	9
0701-0760	60	450 nm Rayleigh Extinction Error (km ⁻¹)	(R)	9
0761-0820	60	Spare	(R)	
0821-0880	60	Spare	(R)	
Aerosol Profiles				
0881-0940	60	1000 nm Extinction (km ⁻¹)	(R)	
0941-1000	60	1000 nm Extinction Error (km ⁻¹)	(R)	
1001-1060	60	Spare	(R)	
1061-1120	60	Spare	(R)	
1121-1180	60	450 nm Extinction (km ⁻¹)	(R)	
1181-1240	60	450 nm Extinction Error (km ⁻¹)	(R)	
1241-1300	60	Spare	(R)	
1301-1360	60	Spare	(R)	
1361-1420	60	1000 nm Extinction Ratio	(R)	10
1421-1480	60	1000 nm Extinction Ratio Error	(R)	10
1481-1488	8	Spare		
End of Event Record				
(Notes on the next page)				

SAGE OZONE PROFILE RECORD FORMAT (v6.1)

Cyber Words (60-bit)	S i z e	Field Content Description	T y p e	N o t e
40 Kilometer Reference Data				
0001	1	Event Date (yymmdd.0)	(R)	1
0002	1	Event Time (hhmmss.0)	(R)	1
0003	1	Subtangent Latitude (0.0 ± 90.0 degrees)	(R)	
0004	1	Subtangent Longitude (0.0 ± 180.0 degrees)	(R)	
0005	1	Spacecraft-Referenced Event Type (0.0 = sunrise; 1.0 = sunset)	(R)	2
0006	1	Earth-Referenced Event Type (0.0 = sunrise; 1.0 = sunset)	(R)	2
0007	1	Spacecraft Beta Angle (0.0 ± 61.0 degrees)	(R)	3
0008	1	Coded Time of Year (ddd.fract)	(R)	4
NMC Meteorological Data (see Appendix A)				
0009-0033	25	Temperature (Kelvin)	(R)	
0034-0058	25	Temperature Error (Kelvin)	(R)	
0059-0083	25	Geometric Altitude (meters)	(R)	
0084-0108	25	Air Density (grams/cubic meter)	(R)	
0109-0133	25	Air Density Error (percent)	(R)	
0134	1	Temperature Correction Value for 5.0 Millibar Level (Kelvin)	(R)	
0135	1	Temperature Correction Value for 2.0 Millibar Level (Kelvin)	(R)	
0136	1	Temperature Correction Value for 1.0 Millibar Level (Kelvin)	(R)	
0137	1	Temperature Correction Value for 0.4 Millibar Level (Kelvin)	(R)	
0138	1	"Meteorological Data Not Complete" Flag (0=complete; 1=incomplete)	(R)	
0139	1	"Start of Model Meteorological Data" Array Index Pointer (1 - 19)	(R)	
0140	1	Model Meteorological Data Selection Code (ssll)	(R)	
0141	1	Revision Date of LaRC Meteorological Model (yymmdd.0)	(R)	
NASA/LaRC Processing Information				
0142	1	LaRC Driver Revision Level	(R)	
0143	1	LaRC Transmission Revision Level	(R)	
0144	1	LaRC Inversion Revision Level	(R)	
0145	1	LaRC Event Tag (yymmddhhmm.sq)	(R)	5
0146	1	LaRC Processing Date (yymmdd.0)	(R)	1
0147	1	LaRC Processing Time (hhmmss.0)	(R)	1
0148	1	Mean Subtangent Altitude for Event Limb Calibration (kilometers)	(R)	6
0149	1	Value Designated as the Data Fill Number for this Event	(R)	7
Event Ground-Track Slew Data				
0150-0157	8	Subtangent Altitude (kilometers)	(R)	
0158-0165	8	Corresponding Latitude (0.0 ± 90.0 degrees)	(R)	
0166-0173	8	Corresponding Longitude (0.0 ± 180.0 degrees)	(R)	
0174	1	Time Span of Data from Level 1 through 70 (seconds)	(R)	
Altitude and Meteorological Data for Profile Arrays				
0175-0244	70	Geometric Altitude (kilometers)	(R)	9
0245-0314	70	Corresponding Pressure (millibars)	(R)	9
0315-0384	70	Corresponding Temperature (Kelvin)	(R)	9
0385-0390	6	Spare		
(continued on the next Page)				

SAGE OZONE PROFILE RECORD FORMAT (v6.1)

(continued from previous page)

Cyber Words (60-bit)	S i z e	Field Content Description	T y p e	N o t e
Channel Optical Depth Profile--Quality Estimations				
391	1	Spare		
392	1	Spare		
393	1	600 nm Wavelength Quality Factor	(R)	8
394	1	Spare		
395	1	Spare		
396	1	Spare		
397	1	Spare		
0398-0400	3	Spare		
Ozone Profiles				
0401-0470	70	Number Density (molecules/cm ³)	(R)	9
0471-0540	70	Number Density Error (molecules/cm ³)	(R)	9
0541-0610	70	Volumetric Mixing Ratio (v/v)	(R)	9
0611-0680	70	Volumetric Mixing Ratio Error (v/v)	(R)	9
0681-0688	8	Spare		
End of Event Record				
(Notes on the next page)				

Appendix D

Nitrogen Dioxide Profile Format

SAGE OZONE PROFILE RECORD FORMAT (v6.1)

Record Format Notes

GENERAL NOTES

- Each field of the event record contains one 60-bit CDC-Cyber floating point number.
- All time and data references are to GMT, except Fields 146 and 147 which are LaRC processing time.
- All latitudes and longitudes are given at the event sub-tangent point.
- If any field in the event record is considered invalid, or has missing data, a fill value will be placed in that field. For each event record, that fill value can be found in Field 149. (See Note 7, below)
- Each profile level bin is centered at the 0.5 kilometer point within a range of 1.0 kilometers.

DATA FIELD NOTES

1. The "yymmdd.0" and "hhmmss.0" fields are generated by the FORTRAN statements:

DATE = FLOAT (IYY*10000 + IMM*100 + IDD) & TIME = FLOAT(II*10000 + IMM*100 + ISS)

2. Spacecraft-Referenced Event Type and Earth-Referenced Event Type fields are normally the same type, but, if the absolute value of the spacecraft beta angle is close to 61 degrees, their values may be opposite. The Earth-Referenced Event Type field is based on a ground-observer's viewpoint.
3. The Spacecraft Beta Angle field is defined as the angle generated by the intersection of the Earth-Sun vector and the spacecraft orbit plane.
4. The Coded Time of Year field is the time at the beginning of the event (not the same time as Fields 1 and 2), and is generated by the FORTRAN statement:
$$\text{CODTIME} = \text{FLOAT}(\text{DOY}) + (\text{SOD}/86400.0); \quad \text{where} \quad \text{DOY} = \text{day of year (1-366) and}$$
$$\text{SOD} = \text{seconds of the day (0.0-86399.99...)}$$
5. The LaRC Event Tag is generated similarly to Note 1. The ".sq" at the end of the value is the event number of the day divided by 100.
6. The Mean Sub-tangent Altitude for Event Limb Calibration field contains the altitude at which data for the exoatmospheric solar image was gathered for use in solar limb normalization for the event.
7. The Value Designated as the Data Fill Number for This Event field must be used to determine what data in the event record is valid. If any field, other than this one, contains this number, that field has no valid information and should not be used by the investigator.
8. The Quality Factor fields for each wavelength are equal to 1.0 minus the summation of the optical depth errors at each profile level from 20.5 to 59.5 kilometers. In cases where a 40 kilometer span cannot be realized, the quality factor is proportioned to a 40 kilometer span to allow a better comparison across wavelengths and other events.
9. The values of altitude, pressure, and temperature in their seventy-element arrays correspond to the other seventy-element arrays within the record. Altitude coincidence for all these arrays is at element 1.

SAGE NO₂ PROFILE RECORD FORMAT (v6.1)

Cyber Words (60-bit)	S i z e	Field Content Description	T y p e	N o t e
40 Kilometer Reference Data				
0001	1	Event Date (yymmdd.0)	(R)	1
0002	1	Event Time (hhmmss.0)	(R)	1
0003	1	Subtangent Latitude (0.0 ± 90.0 degrees)	(R)	
0004	1	Subtangent Longitude (0.0 ± 180.0 degrees)	(R)	
0005	1	Spacecraft-Referenced Event Type (0.0 = sunrise; 1.0 = sunset)	(R)	2
0006	1	Earth-Referenced Event Type (0.0 = sunrise; 1.0 = sunset)	(R)	2
0007	1	Spacecraft Beta Angle (0.0 ± 61.0 degrees)	(R)	3
0008	1	Coded Time of Year (ddd.fract)	(R)	4
NMC Meteorological Data (see Appendix A)				
0009-0033	25	Temperature (Kelvin)	(R)	
0034-0058	25	Temperature Error (Kelvin)	(R)	
0059-0083	25	Geometric Altitude (meters)	(R)	
0084-0108	25	Air Density (grams/cubic meter)	(R)	
0109-0133	25	Air Density Error (percent)	(R)	
0134	1	Temperature Correction Value for 5.0 Millibar Level (Kelvin)	(R)	
0135	1	Temperature Correction Value for 2.0 Millibar Level (Kelvin)	(R)	
0136	1	Temperature Correction Value for 1.0 Millibar Level (Kelvin)	(R)	
0137	1	Temperature Correction Value for 0.4 Millibar Level (Kelvin)	(R)	
0138	1	"Meteorological Data Not Complete" Flag (0=complete; 1=incomplete)	(R)	
0139	1	"Start of Model Meteorological Data" Array Index Pointer (1 - 19)	(R)	
0140	1	Model Meteorological Data Selection Code (ssll)	(R)	
0141	1	Revision Date of LaRC Meteorological Model (yymmdd.0)	(R)	
NASA/LaRC Processing Information				
0142	1	LaRC Driver Revision Level	(R)	
0143	1	LaRC Transmission Revision Level	(R)	
0144	1	LaRC Inversion Revision Level	(R)	
0145	1	LaRC Event Tag (yymmddhhmm.sq)	(R)	5
0146	1	LaRC Processing Date (yymmdd.0)	(R)	1
0147	1	LaRC Processing Time (hhmmss.0)	(R)	1
0148	1	Mean Subtangent Altitude for Event Limb Calibration (kilometers)	(R)	6
0149	1	Value Designated as the Data Fill Number for this Event	(R)	7
Event Ground-Track Slew Data				
0150-0157	8	Subtangent Altitude (kilometers)	(R)	
0158-0165	8	Corresponding Latitude (0.0 ± 90.0 degrees)	(R)	
0166-0173	8	Corresponding Longitude (0.0 ± 180.0 degrees)	(R)	
0174	1	Time Span of Data from Level 1 through 70 (seconds)	(R)	
Altitude and Meteorological Data for Profile Arrays				
0175-0244	70	Geometric Altitude (kilometers)	(R)	9
0245-0314	70	Corresponding Pressure (millibars)	(R)	9
0315-0384	70	Corresponding Temperature (Kelvin)	(R)	9
0385-0390	6	Spare		
(continued on the next Page)				

79-013A-01C

D-74290

02/21/79 - 11/30/79

INPUT TAPE QZC1 ON HT1
DATA INPUT 09 NF=1 FL=1=1=1

FILE	1	RECORD	1	LENGTH	688	BYTES					
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START TIME 10/15/90 15:03:17 STOP TIME 10/15/90 15:04:50

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D-82251

12/01/80 - 4/18/91

INPUT TAPE AER1 ON HT)
DATA INPUT 09 NF 1 FL 1 1 1

Table with columns: FILE, RECORD, LENGTH, 1488 BYTES. Contains multiple rows of numerical data representing file records and their lengths.

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EOJ DUMP STOPPED AFTER FILE 1 # OF PERMANENT READ ERRORS 0

START TIME 10/11/90 12:24:53 STOP TIME 10/11/90 12:26:32

D-82246
02/21/79 - 11/30/79

INPUT TAPE NIT1 ON HT1
DATA INPUT 09 NF 1 FL 1 1 1

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EOJ DUMP STOPPED AFTER FILE 1 # OF PERMANENT READ ERRORS 0

START TIME 10/11/90 12:30:57 STOP TIME 10/11/90 12:31:59

PRINTED IN U.S.A.

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