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Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Jaime Nickeson, Editors

Volume 60

BOREAS RSS-12 Automated Ground Sunphotometer Measurements in the SSA

B. Lobitz, M. Spanner, and R. Wrigley

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

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BOREAS RSS-12 Automated Ground Sunphotometer Measurements in the SSA

Brad Lobitz, Michael Spanner, Bob Wrigley

Summary

The BOREAS RSS-12 team collected both ground and airborne sunphotometer measurements for use in characterizing the aerosol optical properties of the atmosphere during the BOREAS data collection activities. These measurements are to be used to: 1) measure the magnitude and variability of the aerosol optical depth in both time and space; 2) determine the optical properties of the boreal aerosols; and 3) atmospherically correct some remotely sensed data acquired during BOREAS. These data cover selected days and times from May to September 1994 and were taken from one of two ground sites near Candle Lake in the SSA. The data described in this document are from the field sunphotometer data. The data are stored in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS RSS-12 Automated Ground Sunphotometer Measurements in the SSA

1.2 Data Set Introduction

The Automated Ground Sunphotometer (AGSP) data set consists of instrument voltages; Sun position information; and ozone (O_3), nitrogen dioxide (NO_2) and aerosol optical depth values. These data were collected and processed by the BOReal Ecosystem-Atmosphere Study (BOREAS) Remote Sensing Science (RSS)-12 team at the National Aeronautics and Space Administration (NASA) Ames Research Center (ARC). The data provide a good characterization of atmospheric aerosols during the data collection periods.

1.3 Objective/Purpose

The overall goal of this investigation was to measure aerosol optical properties from both ground- and aircraft-based sunphotometers during the BOREAS Intensive Field Campaigns (IFCs). These measurements are to be used to:

- Measure the magnitude and variability of the aerosol optical depth in both time and space.
- Determine the optical properties of the boreal aerosols.
- Atmospherically correct selected remotely sensed data acquired during BOREAS.

1.4 Summary of Parameters

The phenomenon being measured is the atmospheric aerosol optical depth. The parameters include Rayleigh optical depth, aerosol optical depth, time, latitude, longitude, air mass, and solar position.

1.5 Discussion

The AGSP data will be used in conjunction with the Airborne Tracking Sunphotometer (ATSP) data to determine the magnitude and variability of the aerosol optical depth in both time and space. The aerosol optical depth data will be inverted using an algorithm developed by King et al., 1978, to derive the size distribution of the boreal aerosols. Mie theory will then be used to calculate the aerosol phase function and single scattering albedo. Finally, the atmospheric correction algorithm of Wrigley et al., 1992, will be used to atmospherically correct selected NS001 Thematic Mapper (TMS), Landsat Thematic Mapper (TM), and Moderate-resolution Imaging Spectrometer (MODIS) Airborne Simulator (MAS) data collected during the 1994 BOREAS IFCs 1-3.

Atmospheric correction of Landsat TM and other satellite data will use the aerosol properties derived from surface optical depth measurements. Atmospheric correction of NS001 and MAS data will use aerosol properties derived from the airborne optical depth measurements as well as those from the surface measurements.

1.6 Related Data Sets

BOREAS RSS-11 Ground Network of Sunphotometer Measurements
BOREAS RSS-12 Airborne Tracking Sunphotometer Measurements
BOREAS RSS-18 Ground Sunphotometer Measurements in the SSA

2. Investigator(s)

2.1 Investigator(s) Names and Titles

Principal Investigator: Robert C. Wrigley (retired 1995)

Co-Investigators: Michael A. Spanner, Robert E. Slye, Philip B. Russell, John M. Livingston

2.2 Title of Investigation

Aerosol Determinations and Atmospheric Correction for BOREAS Imagery

2.3 Contact Information

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3. Theory of Measurements

The instrument measures direct beam solar radiation for 10 channels in the visible and near-infrared wavelengths. The solar radiation data are collected in the form of voltages. The instrument was calibrated both before and after the experiment using the Langley plot technique. For calibration, data are collected at a number of solar angles from low solar elevation (air mass = 5) to high solar elevation (air mass = 1.8). A regression is developed between log voltage and air mass. This regression equation is then extrapolated to an air mass of 0. This value, called the zero air mass intercept voltage, is the value used to calibrate of the instrument in a given channel. Great care must be taken to ensure the stability of these intercept voltages over time. A calibration history is maintained that attests to the stability of the instrument. The voltages measured by the instrument during the BOREAS IFCs were converted to total optical depth using the zero air mass intercept voltages calculated from the calibrations using the equation:

$$V/V_0 = (Rm/R)^2 \exp(-mt)$$

where V is the measured voltage, V_0 is the zero air mass voltage intercept, R is the radius of Earth's orbit at the time, Rm is the mean radius, m is the air mass at the time, and t is the total optical depth (usually written as the Greek letter tau). The aerosol optical depth is calculated from the total optical depth by subtracting a number of components that contribute to the total optical depth: Rayleigh scattering and gaseous absorption due to ozone and NO_2. The Rayleigh optical depth is calculated using pressure measured on the aircraft. NO_2 and ozone optical depths are subtracted from the total minus Rayleigh optical depth to obtain the aerosol optical depth. NO_2 abundance is obtained from climatology tables based on Noxon, 1979, and convolved with absorption coefficients at field sunphotometer wavelengths. Ozone optical depth is calculated using ozone abundances from the Total Ozone Mapping Spectrometer (TOMS) satellite instrument and convolved with absorption coefficients at the field sunphotometer wavelengths. The result of this processing is the aerosol optical depth measured in nine channels (not including the 940-nm water vapor channel) at approximately 1-minute intervals on the ground.

The correction of remote sensing data acquired from satellites or aircraft for effects due to the intervening atmosphere has proven to be a difficult problem. Not only does the atmosphere reduce the transmission of the incoming, reflected, and emitted radiation, but it contributes reflected and emitted radiation of its own. Under high aerosol concentration conditions, atmospheric radiation comprises over 90% of the satellite-observed radiance, but even much smaller effects would degrade the quantitative use of these data unless they are taken into account. The interaction of radiation with the atmosphere is complex and has proved difficult to calculate without reference to measurements made at, or close to, the time and location of interest. Effects due to Rayleigh scattering from atmospheric gases are well understood because the major gases (nitrogen, oxygen) that comprise 99% of the atmosphere are well mixed and their concentrations with altitude are known. The effects due to small particle (aerosol) scattering are quite variable because of the wide range of aerosol concentrations and the variety of aerosols found in the atmosphere. Because aerosol concentrations cannot be known a

priori, they must be measured at the time and location of remote sensing data acquisition.

The physical properties of aerosols such as size, shape, refractive index, and concentration in the atmosphere control the aerosol interaction with light according to a set of optical properties. Three fundamental properties are (1) the aerosol optical depth, an indirect measure of the size and number of particles present in a given column of air; (2) the single scattering albedo, the fraction of light intercepted and scattered by a single particle; and (3) the phase function, a measure of the light scattered by a particle as a function of angle with respect to the original direction of propagation.

4. Equipment

4.1 Sensor/Instrument Description

The automated solar radiometer instrument consists of a 10-channel solar radiometer, solar-tracking mount, and data acquisition/controller box with tracking and temperature control.

4.1.1 Collection Environment

The data collection took place at either the Sandy Bay Campground site (main site) or the parking lot at the Ship's Lantern Hotel, both in Candle Lake, Saskatchewan. Data were taken to coincide with NASA C-130 flights where airborne sunphotometer measurements were being taken. Ground measurements were more frequent than aircraft flights, however. The field sunphotometer collected data on 52 days between 25-May-1994 and 19-Sep-1994.

4.1.2 Source/Platform

The instrument is mounted on a short tripod that rests on the ground.

4.1.3 Source/Platform Mission Objectives

The AGSP was developed to obtain accurate multispectral atmospheric extinction measurements in the field for the overall purpose of atmospheric correction of remotely sensed data.

4.1.4 Key Variables

The primary quantity being measured is the total optical depth. The aerosol optical depth is derived by subtracting optical depths caused by other components of the atmosphere: Rayleigh scattering, ozone absorption, and NO_2 absorption.

4.1.5 Principles of Operation

The instrument measures energy in the direct beam of the Sun. From the calibrations developed before and after the experiment, these voltages are converted to aerosol optical depth, which is a measure of the extinction of the direct solar beam by aerosols and particulates in the atmosphere.

4.1.6 Sensor/Instrument Measurement Geometry

The field sunphotometer has a 2.0 degree field of view (FOV) and is heated to 44 °C to maintain temperature stability. It has 10 filters. The nominal wavelengths and the full width half maximum (FWHM) for the instrument are presented in the following table.

Wavelength (nm)	FWHM (nm)
380.2	11.7
401.1	10.2
438.6	10.6
521.6	11.6
608.5	10.2
666.9	10.6
779.3	10.1
865.6	12.6
939.8	11.6
1027.1	7.4

4.1.7 Manufacturer of Sensor/Instrument

Dr. John Reagan, Department of Electrical and Computer Engineering, University of Arizona, Tucson, AZ, (520) 621-6203

4.2 Calibration

4.2.1 Specifications

Factors that could affect calibration are instrument variations that may occur between calibrations. Significant drifts in calibration during the time period of the experiment were not observed.

4.2.1.1 Tolerance

The aerosol optical depths are accurate to the uncertainties given with the data.

4.2.2 Frequency of Calibration

The instrument was calibrated at the Mt. Lemmon Steward Observatory, Tucson, AZ, in April 1994 (before the field season) and at the Mauna Loa Observatory, HI, in November 1994 (after the field season).

4.2.3 Other Calibration Information

None given.

5. Data Acquisition Methods

The instrument is initialized through the controller box and then a solar radiometer telescope is manually aligned with the solar image in the crosshairs. Once the telescope is aligned, the automated solar radiometer will collect data at the selected time interval by first tracking the Sun, and then reading the output of all 10 channels, temperature, and the time of data collection. The time interval used for BOREAS was 1-minute. After each data collection sequence, the solar radiometer telescope is stepped away from direct solar alignment to reduce solar exposure on the interference filters. The data collection continues until the final stop time is reached or data collection is terminated. At this point, the instrument turns off the heating elements and is ready to transmit data to a computer through the RS232 port. The instrument has nonvolatile memory.

6. Observations

6.1 Data Notes

None given.

6.2 Field Notes

The field sunphotometer operator normally takes notes of significant events while the instrument is acquiring data. These notes supplement the data file of detector voltages or optical depths and permit determination of the presence of variable cloud interference with remote sensing data collection. The notes, if any, help identify data problems during processing. Anyone interested in these notes should contact RSS-12 personnel at NASA ARC.

7. Data Description

7.1 Spatial Characteristics

The field sunphotometer views the Sun with a 2-degree FOV and typically acquires data every minute during operation. The system is not moved during a collection period, which was about 4 hours at the main site, Sandy Bay. A collection period is a continuous data acquisition cycle.

7.1.1 Spatial Coverage

The field sunphotometer was operated from two locations in the Southern Study Area (SSA): Ship's Lantern Hotel and Sandy Bay Campground.

	BORIS (X,Y)	UTM (E,N)	Latitude,Longitude
Ship's Lantern Hotel	377.02,321.47	481967.2,5955747.4	53.75005°N, 105.27347°W
Sandy Bay Campground	372.84,326.53	478233.5,5961137.1	53.79835°N, 105.33047°W

The North American Datum of 1983 (NAD83) corner coordinates of the SSA are:

	Latitude	Longitude
Northwest	54.321°N	106.228°W
Northeast	54.225°N	104.237°W
Southwest	53.515°N	106.321°W
Southeast	53.420°N	104.368°W

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

The field sunphotometer views the Sun with a 2-degree FOV.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

The AGSP typically acquires data once every minute during operation. The system was not moved during a collection period. Data were acquired during three IFCs in 1994. The data were intended to be coincident with the aircraft and satellite overpasses. The days, times, and locations were:

Date	Time (UTC)	Location
25-May-1994	15:55:09-21:31:09	Sandy Bay
26-May-1994	15:13:17-19:00:13	Sandy Bay
27-May-1994	14:30:07-20:00:13	Sandy Bay
29-May-1994	14:27:08-18:50:08	Sandy Bay
31-May-1994	14:41:09-21:00:08	Sandy Bay
31-May-1994	11:42:11-13:13:08	Ship's Lantern
01-Jun-1994	14:19:10-21:00:09	Sandy Bay
04-Jun-1994	13:50:10-21:00:10	Sandy Bay
06-Jun-1994	15:17:08-19:00:10	Sandy Bay
06-Jun-1994	12:15:09-14:40:20	Ship's Lantern
07-Jun-1994	12:03:07-21:00:10	Ship's Lantern
08-Jun-1994	15:00:09-17:45:08	Sandy Bay
10-Jun-1994	12:02:13-16:35:08	Ship's Lantern
11-Jun-1994	15:51:08-19:00:19	Sandy Bay
11-Jun-1994	12:10:09-12:40:07	Ship's Lantern
20-Jul-1994	15:52:05-21:00:10	Sandy Bay
21-Jul-1994	15:35:11-22:30:08	Sandy Bay
21-Jul-1994	12:04:10-15:00:10	Ship's Lantern
22-Jul-1994	15:31:09-17:30:10	Ship's Lantern
23-Jul-1994	15:40:08-19:00:11	Sandy Bay
23-Jul-1994	11:58:09-14:40:09	Ship's Lantern
24-Jul-1994	15:30:08-21:30:10	Sandy Bay
24-Jul-1994	12:03:12-14:41:08	Ship's Lantern
25-Jul-1994	15:31:09-22:30:21	Sandy Bay
25-Jul-1994	12:12:11-14:39:12	Ship's Lantern
26-Jul-1994	15:43:10-19:00:10	Sandy Bay
27-Jul-1994	15:22:10-22:20:10	Sandy Bay
28-Jul-1994	16:09:09-19:00:09	Sandy Bay
30-Jul-1994	15:30:11-21:00:10	Sandy Bay
31-Jul-1994	15:36:11-19:00:14	Sandy Bay
01-Aug-1994	16:40:11-19:00:10	Sandy Bay
02-Aug-1994	15:47:12-20:22:12	Sandy Bay
04-Aug-1994	19:10:11-23:00:09	Sandy Bay
31-Aug-1994	18:38:05-22:00:09	Sandy Bay
01-Sep-1994	15:27:04-23:00:09	Sandy Bay
01-Sep-1994	13:04:09-14:45:09	Ship's Lantern
02-Sep-1994	15:30:04-23:00:09	Sandy Bay
02-Sep-1994	12:40:10-14:45:08	Ship's Lantern
05-Sep-1994	15:25:03-22:02:12	Sandy Bay
05-Sep-1994	12:45:07-14:44:08	Ship's Lantern
06-Sep-1994	15:22:03-23:00:09	Sandy Bay
06-Sep-1994	12:43:09-14:45:08	Ship's Lantern
07-Sep-1994	15:44:04-22:31:08	Sandy Bay
07-Sep-1994	12:54:09-14:30:08	Ship's Lantern
12-Sep-1994	17:06:05-20:06:03	Sandy Bay
13-Sep-1994	13:21:07-22:00:09	Sandy Bay
14-Sep-1994	18:35:06-19:26:09	Sandy Bay

```
15-Sep-1994  19:43:04-23:00:08  Sandy Bay
16-Sep-1994  13:35:04-23:00:19  Sandy Bay
17-Sep-1994  13:35:03-23:00:08  Sandy Bay
18-Sep-1994  13:31:05-23:00:18  Sandy Bay
19-Sep-1994  13:44:04-22:30:09  Sandy Bay
```

7.2.2 Temporal Coverage Map

Not available.

7.2.3 Temporal Resolution

The AGSP typically acquires data once every minute during operation. The data collection itself normally takes 10 or 15 seconds, dominated primarily by the time needed to re-point the instrument for solar tracking.

7.3 Data Characteristics

7.3.1 Parameter/Variable

The parameters contained in the data files on the CD-ROM are:

Reference Information File

```
        Column Name
-----------------------------
DATE_OBS
INTERCEPT_VOLTAGE_380
INTERCEPT_VOLTAGE_401
INTERCEPT_VOLTAGE_440
INTERCEPT_VOLTAGE_522
INTERCEPT_VOLTAGE_608
INTERCEPT_VOLTAGE_667
INTERCEPT_VOLTAGE_779
INTERCEPT_VOLTAGE_866
INTERCEPT_VOLTAGE_1027
RAYLEIGH_OPT_THICK_380
RAYLEIGH_OPT_THICK_401
RAYLEIGH_OPT_THICK_440
RAYLEIGH_OPT_THICK_522
RAYLEIGH_OPT_THICK_608
RAYLEIGH_OPT_THICK_667
RAYLEIGH_OPT_THICK_779
RAYLEIGH_OPT_THICK_866
RAYLEIGH_OPT_THICK_1027
OZONE_OPT_THICK_380
OZONE_OPT_THICK_401
OZONE_OPT_THICK_440
OZONE_OPT_THICK_522
OZONE_OPT_THICK_608
OZONE_OPT_THICK_667
OZONE_OPT_THICK_779
OZONE_OPT_THICK_866
OZONE_OPT_THICK_1027
NO2_OPT_THICK_380
NO2_OPT_THICK_401
NO2_OPT_THICK_440
NO2_OPT_THICK_522
```

```
NO2_OPT_THICK_608
NO2_OPT_THICK_667
NO2_OPT_THICK_779
NO2_OPT_THICK_866
NO2_OPT_THICK_1027
REVISION_DATE
```

Data File

```
         Column Name
-----------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
SOLAR_ZEN_ANG
AIRMASS
AEROSOL_OPT_THICK_380
AEROSOL_OPT_THICK_401
AEROSOL_OPT_THICK_440
AEROSOL_OPT_THICK_522
AEROSOL_OPT_THICK_608
AEROSOL_OPT_THICK_667
AEROSOL_OPT_THICK_779
AEROSOL_OPT_THICK_866
AEROSOL_OPT_THICK_1027
AEROSOL_OPT_THICK_UNCERT_380
AEROSOL_OPT_THICK_UNCERT_401
AEROSOL_OPT_THICK_UNCERT_440
AEROSOL_OPT_THICK_UNCERT_522
AEROSOL_OPT_THICK_UNCERT_608
AEROSOL_OPT_THICK_UNCERT_667
AEROSOL_OPT_THICK_UNCERT_779
AEROSOL_OPT_THICK_UNCERT_866
AEROSOL_OPT_THICK_UNCERT_1027
CRTFCN_CODE
REVISION_DATE
```

7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Reference Information File

Column Name	Description
DATE_OBS	The date on which the data were collected.
INTERCEPT_VOLTAGE_380	The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 0.380 micrometers.
INTERCEPT_VOLTAGE_401	The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 0.401 micrometers.
INTERCEPT_VOLTAGE_440	The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a

	function of the optical airmass at 0.439 micrometers.
INTERCEPT_VOLTAGE_522	The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 0.522 micrometers.
INTERCEPT_VOLTAGE_608	The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 0.608 micrometers.
INTERCEPT_VOLTAGE_667	The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 0.667 micrometers.
INTERCEPT_VOLTAGE_779	The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 0.779 micrometers.
INTERCEPT_VOLTAGE_866	The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 0.866 micrometers.
INTERCEPT_VOLTAGE_1027	The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 1.027 micrometers.
RAYLEIGH_OPT_THICK_380	Rayleigh (molecular) optical thickness at 0.380 micrometers as calculated by the Young method
RAYLEIGH_OPT_THICK_401	Rayleigh (molecular) optical thickness at 0.401 micrometers as calculated by the Young method
RAYLEIGH_OPT_THICK_440	Rayleigh (molecular) optical thickness at 0.439 micrometers as calculated by the Young method
RAYLEIGH_OPT_THICK_522	Rayleigh (molecular) optical thickness at 0.522 micrometers as calculated by the Young method
RAYLEIGH_OPT_THICK_608	Rayleigh (molecular) optical thickness at 0.608 micrometers as calculated by the Young method
RAYLEIGH_OPT_THICK_667	Rayleigh (molecular) optical thickness at 0.667 micrometers as calculated by the Young method
RAYLEIGH_OPT_THICK_779	Rayleigh (molecular) optical thickness at 0.779 micrometers as calculated by the Young method
RAYLEIGH_OPT_THICK_866	Rayleigh (molecular) optical thickness at 0.866 micrometers as calculated by the Young method
RAYLEIGH_OPT_THICK_1027	Rayleigh (molecular) optical thickness at 1.027 micrometers as calculated by the Young method
OZONE_OPT_THICK_380	Ozone optical thickness at 0.380 micrometers from TOMS data and convolved with absorption coefficients.
OZONE_OPT_THICK_401	Ozone optical thickness at 0.401 micrometers from TOMS data and convolved with absorption coefficients.
OZONE_OPT_THICK_440	Ozone optical thickness at 0.439 micrometers from TOMS data and convolved with absorption coefficients.
OZONE_OPT_THICK_522	Ozone optical thickness at 0.522 micrometers from

	TOMS data and convolved with absorption coefficients.
OZONE_OPT_THICK_608	Ozone optical thickness at 0.608 micrometers from TOMS data and convolved with absorption coefficients.
OZONE_OPT_THICK_667	Ozone optical thickness at 0.667 micrometers from TOMS data and convolved with absorption coefficients.
OZONE_OPT_THICK_779	Ozone optical thickness at 0.779 micrometers from TOMS data and convolved with absorption coefficients.
OZONE_OPT_THICK_866	Ozone optical thickness at 0.866 micrometers from TOMS data and convolved with absorption coefficients.
OZONE_OPT_THICK_1027	Ozone optical thickness at 1.027 micrometers from TOMS data and convolved with absorption coefficients.
NO2_OPT_THICK_380	Nitrogen dioxide optical thickness at 0.380 micrometers as obtained from climatology tables and convolved with absorption coefficients.
NO2_OPT_THICK_401	Nitrogen dioxide optical thickness at 0.401 micrometers as obtained from climatology tables and convolved with absorption coefficients.
NO2_OPT_THICK_440	Nitrogen dioxide optical thickness at 0.439 micrometers as obtained from climatology tables and convolved with absorption coefficients.
NO2_OPT_THICK_522	Nitrogen dioxide optical thickness at 0.522 micrometers as obtained from climatology tables and convolved with absorption coefficients.
NO2_OPT_THICK_608	Nitrogen dioxide optical thickness at 0.608 micrometers as obtained from climatology tables and convolved with absorption coefficients.
NO2_OPT_THICK_667	Nitrogen dioxide optical thickness at 0.667 micrometers as obtained from climatology tables and convolved with absorption coefficients.
NO2_OPT_THICK_779	Nitrogen dioxide optical thickness at 0.779 micrometers as obtained from climatology tables and convolved with absorption coefficients.
NO2_OPT_THICK_866	Nitrogen dioxide optical thickness at 0.866 micrometers as obtained from climatology tables and convolved with absorption coefficients.
NO2_OPT_THICK_1027	Nitrogen dioxide optical thickness at 1.027 micrometers as obtained from climatology tables and convolved with absorption coefficients.
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

Data File

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) when the data were collected.
SOLAR_ZEN_ANG	The angle from the surface normal (straight up) to the sun during the data collection.
AIRMASS	The relative distance measurement of the atmosphere through which the radiance measurement is taken.
AEROSOL_OPT_THICK_380	The aerosol optical thickness measured at 0.380 micrometers.
AEROSOL_OPT_THICK_401	The aerosol optical thickness measured at 0.401 micrometers.
AEROSOL_OPT_THICK_440	The aerosol optical thickness measured between 0.438 and 0.441 micrometers.
AEROSOL_OPT_THICK_522	The aerosol optical thickness measured at 0.522 micrometers.
AEROSOL_OPT_THICK_608	The aerosol optical thickness measured at 0.608 micrometers.
AEROSOL_OPT_THICK_667	The aerosol optical thickness measured at 0.667 micrometers.
AEROSOL_OPT_THICK_779	The aerosol optical thickness measured at 0.779 micrometers.
AEROSOL_OPT_THICK_866	The aerosol optical thickness measured at 0.866 micrometers.
AEROSOL_OPT_THICK_1027	The aerosol optical thickness measured at 1.027 micrometers.
AEROSOL_OPT_THICK_UNCERT_380	The uncertainty of the aerosol optical thickness measured at 0.380 micrometers.
AEROSOL_OPT_THICK_UNCERT_401	The uncertainty of the aerosol optical thickness measured at 0.401 micrometers.
AEROSOL_OPT_THICK_UNCERT_440	The uncertainty of the aerosol optical thickness measured between 0.438 and 0.441 micrometers.
AEROSOL_OPT_THICK_UNCERT_522	The uncertainty of the aerosol optical thickness measured at 0.522 micrometers.
AEROSOL_OPT_THICK_UNCERT_608	The uncertainty of the aerosol optical thickness measured at 0.608 micrometers.
AEROSOL_OPT_THICK_UNCERT_667	The uncertainty of the aerosol optical thickness measured at 0.667 micrometers.

AEROSOL_OPT_THICK_UNCERT_779	The uncertainty of the aerosol optical thickness measured at 0.779 micrometers.
AEROSOL_OPT_THICK_UNCERT_866	The uncertainty of the aerosol optical thickness measured at 0.866 micrometers.
AEROSOL_OPT_THICK_UNCERT_1027	The uncertainty of the aerosol optical thickness measured at 1.027 micrometers.
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Reference Information File

Column Name	Units
DATE_OBS	[DD-MON-YY]
INTERCEPT_VOLTAGE_380	[volts]
INTERCEPT_VOLTAGE_401	[volts]
INTERCEPT_VOLTAGE_440	[volts]
INTERCEPT_VOLTAGE_522	[volts]
INTERCEPT_VOLTAGE_608	[volts]
INTERCEPT_VOLTAGE_667	[volts]
INTERCEPT_VOLTAGE_779	[volts]
INTERCEPT_VOLTAGE_866	[volts]
INTERCEPT_VOLTAGE_1027	[volts]
RAYLEIGH_OPT_THICK_380	[unitless]
RAYLEIGH_OPT_THICK_401	[unitless]
RAYLEIGH_OPT_THICK_440	[unitless]
RAYLEIGH_OPT_THICK_522	[unitless]
RAYLEIGH_OPT_THICK_608	[unitless]
RAYLEIGH_OPT_THICK_667	[unitless]
RAYLEIGH_OPT_THICK_779	[unitless]
RAYLEIGH_OPT_THICK_866	[unitless]
RAYLEIGH_OPT_THICK_1027	[unitless]
OZONE_OPT_THICK_380	[unitless]
OZONE_OPT_THICK_401	[unitless]
OZONE_OPT_THICK_440	[unitless]
OZONE_OPT_THICK_522	[unitless]
OZONE_OPT_THICK_608	[unitless]
OZONE_OPT_THICK_667	[unitless]
OZONE_OPT_THICK_779	[unitless]
OZONE_OPT_THICK_866	[unitless]
OZONE_OPT_THICK_1027	[unitless]
NO2_OPT_THICK_380	[unitless]
NO2_OPT_THICK_401	[unitless]
NO2_OPT_THICK_440	[unitless]
NO2_OPT_THICK_522	[unitless]
NO2_OPT_THICK_608	[unitless]
NO2_OPT_THICK_667	[unitless]
NO2_OPT_THICK_779	[unitless]

NO2_OPT_THICK_866	[unitless]
NO2_OPT_THICK_1027	[unitless]
REVISION_DATE	[DD-MON-YY]

Data File

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
SOLAR_ZEN_ANG	[degrees]
AIRMASS	[unitless]
AEROSOL_OPT_THICK_380	[unitless]
AEROSOL_OPT_THICK_401	[unitless]
AEROSOL_OPT_THICK_440	[unitless]
AEROSOL_OPT_THICK_522	[unitless]
AEROSOL_OPT_THICK_608	[unitless]
AEROSOL_OPT_THICK_667	[unitless]
AEROSOL_OPT_THICK_779	[unitless]
AEROSOL_OPT_THICK_866	[unitless]
AEROSOL_OPT_THICK_1027	[unitless]
AEROSOL_OPT_THICK_UNCERT_380	[unitless]
AEROSOL_OPT_THICK_UNCERT_401	[unitless]
AEROSOL_OPT_THICK_UNCERT_440	[unitless]
AEROSOL_OPT_THICK_UNCERT_522	[unitless]
AEROSOL_OPT_THICK_UNCERT_608	[unitless]
AEROSOL_OPT_THICK_UNCERT_667	[unitless]
AEROSOL_OPT_THICK_UNCERT_779	[unitless]
AEROSOL_OPT_THICK_UNCERT_866	[unitless]
AEROSOL_OPT_THICK_UNCERT_1027	[unitless]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Reference Information File

Column Name	Data Source
DATE_OBS	[Watch/Controller]
INTERCEPT_VOLTAGE_380	[Reagan sunphotometer]
INTERCEPT_VOLTAGE_401	[Reagan sunphotometer]
INTERCEPT_VOLTAGE_440	[Reagan sunphotometer]
INTERCEPT_VOLTAGE_522	[Reagan sunphotometer]
INTERCEPT_VOLTAGE_608	[Reagan sunphotometer]
INTERCEPT_VOLTAGE_667	[Reagan sunphotometer]
INTERCEPT_VOLTAGE_779	[Reagan sunphotometer]
INTERCEPT_VOLTAGE_866	[Reagan sunphotometer]
INTERCEPT_VOLTAGE_1027	[Reagan sunphotometer]
RAYLEIGH_OPT_THICK_380	[Calculated by the Young method]
RAYLEIGH_OPT_THICK_401	[Calculated by the Young method]
RAYLEIGH_OPT_THICK_440	[Calculated by the Young method]
RAYLEIGH_OPT_THICK_522	[Calculated by the Young method]

RAYLEIGH_OPT_THICK_608	[Calculated by the Young method]
RAYLEIGH_OPT_THICK_667	[Calculated by the Young method]
RAYLEIGH_OPT_THICK_779	[Calculated by the Young method]
RAYLEIGH_OPT_THICK_866	[Calculated by the Young method]
RAYLEIGH_OPT_THICK_1027	[Calculated by the Young method]
OZONE_OPT_THICK_380	[Convolved TOMS data]
OZONE_OPT_THICK_401	[Convolved TOMS data]
OZONE_OPT_THICK_440	[Convolved TOMS data]
OZONE_OPT_THICK_522	[Convolved TOMS data]
OZONE_OPT_THICK_608	[Convolved TOMS data]
OZONE_OPT_THICK_667	[Convolved TOMS data]
OZONE_OPT_THICK_779	[Convolved TOMS data]
OZONE_OPT_THICK_866	[Convolved TOMS data]
OZONE_OPT_THICK_1027	[Convolved TOMS data]
NO2_OPT_THICK_380	[Climatological data]
NO2_OPT_THICK_401	[Climatological data]
NO2_OPT_THICK_440	[Climatological data]
NO2_OPT_THICK_522	[Climatological data]
NO2_OPT_THICK_608	[Climatological data]
NO2_OPT_THICK_667	[Climatological data]
NO2_OPT_THICK_779	[Climatological data]
NO2_OPT_THICK_866	[Climatological data]
NO2_OPT_THICK_1027	[Climatological data]
REVISION_DATE	[Assigned by BORIS]

Data File

Column Name	Data Source
SITE_NAME	[Assigned by BORIS]
SUB_SITE	[Assigned by BORIS]
DATE_OBS	[Watch/Controller]
TIME_OBS	[Watch/Controller]
SOLAR_ZEN_ANG	[Solar algorithm]
AIRMASS	[Computed from solar elevation]
AEROSOL_OPT_THICK_380	[Reagan sunphotometer]
AEROSOL_OPT_THICK_401	[Reagan sunphotometer]
AEROSOL_OPT_THICK_440	[Reagan sunphotometer]
AEROSOL_OPT_THICK_522	[Reagan sunphotometer]
AEROSOL_OPT_THICK_608	[Reagan sunphotometer]
AEROSOL_OPT_THICK_667	[Reagan sunphotometer]
AEROSOL_OPT_THICK_779	[Reagan sunphotometer]
AEROSOL_OPT_THICK_866	[Reagan sunphotometer]
AEROSOL_OPT_THICK_1027	[Reagan sunphotometer]
AEROSOL_OPT_THICK_UNCERT_380	[Error propagation]
AEROSOL_OPT_THICK_UNCERT_401	[Error propagation]
AEROSOL_OPT_THICK_UNCERT_440	[Error propagation]
AEROSOL_OPT_THICK_UNCERT_522	[Error propagation]
AEROSOL_OPT_THICK_UNCERT_608	[Error propagation]
AEROSOL_OPT_THICK_UNCERT_667	[Error propagation]
AEROSOL_OPT_THICK_UNCERT_779	[Error propagation]
AEROSOL_OPT_THICK_UNCERT_866	[Error propagation]
AEROSOL_OPT_THICK_UNCERT_1027	[Error propagation]
CRTFCN_CODE	[Assigned by BORIS]
REVISION_DATE	[Assigned by BORIS]

7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

Reference Information File

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
DATE_OBS	25-MAY-94	19-SEP-94	None	None	None	None
INTERCEPT_VOLTAGE_380	4.883	4.913	None	None	None	None
INTERCEPT_VOLTAGE_401	6.95	7.247	None	None	None	None
INTERCEPT_VOLTAGE_440	5.722	5.851	None	None	None	None
INTERCEPT_VOLTAGE_522	6.091	6.115	None	None	None	None
INTERCEPT_VOLTAGE_608	6.178	6.295	None	None	None	None
INTERCEPT_VOLTAGE_667	6.865	6.907	None	None	None	None
INTERCEPT_VOLTAGE_779	6.667	6.714	None	None	None	None
INTERCEPT_VOLTAGE_866	5.952	6.026	None	None	None	None
INTERCEPT_VOLTAGE_1027	6.413	6.868	None	None	None	None
RAYLEIGH_OPT_THICK_380	.417	.426	None	None	None	None
RAYLEIGH_OPT_THICK_401	.333	.341	None	None	None	None
RAYLEIGH_OPT_THICK_440	.23	.235	None	None	None	None
RAYLEIGH_OPT_THICK_522	.113	.116	None	None	None	None
RAYLEIGH_OPT_THICK_608	.06	.062	None	None	None	None
RAYLEIGH_OPT_THICK_667	.042	.043	None	None	None	None
RAYLEIGH_OPT_THICK_779	.022	.023	None	None	None	None
RAYLEIGH_OPT_THICK_866	.014	.015	None	None	None	None
RAYLEIGH_OPT_THICK_1027	.007	.007	None	None	None	None
OZONE_OPT_THICK_380	0	0	None	None	None	None
OZONE_OPT_THICK_401	0	0	None	None	None	None
OZONE_OPT_THICK_440	.001	.001	None	None	None	None
OZONE_OPT_THICK_522	.013	.019	None	None	None	None
OZONE_OPT_THICK_608	.037	.052	None	None	None	None
OZONE_OPT_THICK_667	.013	.018	None	None	None	None
OZONE_OPT_THICK_779	.002	.003	None	None	None	None
OZONE_OPT_THICK_866	.001	.001	None	None	None	None

OZONE_OPT_THICK_1027	0	0	None	None	None	None
NO2_OPT_THICK_380	.003	.003	None	None	None	None
NO2_OPT_THICK_401	.003	.003	None	None	None	None
NO2_OPT_THICK_440	.002	.002	None	None	None	None
NO2_OPT_THICK_522	.001	.001	None	None	None	None
NO2_OPT_THICK_608	0	0	None	None	None	None
NO2_OPT_THICK_667	0	0	None	None	None	None
NO2_OPT_THICK_779	0	0	None	None	None	None
NO2_OPT_THICK_866	0	0	None	None	None	None
NO2_OPT_THICK_1027	0	0	None	None	None	None
REVISION_DATE	17-FEB-98	17-FEB-98	None	None	None	None

Data File

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-999-SBC01	SSA-999-SLH01	None	None	None	None
SUB_SITE	RSS12-SPH01	RSS12-SPH01	None	None	None	None
DATE_OBS	25-MAY-94	19-SEP-94	None	None	None	None
TIME_OBS	1142	2300	None	None	None	None
SOLAR_ZEN_ANG	30.67	87.31	None	None	None	None
AIRMASS	1.162	15.468	None	None	None	None
AEROSOL_OPT_THICK_380	.026	6.749	None	None	None	None
AEROSOL_OPT_THICK_401	.016	6.003	None	None	None	None
AEROSOL_OPT_THICK_440	.017	5.501	None	None	None	None
AEROSOL_OPT_THICK_522	.009	6.908	None	None	None	None
AEROSOL_OPT_THICK_608	-.004	7.362	None	None	None	None
AEROSOL_OPT_THICK_667	.008	6.413	None	None	None	None
AEROSOL_OPT_THICK_779	.009	7.5	None	None	None	None
AEROSOL_OPT_THICK_866	.002	7.452	None	None	None	None
AEROSOL_OPT_THICK_1027	.003	7.507	None	None	None	None
AEROSOL_OPT_THICK_UNCERT_380	.005	.83	None	None	None	None
AEROSOL_OPT_THICK_UNCERT_401	.005	.324	None	None	None	None
AEROSOL_OPT_THICK_UNCERT_440	.003	.138	None	None	None	None
AEROSOL_OPT_THICK_UNCERT_522	.003	.716	None	None	None	None
AEROSOL_OPT_THICK_UNCERT_608	.006	.86	None	None	None	None
AEROSOL_OPT_THICK_UNCERT_667	.002	.253	None	None	None	None

```
AEROSOL_OPT_THICK_   .001           .86            None    None   None    None
UNCERT_779
AEROSOL_OPT_THICK_   .001           .864           None    None   None    None
UNCERT_866
AEROSOL_OPT_THICK_   .002           .86            None    None   None    None
UNCERT_1027
CRTFCN_CODE          CPI            CPI            None    None   None    None
REVISION_DATE        02-JAN-97      02-JAN-97      None    None   None    None
-------------------------------------------------------------------------------
Minimum Data Value -- The minimum value found in the column.
Maximum Data Value -- The maximum value found in the column.
Missng Data Value  -- The value that indicates missing data. This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the attempt was unsuccessful.
Unrel Data Value   -- The value that indicates unreliable data.  This is used
                      to indicate an attempt was made to determine the
                      parameter value, but the value was deemed to be
                      unreliable by the analysis personnel.
Below Detect Limit -- The value that indicates parameter values below the
                      instruments detection limits.  This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the analysis personnel determined
                      that the parameter value was below the detection
                      limit of the instrumentation.
Data Not Cllctd    -- This value indicates that no attempt was made to
                      determine the parameter value.  This usually
                      indicates that BORIS combined several similar but
                      not identical data sets into the same data base table
                      but this particular science team did not
                      measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value.
N/A   -- Indicates that the value is not applicable to the respective column.
None  -- Indicates that no values of that sort were found in the column.
-------------------------------------------------------------------------------
```

7.4 Sample Data Record

The following is a sample of the first few records from the data table on the CD-ROM:

Reference Information File

```
DATE_OBS,INTERCEPT_VOLTAGE_380,INTERCEPT_VOLTAGE_401,INTERCEPT_VOLTAGE_440,
INTERCEPT_VOLTAGE_522,INTERCEPT_VOLTAGE_608,INTERCEPT_VOLTAGE_667,
INTERCEPT_VOLTAGE_779,INTERCEPT_VOLTAGE_866,INTERCEPT_VOLTAGE_1027,
RAYLEIGH_OPT_THICK_380,RAYLEIGH_OPT_THICK_401,RAYLEIGH_OPT_THICK_440,
RAYLEIGH_OPT_THICK_522,RAYLEIGH_OPT_THICK_608,RAYLEIGH_OPT_THICK_667,
RAYLEIGH_OPT_THICK_779,RAYLEIGH_OPT_THICK_866,RAYLEIGH_OPT_THICK_1027,
OZONE_OPT_THICK_380,OZONE_OPT_THICK_401,OZONE_OPT_THICK_440,OZONE_OPT_THICK_522,
OZONE_OPT_THICK_608,OZONE_OPT_THICK_667,OZONE_OPT_THICK_779,OZONE_OPT_THICK_866,
OZONE_OPT_THICK_1027,NO2_OPT_THICK_380,NO2_OPT_THICK_401,NO2_OPT_THICK_440,
NO2_OPT_THICK_522,NO2_OPT_THICK_608,NO2_OPT_THICK_667,NO2_OPT_THICK_779,
NO2_OPT_THICK_866,NO2_OPT_THICK_1027,REVISION_DATE
25-MAY-94,4.913,7.247,5.851,6.115,6.295,6.907,6.714,6.026,6.413,.423,.338,.234,
.115,.061,.042,.022,.015,.007,0.0,0.0,.001,.015,.042,.014,.003,.001,0.0,.003,
.003,.002,.001,0.0,0.0,0.0,0.0,0.0,17-FEB-98
```

```
26-MAY-94,4.913,7.247,5.851,6.115,6.295,6.907,6.714,6.026,6.413,.42,.336,.232,
.114,.061,.042,.022,.015,.007,0.0,0.0,.001,.015,.042,.014,.002,.001,0.0,.003,
.003,.002,.001,0.0,0.0,0.0,0.0,0.0,17-FEB-98
```

Data File: 94-07-21_SSA-999-SLH01.SPH

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,SOLAR_ZEN_ANG,AIRMASS,AEROSOL_OPT_THICK_380,
AEROSOL_OPT_THICK_401,AEROSOL_OPT_THICK_440,AEROSOL_OPT_THICK_522,
AEROSOL_OPT_THICK_608,AEROSOL_OPT_THICK_667,AEROSOL_OPT_THICK_779,
AEROSOL_OPT_THICK_866,AEROSOL_OPT_THICK_1027,AEROSOL_OPT_THICK_UNCERT_380,
AEROSOL_OPT_THICK_UNCERT_401,AEROSOL_OPT_THICK_UNCERT_440,
AEROSOL_OPT_THICK_UNCERT_522,AEROSOL_OPT_THICK_UNCERT_608,
AEROSOL_OPT_THICK_UNCERT_667,AEROSOL_OPT_THICK_UNCERT_779,
AEROSOL_OPT_THICK_UNCERT_866,AEROSOL_OPT_THICK_UNCERT_1027,CRTFCN_CODE,
REVISION_DATE
'SSA-999-SLH01','RSS12-SPH01',21-JUL-94,1204,82.53,7.292,.094,.076,.069,.055,
.039,.042,.036,.031,.029,.006,.006,.004,.003,.007,.003,.002,.002,.003,'CPI',
02-JAN-97
'SSA-999-SLH01','RSS12-SPH01',21-JUL-94,1205,82.4,7.176,.092,.075,.069,.055,.039,
.042,.036,.031,.028,.006,.006,.004,.003,.007,.003,.002,.002,.004,'CPI',02-JAN-97
'SSA-999-SLH01','RSS12-SPH01',21-JUL-94,1206,82.26,7.063,.092,.075,.068,.054,
.038,.041,.035,.03,.028,.006,.006,.004,.003,.007,.003,.002,.002,.004,'CPI',
02-JAN-97
'SSA-999-SLH01','RSS12-SPH01',21-JUL-94,1207,82.13,6.953,.091,.075,.068,.054,
.038,.041,.036,.031,.028,.006,.006,.004,.003,.007,.003,.002,.002,.004,'CPI',
02-JAN-97
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by the BOREAS Information System (BORIS) was the data collected during a given day at a given site.

8.2 Data Format(s)

The data are organized as one file per day at each site. There is also one reference file that contains information about the spectrally dependent exoatmospheric voltages (i.e., zero air mass Langley plot intercept voltages) and the Rayleigh, ozone, and NO_2 optical depths used in deriving the particulate optical depth spectra.

The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

9. Data Manipulations

9.1 Formulae

For all sunphotometer channels except the 940 nm, the Bouguer-Lambert-Beer extinction law was used to describe the attenuation of solar radiation:

$$V = (R'/R)^2 V_0 \exp(-m \tau) = V'_0 \exp(-m \tau)$$

where V is the output voltage of the detector at a given wavelength, V_0 is the zero air-mass voltage intercept at that wavelength for the mean Earth-Sun separation R', R is the Earth-Sun separation at the time of observation, m is the atmospheric air mass between the instrument and the Sun, tau is the wavelength-dependent total vertical optical depth above the sunphotometer, and V'_0 is the zero-air-mass voltage intercept for the Earth-Sun separation R at the time of observation. The 940-nm channel requires different processing and is not included this data set.

The logarithm of the above equation,

$$\ln V = \ln V'_0 - m \tau,$$

is used in calibration to provide the V'_0 values for each channel (i.e., zero air mass Langley plot intercept voltages). When the detector voltages are plotted against the air mass, the intercept is the V'_0. After calibration, this equation can be solved for tau to provide the total optical depth. The total optical depth is then decomposed using

$$\tau = \tau_r + \tau_a + \tau_{O_3} + \tau_{NO_2} + \tau_{H_2O},$$

where these terms are the optical depth due to Rayleigh scattering, aerosols, ozone, NO_2, and water vapor, respectively. The source for each of these terms is given in Section 7.3. Water vapor was ignored because it contributes only in the 940-nm channel.

This description is taken from Spanner et al., 1990, where more information concerning the data processing can be found.

9.1.1 Derivation Techniques and Algorithms

A description of the algorithms can be found in Spanner et al., 1990.

9.2 Data Processing Sequence

9.2.1 Processing Steps

The steps for processing are as follows: 1) acquire the data; 2) transfer data to computer; 3) run program to reformat data; 4) run a program to calculate all the variables, including solar zenith angle, air mass, Rayleigh optical depth, and instantaneous optical depth (total optical depth minus Rayleigh optical depth); 5) calculate NO_2 and ozone optical depths from Noxon et al., 1979, and TOMS data, respectively; and 6) subtract NO_2 and ozone to derive aerosol optical depth.

The ozone abundance was determined from the TOMS satellite instrument convolved with ozone absorption coefficients from Penney (1979). The following table shows the values calculated for NO_2 and ozone optical depth, which were subtracted from the instantaneous optical depth to derive the aerosol optical depth.

Wavelength	NO2 Tau	Ozone Tau
380	0.003	0.000
401	0.003	0.000
439	0.002	0.001
522	0.001	0.015
608	0.0	0.041
667	0.0	0.014
779	0.0	0.002
866	0.0	0.001
1027	0.0	0.0

9.2.2 Processing Changes

The processing sequence has not changed over time.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

No special corrections or adjustments have been made.

9.3.2 Calculated Variables

A description of the algorithms can be found in Spanner et al., 1990.

9.4 Graphs and Plots

Plots have been provided to BORIS and can be made available upon request.

10. Errors

10.1 Sources of Error

Calibration errors are the main source of error in the derivation of aerosol optical depth.

10.2 Quality Assessment

10.2.1 Data Validation by Source

Data were compared with the RSS-11 ATSP measurements (see related data sets, Section 1.6).

10.2.2 Confidence Level/Accuracy Judgment

The data are of high quality, because a good calibration of the instrument was performed before and after the BOREAS field collection effort. However, post-BOREAS calibration data were not available for the 1027-nm channel.

10.2.3 Measurement Error for Parameters

Uncertainties for the aerosol optical depths were determined by using uncertainty propagation through the algorithm. The aerosol optical depth uncertainty is dependent on the uncertainty in the Rayleigh, ozone, and NO_2 optical depths, as well as the uncertainty in the intercept voltage (calibration error), instantaneous measurement, and airmass. Aerosol optical depth uncertainties are given in the data files and are summarized in Section 7.3 of this document.

10.2.4 Additional Quality Assessments

None.

10.2.5 Data Verification by Data Center

Visual review and use of selected subsets of the data have shown them to be of good quality with

no noteworthy problems.

11. Notes

11.1 Limitations of the Data

None given.

11.2 Known Problems with the Data

Because the post-BOREAS calibration in November 1994 did not provide intercept voltage data for the 1027-nm channel, an updated voltage was not available. An estimate based on previous calibrations was used.

11.3 Usage Guidance

The values of aerosol optical depth are accurate instantaneous values of aerosol optical depth. These data were taken every minute; therefore, under conditions of rapid variability in cloudiness or haze, the data may not be internally consistent or appropriate. It is useful to calculate averages of aerosol optical depth over periods of time (for example, 30 minutes) to get a more accurate measure of the average conditions at a site.

11.4 Other Relevant Information

The aerosol optical depth at 940 nm was not calculated because this channel primarily measures absorption due to water vapor.

12. Application of the Data Set

These data can be used for correcting various visible and infrared satellite and aircraft image products or for characterizing the atmospheric aerosols at the times of the flights.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

NASA ARC software was developed in FORTRAN on a VAX to implement the data processing procedure described in Section 9.1. Input data include sunphotometer data files as well as ozone and NO_2 optical depth parameters. Aerosol optical depths were calculated and written to the data files. No special software is needed to read the data files because they are stored comma-delimited.

14.2 Software Access

This software is used to generate the data product from the detector voltages and is not needed to use the data.

15. Data Access

The AGSP data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

None.

16.2 Film Products

None.

16.3 Other Products

These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

Portable Radiometer Data Reduction Manual for use with PDATA7.

17.2 Journal Articles and Study Reports

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Wrigley, R.C., M.A. Spanner, R.E. Slye, R.F. Pueschel, and H.R. Aggarwal. 1992. Atmospheric correction of remotely sensed image data by a simplified model. Journal of Geophysical Research 97(D17):18,797-18,814.

Young, A. 1980. Revised depolarization corrections for atmospheric extinction. Applied Optics 19:3427-3428.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

air mass	secant of the solar zenith angle
optical depth	an indirect measure of the size and number of particles present in a given column of air, which is a measure of the extinction of the direct solar beam by aerosols and particulates in the atmosphere, or by scattering. Also referred to as optical thickness.
phase function	a measure of the light scattered by a particle as a function of angle with respect to the original direction of propagation
radiometer	an instrument for measuring radiant energy
Rayleigh scattering	wavelength-dependent scattering directly proportional to (1 + cos2(angle)) and indirectly proportional to wavelength
single scattering albedo	the fraction of light intercepted and scattered by a single particle

19. List of Acronyms

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AGSP    - Automated Ground Sunphotometer
ARC     - Ames Research Center
ASCII   - American Standard Code for Information Interchange
ATSP    - Airborne Tracking Sunphotometer
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOReas Information System
CD-ROM  - Compact Disk-Read-Only Memory
DAAC    - Distributed Active Archive Center
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
FIFE    - First ISLSCP Field Experiment
FOV     - Field of View
FWHM    - Full Width Half Maximum
GIS     - Geographic Information System
GMT     - Greenwich Mean Time
GSFC    - Goddard Space Flight Center
HTML    - HyperText Markup Language
IFC     - Intensive Field Campaign
ISLSCP  - International Satellite Land Surface Climatology
MAS     - MODIS Airborne Simulator
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MODIS   - MODerate-resolution Imaging Spectrometer
NASA    - National Aeronautics and Space Administration
NSA     - Northern Study Area
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
RSS     - Remote Sensing Science
SSA     - Southern Study Area
TM      - Thematic Mapper
TMS     - Thematic Mapper Simulator
TOMS    - Total Ozone Mapping Spectrometer
URL     - Uniform Resource Locator
UTC     - Universal Time Code
UTM     - Universal Transverse Mercator
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13. ABSTRACT *(Maximum 200 words)*

The BOREAS RSS-12 team collected both ground and airborne sunphotometer measurements for use in characterizing the aerosol optical properties of the atmosphere during the BOREAS data collection activities. These measurements are to be used to: 1) measure the magnitude and variability of the aerosol optical depth in both time and space; 2) determine the optical properties of the boreal aerosols; and 3) atmospherically correct some remotely sensed data acquired during BOREAS. These data cover selected days and times from May to September 1994 and were taken from one of two ground sites near Candle Lake in the SSA. The data described in this document are from the field sunphotometer data. The data are stored in tabular ASCII files.

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