NASA/TM—2000-209891, Vol. 59

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

*Forrest G. Hall and Jaime Nickeson, Editors*

## Volume 59

## BOREAS RSS-12 Airborne Tracking Sunphotometer Measurements

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

National Aeronautics and
Space Administration

**Goddard Space Flight Center**
Greenbelt, Maryland 20771

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*Robert Wrigley, NASA Ames Research Center, Moffett Field, California*

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# BOREAS RSS-12 Airborne Tracking Sunphotometer Measurements

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 remotely sensed data acquired during BOREAS. This data set contains airborne tracking sunphotometer data that were acquired from the C-130 aircraft during its flights over the BOREAS study areas. The data cover selected days and times from May to September 1994. The data are stored in tabular ASCII files.

## Table of Contents



## 1. Data Set Overview

### 1.1 Data Set Identification

BOREAS RSS-12 Airborne Tracking Sunphotometer Measurements

### 1.2 Data Set Introduction

The Airborne Tracking Sunphotometer (ATSP) data set consists of instrument voltages; Sun position information; 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 C-130 flights.

### 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 1994 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, solar position, and aircraft altitude.

### 1.5 Discussion

The ATSP data were used in conjunction with the Automated Ground Sunphotometer (AGSP) 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 Simulation (TMS), Landsat Thematic Mapper (TM), and MODerate-resolution Imaging Spectrometer (MODIS) Airborne Simulator (MAS) data collected during the 1994 BOREAS IFCs.

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 Automatic Ground Sunphotometer Measurements in the SSA
BOREAS RSS-18 Ground Sunphotometer Measurements in the SSA

## 2. Investigator(s)

### 2.1 Investigator(s) Name and Title

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 ATSP measures direct-beam solar radiation for six channels in the visible and near-infrared wavelengths. The solar radiation data are collected in the form of voltages. The instrument was calibrated before and after the experiment at high mountain observatories, which often have clean, stable air masses, so the Langley plot technique could be used. For calibration, data are collected at a range 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 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 ATSP wavelengths. Ozone optical depth is calculated using ozone abundances from the Total Ozone Mapping Spectrometer (TOMS) satellite instrument and convolved with absorption coefficients at ATSP wavelengths. The result of this processing is the aerosol optical depth measured in five channels (not including the 940-nm water vapor channel) at approximately 2-second intervals in the air and 10-second 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 because of 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 instrument consists of a solar-tracking system, detector module, temperature control system, nitrogen-purge system, mechanical drive chain, and data collection system.

### 4.1.1 Collection Environment

The ATSP was used for data collection while mounted on the NASA C-130 aircraft. Data were collected while the aircraft was on the ground and during flight at altitudes up to 10,120 meters.

### 4.1.2 Source/Platform

The ATSP was mounted on the NASA ARC C-130 Earth Resources aircraft.

### 4.1.3 Source/Platform Mission Objectives

The ATSP was developed to obtain accurate multispectral atmospheric extinction measurements at different altitudes.

### 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 sensors used are Clairex photoresistors that have been matched to track each other over the operational range of Sun intensities. The sensing technique uses a shadow mask that bisects each detector when the system is in balance. The design allows for very accurate tracking, yet at the same time provides a field of view (FOV) and accurate tracking in a very compact package. The dome rotation is referred to as azimuth motion. The central section of the dome is free to rotate within the dome, perpendicular to the azimuth, and is referred to as elevation motion. The control system is designed to compensate for the flight characteristics of the aircraft.

### 4.1.6 Sensor/Instrument Measurement Geometry

The six separate detectors view the Sun simultaneously at six independent wavelengths. The FOV of each detector is set by the entrance aperture to 4 degrees; the inside surfaces of the aperture assembly are anodized a dull black to reduce internal reflections. The 4-degree FOV was selected to allow for +/-1 degree of tracking error without affecting the solar-radiation signal. The wavelengths and the full width half maximum (FWHM) of the ATSP are shown in the following table for all channels.

| Wavelength (nm) | FWHM (nm) |
|---|---|
| 379.8 | 11.0 |
| 451.3 | 6.2 |
| 525.7 | 9.1 |
| 860.5 | 13.0 |
| 940.0 | 0.2 |
| 1059.9 | 12.7 |

The system is designed to move in elevation or azimuth at 8 degrees per second. The acceleration that may occur during a turn is estimated to be 1.0 radian per second squared. If the instrument should lose lock, the reacquisition occurs very rapidly as long as the Sun is in the FOV of the instrument. The tracking system responds quickly because it uses a single rate of 8 degrees per second for tracking. The solar-tracking system was designed to achieve two objectives: first, to be able to acquire the Sun starting from a position several degrees away; and second, to track the Sun with an accuracy of +/-2 degrees in the presence of aircraft movements.

#### 4.1.7 Manufacturer of Sensor/Instrument

Manufactured by NASA ARC, Moffett Field, CA 94035, Dr. Philip Russell, Principal Investigator.

### 4.2 Calibration

#### 4.2.1 Specifications

The detectors are temperature controlled, and the amplifier gains are set with precision resistors. The resolution of the detector signals is limited by the 12-bit analog-to-digital converter that can resolve 1 part out of 2048 of the 0 to +10-v detector signals. The instrument is designed to operate in clear skies, and it is assumed that over the period of a flight profile, there are no solar fluctuations.

##### 4.2.1.1 Tolerance

There is evidence in the literature that in the wavelength region of interest, solar fluctuations would account for less than a 1% variation of 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

The calibration coefficients, corrected for Earth-Sun distance, are contained in the data files.

## 5. Data Acquisition Methods

The data collection system was based on a Hewlett-Packard HP9816 computer with floppy disk and printer. This system was used to run data collection, data processing, and printing software developed by NASA ARC. In addition to the computer, the data collection system included a multiplexer, a 12-bit analog-to-digital converter, and electronics to process the aircraft inertial navigation data. The data are sampled approximately every 2 seconds and are synchronized with the aircraft data system, which provides the altitude, longitude, and latitude data. The science data set includes the six detector signals, detector temperature, tracking error, Sun tracker azimuth angle, Sun tracker elevation angle, and Universal Time Code (UTC) time. The data were stored on 3.5-inch floppy disks and were also printed for real-time check and backup. Data were collected for the duration of the optical flights of the C-130 aircraft and were collected on the ground before and/or after the flights to determine the total atmospheric aerosol optical depth.

A new data collection system is under design and construction. It will be based on a 486 laptop PC running Visual Basic in a Windows environment. Digital-to-analog conversion will be significantly enhanced and optimized for each channel using a Dacbook. Data reduction will be simplified because the necessity for hex-to-ASCII conversion will be eliminated. Several programs currently requiring processing on minicomputers will be installed on the PC; this will permit processing to semifinal products in the field (only the postmission calibration will have to be incorporated into the final products).

# 6. Observations

## 6.1 Data Notes

None.

## 6.2 Field Notes

The ATSP operator normally takes notes of significant events while the instrument is acquiring data. These notes supplement the real-time display of detector voltages or optical depths and permit determination of the presence of variable cloud interference with remote sensing data collection; this feature often indicates whether or not a given flight line was acceptable or had to be repeated. If the line was acceptable, then 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 ATSP views the Sun with a 4-degree FOV and typically acquires data every 2 or 3 seconds during flight. A typical ground speed of the C-130 aircraft is 150 m/sec. Hence, data are collected every 300 meters along a flight line. During spiral descents and ascents, typical vertical rates are 1,000 ft/min or 5 m/sec, so the ATSP samples the vertical column every 10 meters.

### 7.1.1 Spatial Coverage

Although most of the data were collected over the BOREAS Northern Study Area (NSA), Southern Study Area (SSA), and tower sites, some data are available over the transect between the NSA and SSA. The North American Datum of 1983 (NAD83) corner coordinates of the 1,000- by 1,000-km BOREAS region are:

| | Latitude | Longitude |
|---|---|---|
| Northwest | 59.97907°N | 111.00000°W |
| Northeast | 58.84379°N | 93.50224°W |
| Southwest | 51.00000°N | 111.00000°W |
| Southeast | 50.08913°N | 96.96951°W |

The NAD83 corner coordinates of the NSA are:

| | Latitude | Longitude |
|---|---|---|
| Northwest | 56.249°N | 98.825°W |
| Northeast | 56.083°N | 97.234°W |
| Southwest | 55.542°N | 99.045°W |
| Southeast | 55.379°N | 97.489°W |

The 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 sunphotometer's spatial resolution was variable based on aircraft maneuvers and flight speed. If the sunphotometer was acquiring data every 2 seconds and the C-130 was flying level at 150 m/sec, then the ground resolution was 300 meters.

### 7.1.4 Projection

The coordinates in the data files are from the C-130 inertial navigation system (INS). The INS geographic position data are from the onboard Global Positioning System (GPS), which uses NAD83.

### 7.1.5 Grid Description

Not applicable.

## 7.2 Temporal Characteristics

### 7.2.1 Temporal Coverage

Data were acquired during three IFCs in 1994. The days and times were:

| Date | Time (GMT) | Date | Time (GMT) |
|---|---|---|---|
| 25-May-1994 | 15:21:28-18:02:23 | 31-Jul-1994 | 12:59:18-18:24:25 |
| 26-May-1994 | 12:51:41-19:15:20 | 02-Aug-1994 | 13:09:15-18:07:19 |
| 31-May-1994 | 13:30:20-16:30:26 | 03-Aug-1994 | 14:37:00-16:46:39 |
| 01-Jun-1994 | 13:34:43-15:20:41 | 04-Aug-1994 | 12:45:25-22:23:19 |
| 04-Jun-1994 | 13:08:07-18:53:02 | 08-Aug-1994 | 12:47:45-15:43:01 |
| 06-Jun-1994 | 15:07:25-17:33:26 | 09-Aug-1994 | 12:36:04-19:20:08 |
| 07-Jun-1994 | 14:15:28-17:08:53 | 10-Aug-1994 | 13:21:34-18:08:37 |
| 08-Jun-1994 | 14:04:34-22:29:33 | 31-Aug-1994 | 14:05:24-19:55:39 |
| 20-Jul-1994 | 15:12:04-18:25:55 | 01-Sep-1994 | 00:40:38-14:27:32 |
| 21-Jul-1994 | 13:46:30-17:33:00 | 02-Sep-1994 | 13:51:45-17:10:32 |
| 22-Jul-1994 | 14:04:43-17:27:18 | 03-Sep-1994 | 14:08:56-16:53:50 |
| 23-Jul-1994 | 13:44:38-14:41:09 | 06-Sep-1994 | 15:03:13-18:33:01 |
| 24-Jul-1994 | 13:50:45-14:08:24 | 08-Sep-1994 | 14:02:31-17:41:14 |
| 26-Jul-1994 | 16:08:00-17:15:44 | 09-Sep-1994 | 15:49:51-16:00:32 |
| 29-Jul-1994 | 13:21:03-18:16:19 | | |

### 7.2.2 Temporal Coverage Map

Not available.

### 7.2.3 Temporal Resolution

The ATSP typically samples every 2 or 3 seconds during flight, but the sampling rate is under computer control and can be modified if necessary.

## 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_450
INTERCEPT_VOLTAGE_525
INTERCEPT_VOLTAGE_862
INTERCEPT_VOLTAGE_1021
OZONE_OPT_THICK_380
OZONE_OPT_THICK_450
OZONE_OPT_THICK_525
OZONE_OPT_THICK_862
OZONE_OPT_THICK_1021
NO2_OPT_THICK_380
NO2_OPT_THICK_450
NO2_OPT_THICK_525
NO2_OPT_THICK_862
NO2_OPT_THICK_1021
REVISION_DATE
```

```
Data File
         Column Name
------------------------------
SPATIAL_COVERAGE
DATE_OBS
TIME
WAVELENGTH
RAYLEIGH_OPT_THICK
AEROSOL_OPT_THICK
AEROSOL_OPT_THICK_UNCERT
SOLAR_ZEN_ANG
AIRMASS
PLATFORM_ALTITUDE
LATITUDE
LONGITUDE
C130_MISSION_ID
C130_LINE_NUM
C130_RUN_NUM
C130_SITE
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_450 | The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 0.451 micrometers. |
| INTERCEPT_VOLTAGE_525 | The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 0.525 micrometers. |
| INTERCEPT_VOLTAGE_862 | The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 0.862 micrometers. |
| INTERCEPT_VOLTAGE_1021 | The y-intercept voltage computed from a Langley plot (ln plot) of the measured voltages and a function of the optical airmass at 1.201 micrometers. |
| OZONE_OPT_THICK_380 | Ozone optical thickness at 0.380 micrometers from TOMS data and convolved with absorption coefficients. |
| OZONE_OPT_THICK_450 | Ozone optical thickness at 0.451 micrometers from TOMS data and convolved with absorption coefficients. |
| OZONE_OPT_THICK_525 | Ozone optical thickness at 0.525 micrometers from TOMS data and convolved with absorption coefficients. |
| OZONE_OPT_THICK_862 | Ozone optical thickness at 0.862 micrometers from TOMS data and convolved with absorption coefficients. |
| OZONE_OPT_THICK_1021 | Ozone optical thickness at 0.1021 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_450 | Nitrogen dioxide optical thickness at 0.451 micrometers as obtained from climatology tables and convolved with absorption coefficients. |
| NO2_OPT_THICK_525 | Nitrogen dioxide optical thickness at 0.525 micrometers as obtained from climatology tables and convolved with absorption coefficients. |
| NO2_OPT_THICK_862 | Nitrogen dioxide optical thickness at 0.862 micrometers as obtained from climatology tables and convolved with absorption coefficients. |

| | |
|---|---|
| NO2_OPT_THICK_1021 | Nitrogen dioxide optical thickness at 1.021 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 |
|---|---|
| SPATIAL_COVERAGE | The general term used to denote the spatial area over which the data were collected. |
| DATE_OBS | The date on which the data were collected. |
| TIME | The Greenwich Mean Time (GMT) when the data were collected. |
| WAVELENGTH | Spectral wavelength at which measurement was acquired. |
| RAYLEIGH_OPT_THICK | The Rayleigh optical thickness calculated at the given altitude and wavelength. |
| AEROSOL_OPT_THICK | The aerosol optical thickness measured at the given wavelength. |
| AEROSOL_OPT_THICK_UNCERT | The optical thickness uncertainty of the measurement. |
| 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. |
| PLATFORM_ALTITUDE | The nominal altitude of the data collection platform above the target. |
| LATITUDE | The NAD83-based latitude coordinate at the site. |
| LONGITUDE | The NAD83-based longitude coordinate at the site. |
| C130_MISSION_ID | The mission identifier assigned to the C130 mission in the form of YY-DDD-FF where YY is the last two digits of the fiscal year, DDD is the deployment number for "official" C130 missions and is day of year for non-"official" C130 missions (i.e., no site coverage), and FF is the flight number within the given deployment (00 is given for non-"official" C130 missions). An example would be 94-006-04. |
| C130_LINE_NUM | The number of the C130 line in its flights over the BOREAS area as given in the flight logs. Zero values are given for non-"official" C130 missions and for data between C130 sites or lines. |
| C130_RUN_NUM | The number of the C130 run in its flights over the BOREAS area as given in the flight logs. Zero value is given for non-"official" C130 missions and data between C130 sites, lines or runs. |
| C130_SITE | The C130 site designator as given in the flight logs. PRE is used for data taken from the airport to the first "official" C130 site, BTW is used for data taken between two "official" C130 |

| | |
|---|---|
| | sites, DSC is used for data taken after the last "official" C130 site, TRN is used for transect data, and YTH and YPA are used for data taken at the YTH and YPA airports (aircraft never left the ground). |
| 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 descriptions of 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_450 | [volts] |
| INTERCEPT_VOLTAGE_525 | [volts] |
| INTERCEPT_VOLTAGE_862 | [volts] |
| INTERCEPT_VOLTAGE_1021 | [volts] |
| OZONE_OPT_THICK_380 | [unitless] |
| OZONE_OPT_THICK_450 | [unitless] |
| OZONE_OPT_THICK_525 | [unitless] |
| OZONE_OPT_THICK_862 | [unitless] |
| OZONE_OPT_THICK_1021 | [unitless] |
| NO2_OPT_THICK_380 | [unitless] |
| NO2_OPT_THICK_450 | [unitless] |
| NO2_OPT_THICK_525 | [unitless] |
| NO2_OPT_THICK_862 | [unitless] |
| NO2_OPT_THICK_1021 | [unitless] |
| REVISION_DATE | [DD-MON-YY] |

**Data File**

| Column Name | Units |
|---|---|
| SPATIAL_COVERAGE | [none] |
| DATE_OBS | [DD-MON-YY] |
| TIME | [HHMMSS GMT] |
| WAVELENGTH | [micrometers] |
| RAYLEIGH_OPT_THICK | [unitless] |
| AEROSOL_OPT_THICK | [unitless] |
| AEROSOL_OPT_THICK_UNCERT | [unitless] |
| SOLAR_ZEN_ANG | [degrees] |
| AIRMASS | [unitless] |
| PLATFORM_ALTITUDE | [meters] |
| LATITUDE | [degrees] |
| LONGITUDE | [degrees] |
| C130_MISSION_ID | [none] |
| C130_LINE_NUM | [none] |
| C130_RUN_NUM | [none] |

| | |
|---|---|
| C130_SITE | [none] |
| 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 | [Aircraft data system] |
| INTERCEPT_VOLTAGE_380 | [Sunphotometer] |
| INTERCEPT_VOLTAGE_450 | [Sunphotometer] |
| INTERCEPT_VOLTAGE_525 | [Sunphotometer] |
| INTERCEPT_VOLTAGE_862 | [Sunphotometer] |
| INTERCEPT_VOLTAGE_1021 | [Sunphotometer] |
| OZONE_OPT_THICK_380 | [Convolved TOMS data] |
| OZONE_OPT_THICK_450 | [Convolved TOMS data] |
| OZONE_OPT_THICK_525 | [Convolved TOMS data] |
| OZONE_OPT_THICK_862 | [Convolved TOMS data] |
| OZONE_OPT_THICK_1021 | [Convolved TOMS data] |
| NO2_OPT_THICK_380 | [Climatological data] |
| NO2_OPT_THICK_450 | [Climatological data] |
| NO2_OPT_THICK_525 | [Climatological data] |
| NO2_OPT_THICK_862 | [Climatological data] |
| NO2_OPT_THICK_1021 | [Climatological data] |
| REVISION_DATE | [Assigned by BORIS] |

**Data File**

| Column Name | Data Source |
|---|---|
| SPATIAL_COVERAGE | [Assigned by BORIS] |
| DATE_OBS | [Aircraft data system] |
| TIME | [Aircraft data system] |
| WAVELENGTH | [Sunphotometer] |
| RAYLEIGH_OPT_THICK | [Calculated by the Young method] |
| AEROSOL_OPT_THICK | [Sunphotometer] |
| AEROSOL_OPT_THICK_UNCERT | [Error propagation] |
| SOLAR_ZEN_ANG | [Calculated from solar algorithm] |
| AIRMASS | [Calculated from solar elevation] |
| PLATFORM_ALTITUDE | [Aircraft navigation system] |
| LATITUDE | [Aircraft navigation system] |
| LONGITUDE | [Aircraft navigation system] |
| C130_MISSION_ID | [Flight summary report] |
| C130_LINE_NUM | [Flight summary report] |
| C130_RUN_NUM | [Flight summary report] |
| C130_SITE | [Flight summary report] |
| 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 | 09-SEP-94 | None | None | None | None |
| INTERCEPT_VOLTAGE_380 | 6.1 | 6.219 | None | None | None | None |
| INTERCEPT_VOLTAGE_450 | 5.254 | 5.29 | None | None | None | None |
| INTERCEPT_VOLTAGE_525 | 7.929 | 7.984 | None | None | None | None |
| INTERCEPT_VOLTAGE_862 | 8.07 | 8.11 | None | None | None | None |
| INTERCEPT_VOLTAGE_1021 | 7.021 | 7.027 | None | None | None | None |
| OZONE_OPT_THICK_380 | 0 | 0 | None | None | None | None |
| OZONE_OPT_THICK_450 | .001 | .001 | None | None | None | None |
| OZONE_OPT_THICK_525 | .016 | .02 | None | None | None | None |
| OZONE_OPT_THICK_862 | 0 | 0 | None | None | None | None |
| OZONE_OPT_THICK_1021 | 0 | 0 | None | None | None | None |
| NO2_OPT_THICK_380 | .003 | .003 | None | None | None | None |
| NO2_OPT_THICK_450 | .002 | .002 | None | None | None | None |
| NO2_OPT_THICK_525 | .001 | .001 | None | None | None | None |
| NO2_OPT_THICK_862 | 0 | 0 | None | None | None | None |
| NO2_OPT_THICK_1021 | 0 | 0 | None | None | None | None |
| REVISION_DATE | 18-FEB-98 | 18-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 |
|---|---|---|---|---|---|---|
| SPATIAL_COVERAGE | N/A | N/A | None | None | None | None |
| DATE_OBS | 25-MAY-94 | 09-SEP-94 | None | None | None | None |
| TIME | 00:40:38 | 24:36:04 | None | None | None | None |
| WAVELENGTH | .3801 | 1.0207 | None | None | None | None |
| RAYLEIGH_OPT_THICK | .003 | .446 | None | None | None | None |
| AEROSOL_OPT_THICK | .002 | 7.063 | None | None | None | None |
| AEROSOL_OPT_THICK_UNCERT | .002 | 1.93 | None | None | None | None |
| SOLAR_ZEN_ANG | 31.757 | 77.137 | None | None | None | None |
| AIRMASS | 1.1749 | 4.40519 | None | None | None | None |
| PLATFORM_ALTITUDE | 12 | 8207 | None | None | None | None |
| LATITUDE | 52.938 | 56.333 | None | None | None | None |
| LONGITUDE | -106.747 | -97.377 | None | None | None | None |
| C130_MISSION_ID | 94-005-04 | 94-252-00 | None | None | None | None |
| C130_LINE_NUM | 0 | 999 | None | None | None | None |
| C130_RUN_NUM | 0 | 99 | None | None | None | None |
| C130_SITE | 429 | YTH | None | None | None | None |

```
CRTFCN_CODE        CPI            CPI            None    None    None    None
REVISION_DATE      12-SEP-95      21-SEP-95      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_450,INTERCEPT_VOLTAGE_525,
INTERCEPT_VOLTAGE_862,INTERCEPT_VOLTAGE_1021,OZONE_OPT_THICK_380,
OZONE_OPT_THICK_450,OZONE_OPT_THICK_525,OZONE_OPT_THICK_862,
OZONE_OPT_THICK_1021,NO2_OPT_THICK_380,NO2_OPT_THICK_450,NO2_OPT_THICK_525,
NO2_OPT_THICK_862,NO2_OPT_THICK_1021,REVISION_DATE
25-MAY-94,6.219,5.29,7.984,8.07,7.027,0.0,.001,.017,0.0,0.0,.003,.002,.001,0.0,
0.0,18-FEB-98
26-MAY-94,6.219,5.29,7.984,8.07,7.027,0.0,.001,.017,0.0,0.0,.003,.002,.001,0.0,
0.0,18-FEB-98
```

```
Data File (format is the same for daily and day-site extractions)
SPATIAL_COVERAGE,DATE_OBS,TIME,WAVELENGTH,RAYLEIGH_OPT_THICK,AEROSOL_OPT_THICK,
AEROSOL_OPT_THICK_UNCERT,SOLAR_ZEN_ANG,AIRMASS,PLATFORM_ALTITUDE,LATITUDE,
LONGITUDE,C130_MISSION_ID,C130_LINE_NUM,C130_RUN_NUM,C130_SITE,CRTFCN_CODE,
REVISION_DATE
'SSA',21-JUL-94,134630,.3801,.425,.107,.007,68.267,2.68196,428.0,53.214,-105.672,
'94-007-02',0,0,'PRE','CPI',19-SEP-95
'SSA',21-JUL-94,134630,.4707,.21,.078,.004,68.267,2.68196,428.0,53.214,-105.672,
'94-007-02',0,0,'PRE','CPI',19-SEP-95
'SSA',21-JUL-94,134630,.5253,.112,.06,.005,68.267,2.68196,428.0,53.214,-105.672,
'94-007-02',0,0,'PRE','CPI',19-SEP-95
'SSA',21-JUL-94,134630,.862,.015,.033,.006,68.267,2.68196,428.0,53.214,-105.672,
'94-007-02',0,0,'PRE','CPI',19-SEP-95
'SSA',21-JUL-94,134630,1.0207,.008,.031,.004,68.267,2.68196,428.0,53.214,
-105.672,'94-007-02',0,0,'PRE','CPI',19-SEP-95
```

# 8. Data Organization

## 8.1 Data Granularity

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

## 8.2 Data Format(s)

There is one single file of the reference information, and both full daily files (multiple sites within a day) and day-site files (single site on a given day).

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 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 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) 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); 3) calculate $NO_2$ and ozone optical depths from Noxon et al., 1979, and TOMS data, respectively; and 4) 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 values calculated for $NO_2$ and ozone optical depth were subtracted from the instantaneous optical depth to derive the aerosol optical depth, are provided in the data files.

#### 9.2.2 Processing Changes

None given.

### 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 field sunphotometer (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.

#### 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.

### 11.2 Known Problems with the Data

None.

### 11.3 Usage Guidance

The values of aerosol optical depth are accurate instantaneous values of aerosol optical depth. These data were taken frequently; 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 to get a more accurate measure of the average conditions at a site. Users should take note that the daily extracted files have a large size range (400 to 38,000 records)

### 11.4 Other Relevant Information

The aerosol optical depth at 941 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

Future plans for the airborne instrument include the design and development of a new 14-channel airborne instrument.

# 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 ATSP 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/ [Internet Link].

### 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
None.

### 17.2 Journal Articles and Study Reports
Bruegge, C.J., R.N. Halthore, B. Markham, M. Spanner, and R. Wrigley. 1992. Aerosol optical depth retrievals over the Konza Prairie. Journal of Geophysical Research 97(D17):18,743-18,758.

King, M., D. Bryne, B. Herman, and J. Reagan. 1978. Aerosol size distributions obtained by inversion of spectral optical depth measurements. J. Atmos. Sci. 35:2153-2167.

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Noxon, J. 1979. Stratospheric $NO_2$, 2, Global behavior. Journal of Geophysical Research 84:5,067-5,076.

Penney, C.M. 1979. Study of temperature dependence of the Chappuis band absorption of ozone, NASA Contract Rep. 158977, General Electric Company, Schenectady, NY.

Russell, P., J. Livingston, E. Dutton, R. Pueschel, J. Reagan, T. DeFoor, M. Box, D. Allen, P. Pilewskie, B. Herman, S. Kinne, and D. Hofmann. 1994. Pinatubo and pre-Pinatubo optical depth spectra: Mauna Loa measurements, comparisons, inferred particle size distributions, radiative effects, and relationship to lidar data. Journal of Geophysical Research 98:22,969-22,985.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

Spanner, M., R. Wrigley, R. Pueschel, J. Livingston, and D. Colburn. 1990. Determination of atmospheric optical properties for the First ISLSCP Field Experiment (FIFE). Journal of Spacecraft and Rockets 27:373-379.

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

| | |
|---|---|
| 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 |
| GPS | - Global Positioning System |
| GSFC | - Goddard Space Flight Center |
| HTML | - HyperText Markup Language |
| IFC | - Intensive Field Campaign |
| INS | - Inertial Navigation System |
| ISLSCP | - International Satellite Land Surface Climatology Project |
| MAS | - MODIS Airborne Simulator |
| 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 |

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When using or referencing these data, please acknowledge the NASA ARC investigation (RSS-12) and Michael Spanner, Principal Investigator. Also, include the citations of relevant papers in Section 17.2.

If using data from the BOREAS CD-ROM series, also reference the data as:

Wrigley, R.C., M.A. Spanner, R.E. Slye, P.B. Russell, and J.M. Livingston, "Aerosol Determinations and Atmospheric Correction for BOREAS Imagery." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

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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 remotely sensed data acquired during BOREAS. This data set contains airborne tracking sunphotometer data that were acquired from the C-130 aircraft during its flights over the BOREAS study areas. The data cover selected days and times from May to September 1994. The data are stored in tabular ASCII files.

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