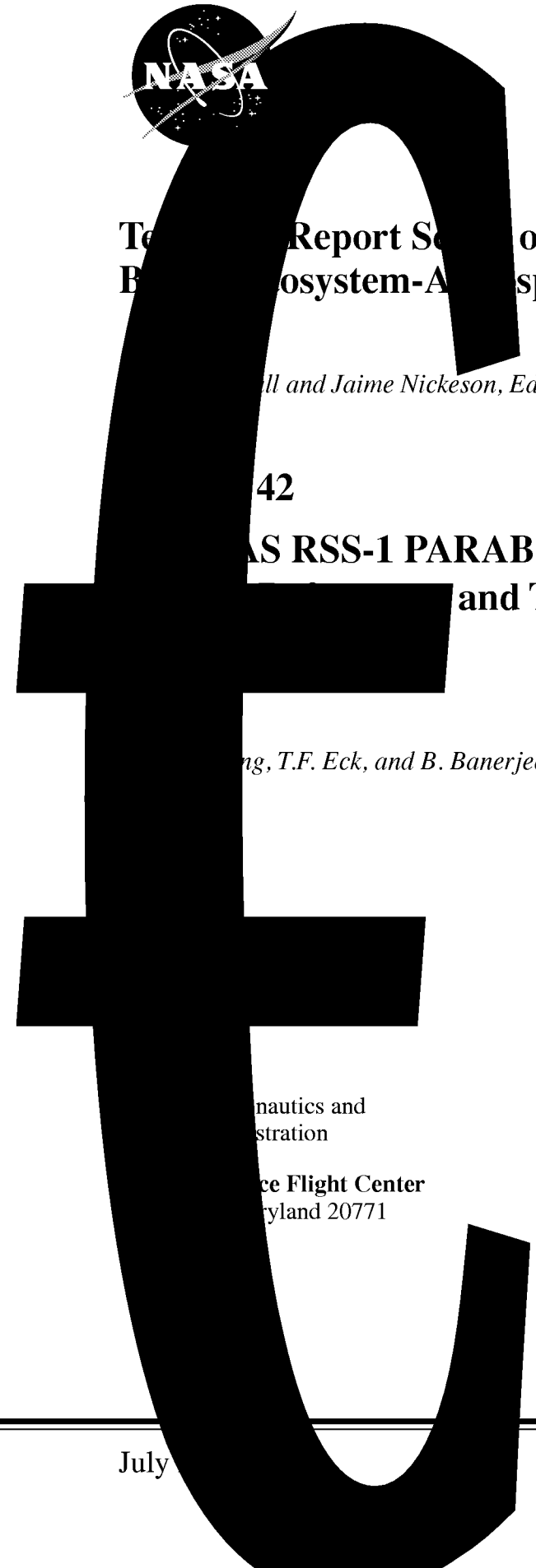
NASA/TM—2000–209891, Vol. 42



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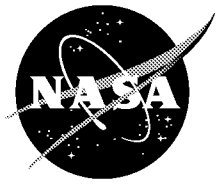

Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall and Jaime Nickeson, Editors

Volume 42

BOREAS RSS-1 PARABOLA SSA Surface Reflectance and Transmittance Data

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BOREAS RSS-1 PARABOLA SSA Surface Reflectance and Transmittance Data

Donald W. Deering, Thomas F. Eck, Babu Banerjee

Summary

The BOREAS RSS-1 team collected surface reflectance and transmittance data from three forested sites in the SSA. This data set contains averaged reflectance factors and transmitted radiances measured by the PARABOLA instrument at selected sites in the BOREAS SSA at different view angles and at three wavelength bands throughout the day. PARABOLA measurements were made during each of the three BOREAS IFCs during the growing season of 1994 at three SSA tower flux sites as well as during the FFC-T. Additional measurements were made in early and mid-1996 during the FFC-W and during IFC-2. The data are stored in tabular ASCII files.

Note that data other than those described here were collected by the RSS-01 team but were either not provided to or integrated into BORIS. However, these additional data are available from the ORNL DAAC (see Sections 15 and 16).

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS RSS-01 PARABOLA SSA Surface Reflectance and Transmittance Data

1.2 Data Set Introduction

The Portable Apparatus for Rapid Acquisitions of Bidirectional Observations of Land and Atmosphere (PARABOLA) is an instrument specifically designed to measure variations in reflectance of forest canopies as a function of solar and sensor viewing geometry, wavelength, and canopy biophysical characteristics. These data are averaged reflectance factors and transmitted radiance values of selected sites in the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) at

different view angles within three wavelength regions throughout the day. The raw data for each channel during each acquisition were binned by creating 144 conical bins within the spherical space that surrounds the instrument; the data points that fell within each bin were then averaged.

1.3 Objective/Purpose

This study had the following objectives:

- Characterize the multidirectional interactions of solar energy in various types of boreal forest canopies through intensive measurements and modeling.
- Relate these characteristics to ecologically important biophysical parameters.
- Provide bidirectional reflectance measurements of the various boreal forest canopies.
- Determine the variability of reflected and emitted radiation in selected spectral wavebands as a function of canopy type, phenological growth stage, and solar zenith angle (SZA).
- Estimate surface albedo and Photosynthetically Active Radiation (PAR) albedo from bidirectional reflectance and irradiance data.

The PARABOLA allowed for rapid acquisition of bidirectional observations of the land and atmosphere, by measurement of the angular distributions of reflected and transmitted radiation of natural Earth surface targets. Its specific purpose was to provide bidirectional reflectance measurements of the various boreal forest canopy types.

1.4 Summary of Parameters

Radiance, reflectance, and illumination and viewing angles.

1.5 Discussion

PARABOLA is an instrument specifically designed to measure variations in vegetation reflectance as a function of solar and sensor viewing geometry, wavelength, and plant canopy biophysical characteristics. The data are averaged reflectance factors and transmitted radiances of selected sites in the BOREAS SSA at different view angles and in three wavelength regions throughout the day. The raw data for each channel and time period were binned by creating 144 conical bins within the spherical space that surrounds the instrument. The measured data points that fell within each bin were then averaged. PARABOLA measurements were made during the Focused Field Campaign-Thaw (FFC-T) as well as during each of the three BOREAS Intensive Field Campaigns (IFCs) in 1994 at three tower sites within the BOREAS SSA. Measurements also were made during the Focused Field Campaign-Winter (FFC-W) and during IFC-2 in 1996.

1.6 Related Data Sets

BOREAS RSS-02 Level-1b ASAS Imagery: At-sensor Radiance in BSQ Format
BOREAS RSS-03 Reflectance Measured from a Helicopter-Mounted Barnes MMR
BOREAS RSS-03 Reflectance Measured from a Helicopter-Mounted SE-590
BOREAS RSS-11 Ground Network of Sunphotometer Measurements
BOREAS RSS-12 Automated Ground Sunphotometer Measurements in the SSA
BOREAS RSS-18 Level-1B AVIRIS Imagery: At-sensor Radiance in BIL Format
BOREAS RSS-19 1994 CASI At-sensor Radiance and Reflectance Images
BOREAS RSS-19 1996 CASI At-sensor Radiance and Reflectance Images
BOREAS RSS-20 POLDER C-130 Measurements of Surface BRDF

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Donald W. Deering, Principal Investigator
Dr. Elizabeth M. Middleton, Co-Investigator
Dr. Suraiya P. Ahmad, Co-Investigator
Mr. Thomas F. Eck, Co-Investigator

2.2 Title of Investigation

Radiative Transfer Characteristics of Boreal Forest Canopies and Algorithms for Energy Balance and PAR Absorption

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3. Theory of Measurements

The focus of this research was to characterize the variation in vegetation reflectance as a function of solar and sensor viewing geometry, wavelength, and plant canopy biophysical characteristics. An understanding of these relationships is necessary for meaningful biophysical and ecological interpretations of measurements acquired from airborne and satellite sensors. PARABOLA can measure these variations in reflectance because it measures at different viewing angles and at three spectral bands.

Light radiation striking a vegetative canopy interacts with individual phytoelements (leaves, stems, branches) and the underlying substrate. The interaction depends on light quality, radiative form (direct

or diffuse), illumination incidence angle, vegetative component optical properties, and canopy architecture. Radiation is reflected, transmitted, or absorbed. Researchers have shown that phytoelements and substrates are not perfect Lambertian reflectors; i.e., they do not reflect equally in all directions (Walter-Shea, et al., 1989; Irons et al., 1989). The amount of leaf area and the leaf angle distribution will determine the amount of vegetation and substrate that is sunlit and shaded. The amount of vegetation and substrate and respective amounts of sunlit and shaded components in a scene will vary depending on the angle at which it is viewed; i.e., the canopy is itself a non-Lambertian surface. Thus, canopy illumination and viewing geometry are critical in determining the amount of reflected radiation received at the sensor.

Reflected radiation measurements were converted to radiance and reflectance factors (the ratio of reflected radiance to incident radiance). The reflectance factor is the ratio of the target reflected radiant flux to an ideal radiant flux reflected by an ideal Lambertian standard surface irradiated in exactly the same way as the target. Reflected radiation from a field reference panel corrected for nonperfect reflectance and Sun angle was used as an estimate of the ideal Lambertian standard surface (Walter-Shea and Biehl, 1990).

4. Equipment

4.1 Sensor/Instrument Description

The basic PARABOLA instrument is a three-channel, rotating-head radiometer consisting of three primary units: the sensor head, the data recording unit, and the internal power pack. The sensor head is composed of a motor-driven tow-axis gimbal on which three detector units are jointly mounted. The three detectors include two silicon and one germanium solid-state detectors, with filters configured to correspond to Thematic Mapper (TM) spectral bands 3, 4, and 5 (630-690, 760-900, and 1550-1750 nm), respectively. They are temperature-regulated (by cooling or heating) through thermoelectric proportional control circuits. Also, because of the tremendous range in target brightness that can be expected in scanning a two-hemisphere field of view (FOV), an auto-ranging amplifier is used to switch the gain levels back and forth by factors of 1, 10, and 100 to maintain maximum radiometric sensitivity. The detector cones confine the FOV to 15 degrees. The two-axis, two-motor rotation of the head enables a near-complete sampling of the entire sky/ground sphere. There is a 15 degree exclusion area toward the mounting device because of mechanical limitations.

4.1.1 Collection Environment

The PARABOLA instrument was mounted on a tram that traversed a fixed set of tram cables at each of the three BOREAS tower/tram sites in the SSA (Old Aspen (OA), Old Jack Pine (OJP), and Old Black Spruce (OBS)). The tram cabling height was approximately 13-14 meters above the height of the forest canopy at each site. PARABOLA measurements were made on days of 0 to 30% cloud cover, beginning at about 75 degrees SZA to solar noon.

4.1.2 Source/Platform

PARABOLA's two-axis motorized radiometer and leveling head, with a camera-mounting attachment, were mounted on a tram that traversed a fixed set of tram cables at each of the three BOREAS tower/tram sites in the SSA OA, OJP, and OBS. The tram cabling height was approximately 13-14 meters above the height of the forest canopy at each site. PARABOLA data measurement scans were made at distances from the principal scaffold flux tower ranging from 25 meters to 5 meters at 2-meter increments. This resulted in PARABOLA scans being taken at 11 subsites along the tram transect for each SZA set. All operations of PARABOLA and the adjacent canopy wide-angle camera were controlled from PARABOLA's data system control panel on the flux tower. PARABOLA measurements were also taken on under-canopy trams at 4 meters above ground level with the same sampling interval as the above-canopy measurements for both the OA and the OJP data sets. For the OBS site, under-canopy measurements were taken with the instrument mounted on a large tripod that was lifted and moved manually for spatial sampling.

4.1.3 Source/Platform Mission Objectives

The purpose of the installed towers and tram wires was to provide a place on which the PARABOLA could rest and obtain measurements.

4.1.4 Key Variables

Radiances, reflectance, and viewing angle.

4.1.5 Principles of Operation

The scan system is designed such that sampling is done in a continuous helical pattern. The data are recorded serially in digital form. There is also a "calibrate"/hold position (mode) that allows manual pointing of the detector head for individual measurements of calibration sources in any direction. In the helical sampling mode, a complete data set can be taken in 11 seconds followed by a data dump to a portable PC from the buffer.

4.1.6 Sensor/Instrument Measurement Geometry

PARABOLA's design provides multidirectional viewing, but the system's geometry does not allow the same "spot" on the ground to be measured at each view direction. Thus, target surfaces that are homogeneous over relatively large areas are sampled with replication. Routinely, 11 subsites were sampled along each BOREAS tram transect to minimize any within-field heterogeneity effects and to improve the sensitivity to angular reflectance features of the surfaces. The 15-degree internal field of view (FOV) of the sensor provides "viewing areas" that are similar in scale relative to the spatial structure of the surfaces measured. The various pixels range from approximately 5.4 square meters at nadir to approximately 46.6 square meters at an off nadir angle of 60 degrees.

4.1.7 Manufacturer of Instrument

National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) Biospheric Sciences Branch Greenbelt, MD 20771

4.2 Calibration

Radiometric laboratory calibration of PARABOLA was performed at NASA GSFC on a 1.8-m spherical integrator using 12 200-W quartz halogen lamps (2950 K at 6.5 A). The number of lamps illuminating the sphere is varied to produce 12 radiance levels for calibration. No field calibration was performed.

4.2.1 Specifications

Laboratory Calibration:
Three separate calibration runs are made to fully calibrate PARABOLA at a wide range of radiance levels. Neutral density filters (0.1 density level) are used for the lowest gain setting. The voltage response to radiance level relationship is linear in all three spectral channels for each gain setting with correlation coefficients of 0.999.

4.2.1.1 Tolerance

None given.

4.2.2 Frequency of Calibration

Laboratory Calibration:
The last PARABOLA calibration was done on 02-Oct-1996. The PARABOLA instrument is calibrated using the GSFC 1.8-m integrating sphere (located in Bldg. 22) as the standard radiance source. The PARABOLA instrument was calibrated against the 1.8-m sphere before the FFC-T on 28-Mar-1994, between IFC-1 and -2 on 24-Jun-1994, and after IFC-3 on 04-Oct-1994. Measurements are made with and without a nominal 10% neutral density filter for the 12 lamp levels of the 1.8-m sphere.

4.2.3 Other Calibration Information

None.

5. Data Acquisition Methods

Data were acquired from the PARABOLA instrument mounted on a tram system that traversed a fixed set of cables at each of the three BOREAS tower/tram sites in the SSA OA, OJP, and OBS. The tram cabling height was approximately 13-14 meters above the height of the forest canopy at each site. PARABOLA data measurement scans were made at distances from the principal scaffold flux tower ranging from 5 meters to 25 meters at 2-meter increments. This resulted in PARABOLA scans being taken at 11 subsites along the tram transect for each SZA set. All operations of PARABOLA and the adjacent canopy wide-angle camera were controlled from the PARABOLA data system control panel on the flux tower. PARABOLA measurements were also taken on under-canopy trams at 4 meters above ground level with the same sampling interval as the above-canopy measurements for both the OA and the OJP data sets. For the OBS site, under-canopy measurements were taken with the instrument mounted on a large tripod that was lifted and moved manually for spatial sampling (see Section 9.2 for details).

6. Observations

6.1 Data Notes

The SZA views that were provided with the data represented a solar angle at the end time of the data acquisition period. Solar azimuth angles were not provided in the original data files. BOREAS Information System (BORIS) staff calculated both the solar azimuth and zenith angles from location, date, and Greenwich Mean Time (GMT), and loaded these values with the PARABOLA data.

In general, it took about 20 minutes for a PARABOLA data acquisition at one site and SZA. The solar zenith would range at most 1.5 degrees during this time. The acquisition time increased during the summer IFC in 1996, with SZA ranging as much as 3.7 degrees. This was because the Remote Sensing Science (RSS)-01 team was also testing the new PARABOLA III instrument during this IFC, which increased the overall data collection time.

The column PARABOLA_MEAN_VIEW_AZ_ANG is reported as an angle relative to the solar principal plane. To calculate this angle relative to north, add the SOLAR_AZ_ANG column to the PARABOLA_MEAN_VIEW_AZ_ANG. If the result is greater than 360 degrees, subtract 360 to get the correct value relative to north.

6.2 Field Notes

None given.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

The PARABOLA data were collected at the following three SSA locations along the tram cable systems erected between the principal scaffold flux tower and a Rohn tower located approximately 70 m from the flux tower.

- Old Aspen (SSA-9OA)
- Old Jack Pine (SSA-OJP)
- Old Black Spruce (SSA-OBS)

The North American Datum of 1983 (NAD83) site coordinates:

Site Id	Longitude	Latitude	UTM Easting	UTM Northing	UTM Zone
SSA-9OA-PRB01	106.19779° W	53.62889° N	420790.5	5942899.9	13
SSA-OJP-PRB01	104.69203° W	53.91634° N	520227.7	5974257.5	13
SSA-OBS-PRB01	105.11779° W	53.98717° N	492276.5	5982100.5	13

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
The spatial resolution of the data ranges from 5.4 square meters at nadir to 15.6 square meters at an angle of 45 degrees off-nadir and 46.6 square meters at 60 degrees off-nadir.

7.1.4 Projection
Not applicable.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
The overall period of PARABOLA data acquisition was from 16-Apr-1994 through 30-Jul-1996.

7.2.2 Temporal Coverage Map
The following table lists the data that were integrated into BORIS and are being provided on the BOREAS Compact Disk-Read Only Memory (CD-ROM) series. For information about additional data that were collected, see Sections 15 and 16.

DATE	IFC#	SITE	NUMBER OF SOLAR ZENITH ANGLE VIEWS	PARABOLA POSITION
16-Apr-1994	FFC-T	SSA-OBS	4	Above Canopy
17-Apr-1994	FFC-T	SSA-OBS	1	Above Canopy
19-Apr-1994	FFC-T	SSA-OBS	6	Above Canopy
24-Apr-1994	FFC-T	SSA-OA	4	Above Canopy
25-Apr-1994	FFC-T	SSA-OA	1	Above Canopy
25-May-1994	1	SSA-OA	3	Above Canopy
26-May-1994	1	SSA-OA	3	Above Canopy
31-May-1994	1	SSA-OJP	8	Above Canopy
07-Jun-1994	1	SSA-OBS	8	Above Canopy
11-Jun-1994	1	SSA-OA	5	Above Canopy
21-Jul-1994	2	SSA-OA	6	Above Canopy
25-Jul-1994	2	SSA-OJP	9	Above Canopy
04-Aug-1994	2	SSA-OBS	6	Above Canopy
31-Aug-1994	3	SSA-OA	6	Above Canopy
06-Sep-1994	3	SSA-OJP	6	Above Canopy
13-Sep-1994	3	SSA-OBS	6	Above Canopy
17-Sep-1994	3	SSA-OA	7	Above Canopy
05-Mar-1996	FFC-W	SSA-OBS	3	Above Canopy

```
08-Mar-1996    FFC-W    SSA-OA       2       Above Canopy
12-Mar-1996    FFC-W    SSA-OJP      2       Above Canopy
20-Jul-1996  IFC-2-96   SSA-OJP      1       Above Canopy
29-Jul-1996  IFC-2-96   SSA-OBS      1       Above Canopy
30-Jul-1996  IFC-2-96   SSA-OBS      1       Above Canopy
```

7.2.3 Temporal Resolution

PARABOLA data were collected at 5-degree SZA intervals, clouds permitting, from approximately 75 degrees SZA to solar noon. The PARABOLA measures a four-hemisphere area with 15-degree IFOV sectors in 11 seconds. Measurements of the reflected radiance from a characterized barium sulfate ($BaSO_4$) reference panel were taken concurrently with PARABOLA measurements during the BOREAS experiment in order to characterize spectral solar irradiance. These $BaSO_4$ measurements were made with a Barnes Modular Multiband Radiometer (MMR) mounted approximately 0.4 meters above a horizontally leveled $BaSO_4$ panel so that the MMR viewed the panel with a nadir view angle. The MMR scanned the panel continuously throughout the day, and a Polycorder data logger was set to record the measurements at a 1-minute time step interval.

7.3 Data Characteristics

7.3.1 Parameter/Variable

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

BaSO4 file:

```
        Column Name
------------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
SOLAR_ZEN_ANG
PARABOLA_CH1_BASO4
PARABOLA_CH2_BASO4
PARABOLA_CH3_BASO4
CRTFCN_CODE
REVISION_DATE
```

Site data:

```
         Column Name
------------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
HEMISPHERE_ID
PARABOLA_NUM_OBS
SOLAR_ZEN_ANG
SOLAR_AZ_ANG
PARABOLA_MEAN_VIEW_ZEN_ANG
PARABOLA_MEAN_VIEW_AZ_ANG
PARABOLA_BIN_VIEW_ZEN_ANG
PARABOLA_BIN_VIEW_AZ_ANG
MEAN_PARABOLA_CH1_RAD
SDEV_PARABOLA_CH1_RAD
MEAN_PARABOLA_CH2_RAD
```

SDEV_PARABOLA_CH2_RAD
MEAN_PARABOLA_CH3_RAD
SDEV_PARABOLA_CH3_RAD
MEAN_PARABOLA_NDVI_RAD
SDEV_PARABOLA_NDVI_RAD
MEAN_PARABOLA_CH1_REFL
MEAN_PARABOLA_CH2_REFL
MEAN_PARABOLA_CH3_REFL
MEAN_PARABOLA_NDVI_REFL
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:

BaSO4 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.
PARABOLA_CH1_BASO4	MMR measurements of a characterized barium sulfate panel at the given date and time for PARABOLA channel 1.
PARABOLA_CH2_BASO4	MMR measurements of a characterized barium sulfate panel at the given date and time for PARABOLA channel 2.
PARABOLA_CH3_BASO4	MMR measurements of a characterized barium sulfate panel at the given date and time for PARABOLA channel 3.
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.

Site data:

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.
HEMISPHERE_ID	The hemisphere from which the instrument collected data, where GR is ground and SK is sky.
PARABOLA_NUM_OBS	The number of data points used for the averaged data listed. A negative number means there was a data gap and data was instead taken from the opposite hemisphere. A zero means interpolated data.
SOLAR_ZEN_ANG	The angle from the surface normal (straight up) to the sun during the data collection.
SOLAR_AZ_ANG	The azimuthal direction of the sun during data collection expressed in clockwise increments from north.
PARABOLA_MEAN_VIEW_ZEN_ANG	The mean zenith angle at which the radiant energy was traveling when measured by the PARABOLA instrument. The mean values were calculated from measurements made within 15 degree zenith angle incremental bins, with the view zenith values increasing from the surface normal (straight up).
PARABOLA_MEAN_VIEW_AZ_ANG	The mean azimuthal angle at which the radiant energy was traveling when measured by the PARABOLA instrument, relative to the solar principal plane. The mean values were calculated from measurements made within 30 degree azimuthal angle incremental bins, with view azimuth values increasing in a clockwise direction from the solar position.
PARABOLA_BIN_VIEW_ZEN_ANG	The center value of the 15 degree view zenith angle bin from which the PARABOLA instrument viewed the target. The center values increase relative to surface normal (straight up).
PARABOLA_BIN_VIEW_AZ_ANG	The center value of the 30 degree view azimuth angle bin from which the PARABOLA instrument viewed the target. The center values increase in a clockwise direction from the solar principal plane.

MEAN_PARABOLA_CH1_RAD	The mean radiance value in PARABOLA channel 1 (.65-.67 microns).
SDEV_PARABOLA_CH1_RAD	The standard deviation of the radiance value in PARABOLA channel 1 (.65-.67 microns).
MEAN_PARABOLA_CH2_RAD	The mean radiance value in PARABOLA channel 2 (.81-.84 microns).
SDEV_PARABOLA_CH2_RAD	The standard deviation of the radiance value in PARABOLA channel 2 (.81-.84 microns).
MEAN_PARABOLA_CH3_RAD	The mean radiance value in PARABOLA channel 3 (1.62-1.69 microns).
SDEV_PARABOLA_CH3_RAD	The standard deviation of the radiance value in PARABOLA channel 3 (1.62-1.69 microns).
MEAN_PARABOLA_NDVI_RAD	The mean NDVI calculated from PARABOLA radiance in channels 1 and 2.
SDEV_PARABOLA_NDVI_RAD	The standard deviation of NDVI calculated from PARABOLA radiance in channels 1 and 2.
MEAN_PARABOLA_CH1_REFL	The mean reflectance factor in PARABOLA channel 1 (.65-.67 microns) calculated from PARABOLA radiance values and MMR measurements of a characterized barium sulfate panel.
MEAN_PARABOLA_CH2_REFL	The mean reflectance factor in PARABOLA channel 2 (.81-.84 microns) calculated from PARABOLA radiance values and MMR measurements of a characterized barium sulfate panel.
MEAN_PARABOLA_CH3_REFL	The mean reflectance factor in PARABOLA channel 3 (1.62-1.69 microns) calculated from PARABOLA radiance values and MMR measurements of a characterized barium sulfate panel.
MEAN_PARABOLA_NDVI_REFL	The mean NDVI calculated from reflectance in PARABOLA channels 1 and 2.
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:

BaSO4 data:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
SOLAR_ZEN_ANG	[degrees]
PARABOLA_CH1_BASO4	[Watts][meter^-2][steradian^-1][micrometer^-1]
PARABOLA_CH2_BASO4	[Watts][meter^-2][steradian^-1][micrometer^-1]
PARABOLA_CH3_BASO4	[Watts][meter^-2][steradian^-1][micrometer^-1]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

Site data:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
HEMISPHERE_ID	[none]
PARABOLA_NUM_OBS	[counts]
SOLAR_ZEN_ANG	[degrees]
SOLAR_AZ_ANG	[degrees]
PARABOLA_MEAN_VIEW_ZEN_ANG	[degrees]
PARABOLA_MEAN_VIEW_AZ_ANG	[degrees]
PARABOLA_BIN_VIEW_ZEN_ANG	[degrees]
PARABOLA_BIN_VIEW_AZ_ANG	[degrees]
MEAN_PARABOLA_CH1_RAD	[Watts][meter^-2][steradian^-1][micrometer^-1]
SDEV_PARABOLA_CH1_RAD	[Watts][meter^-2][steradian^-1][micrometer^-1]
MEAN_PARABOLA_CH2_RAD	[Watts][meter^-2][steradian^-1][micrometer^-1]
SDEV_PARABOLA_CH2_RAD	[Watts][meter^-2][steradian^-1][micrometer^-1]
MEAN_PARABOLA_CH3_RAD	[Watts][meter^-2][steradian^-1][micrometer^-1]
SDEV_PARABOLA_CH3_RAD	[Watts][meter^-2][steradian^-1][micrometer^-1]
MEAN_PARABOLA_NDVI_RAD	[none]
SDEV_PARABOLA_NDVI_RAD	[none]
MEAN_PARABOLA_CH1_REFL	[percent]
MEAN_PARABOLA_CH2_REFL	[percent]
MEAN_PARABOLA_CH3_REFL	[percent]
MEAN_PARABOLA_NDVI_REFL	[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:

BaSO4 data:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS Staff]
SUB_SITE	[Assigned by BORIS Staff]
DATE_OBS	[Controller]
TIME_OBS	[Controller]
SOLAR_ZEN_ANG	[Calculated]
PARABOLA_CH1_BASO4	[PARABOLA]
PARABOLA_CH2_BASO4	[PARABOLA]
PARABOLA_CH3_BASO4	[PARABOLA]
CRTFCN_CODE	[Assigned by BORIS Staff]
REVISION_DATE	[Assigned by BORIS Staff]

Site data:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS Staff]
SUB_SITE	[Assigned by BORIS Staff]
DATE_OBS	[Controller]
TIME_OBS	[Controller]
HEMISPHERE_ID	[Instrument operator]
NUM_OBS	[Controller]
SOLAR_ZEN_ANG	[Calculated]
SOLAR_AZ_ANG	[Calculated]
PARABOLA_MEAN_VIEW_ZEN_ANG	[PARABOLA]
PARABOLA_MEAN_VIEW_AZ_ANG	[PARABOLA]
PARABOLA_BIN_VIEW_ZEN_ANG	[PARABOLA]
PARABOLA_BIN_VIEW_AZ_ANG	[PARABOLA]
MEAN_PARABOLA_CH1_RAD	[PARABOLA]
SDEV_PARABOLA_CH1_RAD	[PARABOLA]
MEAN_PARABOLA_CH2_RAD	[PARABOLA]
SDEV_PARABOLA_CH2_RAD	[PARABOLA]
MEAN_PARABOLA_CH3_RAD	[PARABOLA]
SDEV_PARABOLA_CH3_RAD	[PARABOLA]
MEAN_PARABOLA_NDVI_RAD	[PARABOLA]
SDEV_PARABOLA_NDVI_RAD	[PARABOLA]
MEAN_PARABOLA_CH1_REFL	[PARABOLA]
MEAN_PARABOLA_CH2_REFL	[PARABOLA]
MEAN_PARABOLA_CH3_REFL	[PARABOLA]
MEAN_PARABOLA_NDVI_REFL	[PARABOLA]
CRTFCN_CODE	[Assigned by BORIS Staff]
REVISION_DATE	[Assigned by BORIS Staff]

7.3.5 Data Range

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

BaSO4 data:

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-9OA-FLXTR	SSA-OJP-FLXTR	None	None	None	None
SUB_SITE	RSS01-PRB01	RSS01-PRB01	None	None	None	None
DATE_OBS	16-APR-94	30-JUL-96	None	None	None	None
TIME_OBS	11	2356	None	None	None	None
SOLAR_ZEN_ANG	33.241	76.959	None	None	None	None
PARABOLA_CH1_BASO4	90.73	371.91	None	None	None	None
PARABOLA_CH2_BASO4	62.7	255.76	None	None	None	None
PARABOLA_CH3_BASO4	14.31	57.04	None	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	10-NOV-98	10-NOV-98	None	None	None	None

Site data:

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-9OA-FLXTR	SSA-OJP-FLXTR	None	None	None	None
SUB_SITE	RSS01-PRB01	RSS01-PRB01	None	None	None	None
DATE_OBS	16-APR-94	30-JUL-96	None	None	None	None
TIME_OBS	11	2356	None	None	None	None
HEMISPHERE_ID	GR	SK	None	None	None	None
PARABOLA_NUM_OBS	-70	73	None	None	None	None
SOLAR_ZEN_ANG	33.241	76.959	None	None	None	None
SOLAR_AZ_ANG	75.893	273.583	None	None	None	None
PARABOLA_MEAN_VIEW_ZEN_ANG	0	80	None	None	None	None
PARABOLA_MEAN_VIEW_AZ_ANG	0	360	None	None	None	None
PARABOLA_BIN_VIEW_ZEN_ANG	0	75	None	None	None	None
PARABOLA_BIN_VIEW_AZ_ANG	0	360	None	None	None	None
MEAN_PARABOLA_CH1_RAD	1.18	280.31	-999	None	None	None
SDEV_PARABOLA_CH1_RAD	0	170	None	None	None	None
MEAN_PARABOLA_CH2_RAD	2.19	139.91	-999	None	None	None
SDEV_PARABOLA_CH2_RAD	0	89.7	None	None	None	None
MEAN_PARABOLA_CH3_RAD	.09	59.49	-999	None	None	None
SDEV_PARABOLA_CH3_RAD	0	38.78	None	None	None	None
MEAN_PARABOLA_NDVI_RAD	-.714	.889	-999	None	None	None
SDEV_PARABOLA_NDVI_RAD	0	.45	None	None	None	None
MEAN_PARABOLA_CH1_REFL	.9	122.6	-999	None	None	None
MEAN_PARABOLA_CH2_REFL	1.7	97.1	-999	None	None	None
MEAN_PARABOLA_CH3_REFL	.3	129.3	-999	None	None	None
MEAN_PARABOLA_NDVI_REFL	-.378	.925	-999	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	10-NOV-98	12-NOV-98	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:

BaSO4 data:

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,SOLAR_ZEN_ANG,PARABOLA_CH1_BASO4,
PARABOLA_CH2_BASO4,PARABOLA_CH3_BASO4,CRTFCN_CODE,REVISION_DATE
'SSA-OBS-FLXTR','RSS01-PRB01',16-APR-94,2156,56.002,243.76,182.1,41.63,'CPI',
10-NOV-98
'SSA-OBS-FLXTR','RSS01-PRB01',16-APR-94,2219,58.881,223.42,166.92,38.27,'CPI',
10-NOV-98
'SSA-OBS-FLXTR','RSS01-PRB01',16-APR-94,2312,66.054,170.71,128.07,28.73,'CPI',
10-NOV-98
'SSA-OBS-FLXTR','RSS01-PRB01',16-APR-94,2356,72.37,125.77,95.11,20.79,'CPI',
10-NOV-98
'SSA-OBS-FLXTR','RSS01-PRB01',17-APR-94,22,76.18,90.73,69.13,14.31,'CPI',
10-NOV-98
```

Site data:

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,HEMISPHERE_ID,PARABOLA_NUM_OBS,
SOLAR_ZEN_ANG,SOLAR_AZ_ANG,PARABOLA_MEAN_VIEW_ZEN_ANG,PARABOLA_MEAN_VIEW_AZ_ANG,
PARABOLA_BIN_VIEW_ZEN_ANG,PARABOLA_BIN_VIEW_AZ_ANG,MEAN_PARABOLA_CH1_RAD,
SDEV_PARABOLA_CH1_RAD,MEAN_PARABOLA_CH2_RAD,SDEV_PARABOLA_CH2_RAD,
MEAN_PARABOLA_CH3_RAD,SDEV_PARABOLA_CH3_RAD,MEAN_PARABOLA_NDVI_RAD,
SDEV_PARABOLA_NDVI_RAD,MEAN_PARABOLA_CH1_REFL,MEAN_PARABOLA_CH2_REFL,
MEAN_PARABOLA_CH3_REFL,MEAN_PARABOLA_NDVI_REFL,CRTFCN_CODE,REVISION_DATE
'SSA-9OA-FLXTR','RSS01-PRB01',21-JUL-94,1419,'GR',8,63.6,90.755,14.2,114.8,0,0,
3.38,1.0,47.7,12.5,3.64,.91,.868,.01,1.9,43.2,12.8,.915,'CPI',10-NOV-98
'SSA-9OA-FLXTR','RSS01-PRB01',21-JUL-94,1419,'GR',-9,63.6,90.755,16.8,6.3,15,0,
2.93,1.4,39.71,18.7,3.07,1.07,.861,.02,1.7,35.9,10.8,.911,'CPI',10-NOV-98
'SSA-9OA-FLXTR','RSS01-PRB01',21-JUL-94,1419,'GR',11,63.6,90.755,45.3,12.4,45,
0,3.58,.7,38.51,9.5,3.23,.56,.829,.04,2.0,34.8,11.4,.89,'CPI',10-NOV-98
'SSA-9OA-FLXTR','RSS01-PRB01',21-JUL-94,1419,'GR',11,63.6,90.755,30.7,7.5,30,0,
2.87,.6,35.29,7.3,2.81,.48,.848,.03,1.6,31.9,9.9,.903,'CPI',10-NOV-98
```

8. Data Organization

8.1 Data Granularity

The unit of data tracked by BORIS is all the data collected at a site on a given day or for a given time period.

8.2 Data Format(s)

The 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

None given.

9.1.1 Derivation Techniques and Algorithms

Characterization of spectral solar irradiance was carried out using two separate techniques. First, a Barnes MMR was mounted above a $BaSO_4$ reference panel, both clamped to the tower above the canopy top in order to sample the spectral downwelling irradiance. The MMR and PARABOLA were intercalibrated at the GSFC 1.8-m integrating sphere radiance source. The MMR measurements of the $BaSO_4$ panel were corrected for reflectance anisotropy, which had been previously characterized using the procedure of Jackson et al. (1987). However, because of different band passes of the PARABOLA and MMR instruments (e.g., PARABOLA 810-840 nm versus MMR 750-880 nm), the MMR response to different total columnar atmospheric water vapor amount differed from PARABOLA's response due to different water vapor transmittances. Therefore, the cloudless sky spectral irradiance model was used (an integral part of the Second Simulation of the Satellite Signal in the Solar Spectrum (6S) model (Vermote et al., 1997)). The model was used with measured aerosol optical depths, total water vapor, and aerosol volume size distributions from Cimel automatic spectral solar radiometers located in the BOREAS SSA (Markham et al. (1997)). The total ozone amount used in the 6S model calculations was climatological means from London et al. (1976). For PARABOLA channel 1 (650-670 nm; with no water vapor absorption), the irradiances computed from 6S agreed very well with MMR measured irradiances, typically within 2-3%. However, for PARABOLA channel 2 (810-840 nm), the differences between the two techniques varied from approximately 1% to 15% depending on water vapor amount and SZA. Differences between the two techniques for PARABOLA channel 3 (1620-1690 nm) were intermediate to those found for the other channels, since the water vapor transmittance differences for the two instrument band passes were less in channel 3 than for channel 2. Therefore, because of the differing effects of the water vapor transmittances for the differing band passes of the two instruments, the spectral irradiance computed from 6S was used in the calculations of reflectance factors.

9.2 Data Processing Sequence

9.2.1 Processing Steps

Directional reflectances are normally computed as hemispherical-directional reflectance factors using the PARABOLA directional radiance measurements from the ground-looking hemisphere. The ground-looking hemisphere values are divided by the PARABOLA-derived incident irradiance as computed from the PARABOLA sky irradiance data or from a calibrated $BaSO_4$ painted reference

standard panel.

The PARABOLA data scans taken from the 11 subsites at each SZA measurement sequence are combined in software written to analyze the bidirectional reflectance distribution characteristics of the site. This procedure also enables more accurate sampling of the "hot spot" effects and the aureole surrounding the Sun.

Because the PARABOLA observations are not acquired at equal angles of azimuth and zenith, and because most users prefer the data at equal intervals, these data have been averaged into standard bins.

A data aggregation scheme was established that defines bins of 30 degrees of azimuth and 15 degrees of zenith for each of the sky and ground hemispheres, resulting in (360/30) * (90/15) bins (i.e., 12 * 6 = 76 bins) per hemisphere. The observed pixels falling in a given bin were averaged to derive the supplied radiance value. The number of pixels used in computing the bin average is contained in the column NUM_OBS. Data gaps resulting from the scanning pattern, shadowing, or contamination of the pixel by instrument support equipment or operators and/or other anomalies are handled as follows:

- If data are available from the opposite side of the hemisphere, the data gap is filled by placing the information from the opposite side into the empty area. Note that this assumes symmetry in the azimuth plane with respect to the solar principal plane. These instances are identified with a negative number of observations.
- If no data are available from the opposite side of the hemisphere, an interpolated value is used. These instances are identified with a zero in the number of observations column.

BORIS processing steps for PARABOLA data:

- Reformatted the PARABOLA .AFF files to add date, time, hemisphere, solar azimuth, and reflectance columns.
- Computed the SZA and solar azimuth angles based on site location, observation date, and observation time. Replaced the SZA given with that which was computed because the angles in the original files were computed from an end time rather than the mid-point of the data collection time. Entered the solar azimuth.
- Calculated reflectance from radiance using the Barium Sulfate measurements given. The $BaSO_4$ measurement values are contained within the table RSS01_PARABOLA_BASO4_REF.
- Computed NDVI from the reflectance values.
- Loaded and inventoried the data in to the BORIS data base.
- Extracted the PARABOLA data to create files for each date and site.

9.2.2 Processing Changes

None given.

9.3 Calculations

See Section 9.1.1.

9.3.1 Special Corrections/Adjustments

Because most users prefer the data at equal intervals of viewing angles, an averaged data set is provided. The pixels falling in a cell or bin of fixed off-nadir and azimuth width are averaged. The centers of these bins are at intervals of 15 degrees in off-nadir and 30 degrees in azimuthal plane. One of the columns gives the number of points used in computing the average values for that bin. If there is a data gap caused by the scanning pattern, shadowing of the target by the instrument, or its support equipment (or "contaminated" by the instrument or operators), or other anomalies (e.g., instrument "noise"), the gap is filled by substituting the data point from the opposite side of the hemisphere (assumes symmetry in azimuth plane with respect to the solar principal plane). To identify such cases, the number of data points averaged is given as negative (mirror image) values. If for some reason there are no data for substitution then an interpolated value is used. Because the interpolated values are not real measured values, a zero is placed in the column specifying the number of points averaged in order to caution the user about this potential reliability factor.

9.3.2 Calculated Variables
See Section 9.1.1.

9.4 Graphs and Plots
None.

10. Errors

10.1 Sources of Error
None given.

10.2 Quality Assessment
The PARABOLA instrument data quality and accuracy are discussed in detail in the following references:

Deering, D.W. and P. Leone. 1986. A sphere-scanning radiometer for rapid directional measurements of sky and ground radiance. Remote Sens. Environ. 19:1-24.

Deering, D.W., E.M. Middleton, J.R. Irons, B.L. Blad, E.A. Walter-Shea, C.J. Hays, C. Walthall, T.F. Eck, S.P. Ahmad, and B.P. Banerjee. 1992. Prairie grassland bidirectional reflectances measured by different instruments at the FIFE site, Journal of Geophysical Research 97(D17:18,887-18,903.

10.2.1 Data Validation by Source
None given.

10.2.2 Confidence Level/Accuracy Judgment
None given.

10.2.3 Measurement Error for Parameters
None given.

10.2.4 Additional Quality Assessments
None given.

10.2.5 Data Verification by Data Center
BORIS staff applied a general Quality Assurance (QA) procedure to the data before the steps described in Section 9 were applied.

11. Notes

11.1 Limitations of the Data
None given.

11.2 Known Problems with the Data
It is recommended that users read Deering and Leone (1986) before using the PARABOLA data.

11.3 Usage Guidance
None given.

11.4 Other Relevant Information
None given.

12. Application of the Data Set

Data can be used to characterize directional anisotropy of solar radiance reflected from terrestrial surfaces and Bidirectional Reflectance Distribution Function (BRDF) modeling and validation. PARABOLA data can also be used to estimate hemispherical reflectance (albedo).

13. Future Modifications and Plans

None given.

14. Software

14.1 Software Description

None given.

14.2 Software Access

None given.

15. Data Access

The PARABOLA SSA surface reflectance and transmittance 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. Note that the other ('FFL') data sets (described below) are available but were not loaded into the BOREAS data base and are not contained on the CD-ROM series; however, they are available from Oak Ridge National Laboratory (ORNL) (see Section 15).

For PARABOLA-data users there are two output PARABOLA data formats that have been created, which have the filename extensions 'AFF' and 'FFL'. The data loaded into the BOREAS data base and described in section 7 were the 'AFF' type. The 'FFL' data type is a complete, but filtered, data set consisting of almost all of the individual pixels from the replicate scans (usually 11 for BOREAS sites) of the same target. Because of the scanning pattern of the PARABOLA, the pixels are not at equidistant angles in the off-nadir or azimuth viewing planes. It is recommended that users familiarize themselves with the instrument by reviewing the article by Deering and Leone (1986) before using the PARABOLA data.

OUTPUT FORMAT FOR FILE 'filename.FFL':

The first record gives the following HEADER INFORMATION:

- Filename or data ID, extracted from first input filename
- Hemisphere-ID, 'GR' for ground, ..'SK' for sky
- Latitude of the target site (-ve for south)
- Longitude of the target (-ve for west of Greenwich)
- Date of the observations (e.g., 06-04-1987)
- Local time of the measurements, hours:min (e.g., 15:22)
- Julian day (e.g., 155)
- GMT of measurements, hours:min (e.g., 20:22)
- SZA
- Total hemispheric diffuse flux (upwelling or downwelling ($W/m^2/\mu m$) for channel 1)
- Total hemispheric diffuse flux (upwelling or downwelling ($W/m^2/\mu m$) for channel 2)
- Total hemispheric diffuse flux (upwelling or downwelling ($W/m^2/\mu m$) for channel 3)

Please note that for the BOREAS data set, a negative sign is put in front of these flux values to caution the user that these values will be updated in the near future once the algorithm is tested and validated for the extrapolation mechanism used beyond 75-degree off-nadir view angles.

DATA RECORDS follow the header record. First, all GROUND pixels are written; then the SKY pixels are written following the ground pixels. However, before starting the first sky pixel, the header record is repeated.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

Deering, D.W. and P. Leone. 1986. A sphere-scanning radiometer for rapid directional measurements of sky and ground radiance. Remote Sens. Environ. 19:1-24.

17.2 Journal Articles and Study Reports

Ahmad, S.P., E.M. Middleton, and D.W. Deering. 1987. Computation of diffuse sky irradiance from multidirectional radiance measurements. Remote Sens. Environ. 21:185-200.

Deering, D.W. 1989. Field measurements of bidirectional reflectance. In: Theory and Applications of Optical Remote Sensing. John Wiley & Sons, Inc. pp. 14-65.

Deering, D.W. and T.F. Eck. 1987. Atmospheric optical depth effects on angular anisotropy of plant canopy reflectance. Int. J. Remote Sens. 8:893-916.

Deering, D.W., E.M. Middleton, J.R. Irons, B.L. Blad, E.A. Walter-Shea, C.J. Hays, C.W. Walthall, T.F. Eck, S.P. Ahmad, and B.P. Banerjee. 1992. Prairie grassland bidirectional reflectance measured by different instruments at the FIFE site. Journal of Geophysical Research 97(D17):18,887-18,903.

Deering, D.W., T.F. Eck, and J. Otterman. 1990. Bidirectional reflectances of three desert surfaces and their characterization through model inversion. J. Agric. and Forest Meteorol. 52:71-93.

Irons, J.R., F.G. Huegel, and R.R. Irish. 1989. Prairie grass hemispherical reflectances from airborne multi-directional observations. Proc. of 19th Conf. on Agriculture and Forest Meteorology and the Ninth Conf. on Biometeorology and Aerobiology. March 7-10, 1989. Charleston, SC. Published by American Meteorological Society, Boston, MA.

Irons, J.R., R.A. Weismiller, and G.W. Peterson. 1989. Soil reflectance. G. Asrar (ed.). In Theory and Applications of Optical Remote Sensing. John Wiley & Sons. New York. pp. 66-106.

Jackson, R.D., M.S. Moran, P.N. Slater, and S.F. Bigger. 1987. Field calibration of reference reflectance panels. Remote Sens. Environ., 17:37-53.

Leshkevich, G.A., D.W. Deering, T.F. Eck, and S.P. Ahmad. 1990. Diurnal patterns of the bidirectional reflectance of freshwater ice. Annals of Glaciol. 14:153-157.

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

6S - Second Simulation of the Satellite Signal in the Solar Spectrum
ASAS - Advanced Solid-state Array Spectroradiometer
ASCII - American Standard Code for Information Interchange
AVIRIS - Airborne Visible InfraRed Imaging Spectrometer
BIL - Band Interleaved by Line
BOREAS - BOReal Ecosystem-Atmosphere Study
BORIS - BOREAS Information System
BRDF - Bidirectional Reflectance Distribution Function
BSQ - Band Sequential
CASI - Compact Airborne Spectrographic Imager
CD-ROM - Compact Disk-Read-Only Memory
DAAC - Distributed Active Archive Center
EOS - Earth Observing System
EOSDIS - EOS Data and Information System
FFC-T - Focused Field Campaign-Thaw
FFC-W - Focused Field Campaign-Winter
FOV - Field of view
GIS - Geographic Information System
GMT - Greenwich Mean Time
GSFC - Goddard Space Flight Center
HTML - HyperText Markup Language
IFC - Intensive Field Campaign
IFOV - Instantaneous Field of View
MMR - Modular Multiband Radiometer
NAD83 - North American Datum of 1983
NASA - National Aeronautics and Space Administration
NDVI - Normalized Difference Vegetation Index
NSA - Northern Study Area
OA - Old Aspen
OBS - Old Black Spruce
OJP - Old Jack Pine
ORNL - Oak Ridge National Laboratory
PANP - Prince Albert National Park
PAR - Photosynthetically Active Radiation
PARABOLA - Portable Apparatus for Rapid Acquisitions of BiDirectional Observations of Land and Atmosphere
POLDER - Polarization and Directionality of Earth Reflectances
QA - Quality Assurance
RSS - Remote Sensing Science
SSA - Southern Study Area
SZA - Solar Zenith Angle
TM - Thematic Mapper
URL - Uniform Resource Locator
UTM - Universal Transverse Mercator

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The BOREAS RSS-1 team collected surface reflectance and transmittance data from three forested sites in the SSA. This data set contains averaged reflectance factors and transmitted radiances measured by the PARABOLA instrument at selected sites in the BOREAS SSA at different view angles and at three wavelength bands throughout the day. PARABOLA measurements were made during each of the three BOREAS IFCs during the growing season of 1994 at three SSA tower flux sites as well as during the FFC-T. Additional measurements were made in early and mid-1996 during the FFC-W and during IFC-2. The data are stored in tabular ASCII files.

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