NASA/TM—2000–209891, Vol. 77

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

Forrest G. Hall and Jaime Nickeson, Editors

Volume 77
BOREAS RSS-19 1994 Seasonal Understory Reflectance Data

J.R. Miller, H.P. White, D. Peddle and J. Freemantle

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

August 2000

The NASA STI Program Office ... in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.
- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.
- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at http://www.sti.nasa.gov/STI-homepage.html
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320

NASA/TM—2000-209891, Vol. 77

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

Forrest G. Hall and Jaime Nickeson, Editors

Volume 77

BOREAS RSS-19 1994 Seasonal Understory Reflectance Data

John R. Miller, York University, Ontario, Canada
H. Peter White, York University, Ontario, Canada
Derek Peddle, University of Waterloo, Institute for Space and Terrestrial Science
Jim Freemantle, Institute for Space and Terrestrial Science

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

August 2000

Available from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076-1320
Price Code: A17

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Price Code: A10

BOREAS RSS-19 1994 Seasonal Understory Reflectance Data

John R. Miller, H. Peter White, Derek Peddle, Jim Freemantle

Summary

The BOREAS RSS-19 team collected airborne remotely sensed images and ground reflectance data for characterizing the radiometric properties of the boreal forest landscape. One objective of BOREAS is to further the understanding of the spectral bidirectional reflectance of typical boreal ecosystem stands in the visible/near-infrared regime. An essential input for any canopy BRDF model is an accurate estimate of the average understory reflectance, both for sunlit and shaded conditions. These variables can be expected to vary seasonally because of species-dependent differences in the phenological cycle of foliar display. In response to these requirements, the average understory reflectance for the flux tower sites of both the NSA (Thompson, Manitoba) and the SSA (Candle Lake, Saskatchewan) was observed throughout the year during five field campaigns. This was done by measuring the nadir reflectance (400 to 850 nm) of sunlit and shaded understory (vegetation and snow cover) along a surveyed LAI transect line (Chen, RSS-07) at each site near solar noon and documenting an average site reflectance. Comparisons between sites reveal differences in the green and infrared regions of the spectra, because of the differing species in the understory for each site. Temporal (seasonal) variation for each site was also observed (06-Feb-1994 to 16-Sep-1994), indicating the changing flora mixtures and changing spectral signatures as the understory matures during the growing season. The data are stored in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS RSS-19 1994 Seasonal Understory Reflectance Data

1.2 Data Set Introduction

Mean sunlit nadir understory reflectance spectra (400 to 850 nm) and their standard errors for the following canopy types are presented: Fen, Old Black Spruce (OBS), Old Jack Pine (OJP), and Young Jack Pine (YJP). Data for the tower flux sites are provided for both Northern Study Area (NSA) and Southern Study Area (SSA) locations for all five BOReal Ecosystem-Atmosphere Study (BOREAS) field campaigns. These five field campaigns are referred to as Focused Field Campaign-Winter (FFC-W) (February 1994), FFC-Thaw (T) (April 1994), Intensive Field Campaign (IFC)-1 (May/June 1994), IFC-2 (July 1994), and IFC-3 (September 1994).

1.3 Objective/Purpose

The objective was to characterize seasonal change in the understory spectral reflectance at eight BOREAS tower flux sites, from February to September, for all five BOREAS field campaigns.

1.4 Summary of Parameters

Each data file contains about 20 records of header information, such as:

Field Instrument, Reference Calibration Panel, Spectral Range, Wavelength Step, Spectrum Description, Field Of View (FOV), Field Campaign, Location, Latitude, Longitude, Date, Time, Solar Zenith Angle (SZA), Solar Azimuth, Illumination, Target Description, and Comments.

After the header information, there are reflectance and standard error measurements for each cover type in the file (one to three) given at each wavelength step within the spectral range. This list is often about 150 records for the Spectron Engineering spectroradiometer (SE)-590, and 378 records for the Analytic Spectral Devices, Inc. (ASD) instrument.

1.5 Discussion

Mean sunlit nadir understory reflectance was determined by taking measurements at various points along a surveyed Leaf Area Index (LAI) transect (Chen, 1994), each observation target being chosen as representative of the local area, converting to reflectance, and producing a mean from all the derived reflectances along the transect line (White et al., 1995). This provided mean understory reflectance, weighted by the component vegetation in the understory throughout the canopy site.

BOREAS sites have shown a definite and observable variation in the sunlit mean understory reflectance coefficients in the visible/near-infrared regions as a function of forest species stand. This can be related to change in vegetation in the understory, as well as the difference in growing conditions at each site. Phenological changes are also clearly observable, especially in the case of OBS, indicating the influence of changes in coverage of species type and growth on the nadir reflectance spectrum.

1.6 Related Data Sets

BOREAS RSS-01 PARABOLA SSA Surface Reflectance and Transmittance Data
BOREAS RSS-03 Reflectance Measured from a Helicopter-Mounted Barnes MMR
BOREAS RSS-03 Reflectance Measured from a Helicopter-Mounted SE-590

2. Investigator(s)

2.1 Investigator(s) Name and Title

John R. Miller (RSS-19), Professor, York University
H. Peter White (RSS-19), York University
Jim Freemantle (RSS-19), Institute for Space and Terrestrial Science (ISTS)
Greg McDermid (RSS-19), University of Waterloo, ISTS
Derek R. Peddle(RSS-19), University of Waterloo, ISTS
Irene Rubinstein (RSS-19), ISTS
Paul Shepherd (RSS-19), ISTS
Raymond Soffer (RSS-19), York University
Jing Chen (RSS-07), Canada Centre for Remote Sensing (CCRS)
Richard Fournier (RSS-19 and TE-09), Universite Laval

2.2 Title of Investigation

Seasonal Change in Mean Understory Reflectance for Conifer Flux Tower Sites at BOREAS

2.3 Contact Information

Contact 1:
John R. Miller (RSS-19)
Dept. Physics & Astronomy
York University, 4700 Keele St.
North York, Ontario, M3J 1P3, Canada
(416) 736-2100
(416) 736-5626 (fax)
miller@eol.ists.ca
http://eol.ists.ca

Contact 2:
H. Peter White
Dept. Physics & Astronomy
York University, 4700 Keele St.
North York, Ontario, M3J 1P3, Canada
(416) 736-2100
(416) 736-5626 (fax)
white@eol.ists.ca
http://eol.ists.ca/

Contact 3:
Jaime Nickeson
Raytheon ITSS
NASA GSFC
Code 923
Greenbelt, MD 20771
(301) 286-3373
(301) 286-0239 (fax)
Jaime.Nickeson@gsfc.nasa.gov

3. Theory of Measurements

An estimate of the average spectral reflectance of the understory for each IFC was made in order to specify the boundary condition in canopy reflectance modeling for Remote Sensing Science (RSS) investigators. The experimental design was focused on (i) determination of an appropriate method of spatial averaging, (ii) characterization of the spectral reflectance of the understory under direct Sun (Sun fleck) and shadow illumination conditions, and (iii) observations within 2 hours of local solar noon to generate measurements of the understory reflectance factor that is representative of remote sensing observations.

Observations of 5 to 40 individual spectra at each flux tower site, converted to reflectance by comparison to calibrated reference target, produced a mean reflectance along the transect line (White et al., 1995), considered to be representative of the understory at the date of the measurement.

4. Equipment

4.1 Sensor/Instrument Description

Observations were made with the SE-590 field-portable data-logging spectroradiometer except during IFC-1 and some sites during IFC-3, where additional observations were obtained with the ASD instrument. The two instruments used during these campaigns were detector array field spectrometers with spectral ranges nominally 350-1100 nm but with data reported in the 400 to 900 nm range. The calibration panels used in the field were the white and grey side of a Kodak Grey Card (KGW-W and KGC-G respectively), which were spectrally and angularly calibrated at ISTS (Soffer et al., 1995).

4.1.1 Collection Environment

The understory conditions at the time of observations as indicated in Section 7.2.2, Table 1, are: Sun - target illuminated by unobscured direct Sun (in a Sun fleck), Shade - target outside of a Sun fleck area illuminated only by diffuse, undercanopy radiation, (s) - snow was observed, (v) - vegetation observed.

Observations were made under clear sky conditions or with minimal cloud cover, and in this case without clouds within 60 degrees of the Sun. Observations were made within 2 hours of local solar noon. The ambient air temperature range during observations varied from -35 °C during FFC-W to more than +25 °C in IFC-2.

4.1.2 Source/Platform

Both the SE-590 and the SD field spectroradiometer were hand-held by the observer during measurements.

4.1.3 Source/Platform Mission Objectives

An estimate of the average spectral reflectance of the understory for each IFC was made in order to specify the boundary condition in canopy reflectance modeling for RSS investigators.

4.1.4 Key Variables

Spectral reflectance.

4.1.5 Principles of Operation

A nadir-viewing field spectrometer was used to measure the sunlit and shaded (where possible) understory reflectance at marked 10-m-interval transect lines, At each marker location, an understory observation target was chosen as representative of the local area. The observations were made in the nadir position, with care to minimize spectral contamination from observers and equipment. The light source for all observations was natural illumination generated by solar direct/diffuse radiation that reaches the forest stand floor.

4.1.6 Sensor/Instrument Measurement Geometry

The sensor was kept in a nadir viewing position for all measurements. The height of the instrument was approximately 1 m, translating to an FOV with about a 5-6 m radius.

4.1.7 Manufacturer of Sensor/Instrument

The SE-590 was manufactured by:
Spectron Engineering, Inc.
225 Yuma Court
Denver, CO 80223
USA

The ASD field spectroradiometer was manufactured by:

Analytic Spectral Devices, Inc.
4760 Walnut Street
Suite 105
Boulder, CO 80301
USA

Kodak, of Rochester, NY, manufactures the reference reflectance card.

4.2 Calibration

All calibrations of the instruments and the reflecting panels were performed at ISTS using standard laboratory methods. Special care was taken to establish the calibration and estimates of reliability for the Kodak reference cards (KGCs), which were selected for use in the field because of their portability in a relatively difficult field environment and their reported stability (Milton, 1989). Laboratory bidirectional reflectance measurements were made between 15 and 80 degrees at 5-degree intervals for all six KGCs used in the BOREAS field campaigns. Absolute variability in the reflectance was less than 2% for the white cards and less than 1% for the grey cards, for the entire range of view angles. Data were gathered with a fiber Ocean Optics array-spectrometer mounted on a goniometer and comparisons were made to a Spectralon calibration panel (Labsphere) to obtain absolute panel bidirectional reflectance distribution functions (BRDFs). For validation of ISTS calibration methodology, York University's white Spectralon panel (Labsphere SN 3484 99%) and grey Spectralon panel (Labsphere SN 9485A 50%) were shipped to Dr. Elizabeth Walter-Shea (TE-12) for BOREAS panel field intercalibrations at the University of Nebraska. Comparisons between the Spectralon panel BRDF calibrations for view angles between 15 and 75 degrees were found to be within 2% for the white panel and within 1% for the grey panel. The calibration procedures and results are described in more detail in Soffer et al. (1995).

4.2.1 Specifications

None given.

4.2.1.1 Tolerance

None given.

4.2.2 Frequency of Calibration

BRDF calibrations of the York University Spectralon panels was carried out prior to IFC-1 (1994), and comparative measurements were made between this Spectralon (white) and KGCs in the field at BOREAS on at least one occasion during each campaign. The detailed BRDF characterization of six KGCs was carried out at ISTS after IFC-3. However, the consistency (<2% for white, <1% for grey) of results between KGCs used at BOREAS and fresh, unused cards indicates insignificant panel deterioration during the campaigns.

4.2.3 Other Calibration Information

None given.

5. Data Acquisition Methods

A nadir-viewing field spectrometer was used to measure the sunlit and shaded (where possible) understory reflectance at marked 10-m intervals along the surveyed LAI transect line (Chen, 1994), which normally ran in a southeastern direction from each site tower. At each marker location, an understory observation target was chosen as representative of the local area. The observations were made in the nadir position, with care to minimize spectral contamination from observers and equipment.

The FOV used allowed for an approximately 5-cm-radius area of understory to be observed, which was followed with a calibration panel observation taken within 1 minute of the target measurement. The calibration panel used was dependent on the conditions and availability during each campaign.

The above methodology was followed closely for all but one field campaign, IFC-2. During IFC-2, field observations were obtained for species-specific reflectances accompanied by aerial coverage estimates of the species, thereby allowing weighted-average understory reflectance spectra to be determined.

Each location was observed with the objective of viewing the average understory composition. When more than one type of understory species mixing occurred at a marker, observations of each flora distribution were performed. Thus, when averaged together, a mean understory reflectance weighted to each type of understory component population was possible. In some cases, sites were divided specifically into small grids, with each grid being observed to provide a detailed understory BRDF for unique locations within the flux tower site, and where possible, observation runs were performed to correspond to Compact Airborne Spectrographic Imager (CASI) multiangle, multialtitude observations also being performed.

6. Observations

6.1 Data Notes

None given.

6.2 Field Notes

At some sites it was not possible to place the calibration panel level in the exact location of the target being observed. Every effort was made to keep the panel level to the horizon and as close as possible to the target location. It was sometimes necessary to raise the calibration panel above the understory to avoid contamination or destruction, which caused the incident irradiance field to be slightly different between panel and target observations, because of scattering, etc., in the overstory. Such location discrepancies were kept at a minimum, and are not believed to have influenced the results significantly.

7. Data Description

7.1 Spatial Characteristics

Nadir-viewing spectrometer readings were made of the understory at marked 10-m intervals along the surveyed LAI transect line (White et al., 1995). Also, see Chen et al., 1997, for graphics and details about the layout of LAI transects.

7.1.1 Spatial Coverage

The North American Datum of 1983 (NAD83) coordinates for the sites are:

Flux Tower Sites

Site	Grid Id	Longitude	Latitude	UTM Easting	UTM Northing	UTM Zone
Southern Study Area:						
SSA-FEN	F0L9T	104.61798W	53.80206N	525159.8	5961566.6	13
SSA-OBS	G8I4T	105.11779W	53.98717N	492276.5	5982100.5	13
SSA-OJP	G2L3T	104.69203W	53.91634N	520227.7	5974257.5	13
SSA-YJP	F8L6T	104.64529W	53.87581N	523320.2	5969762.5	13
Northern Study Area:						
NSA-OBS	T3R8T	98.48139W	55.88007N	532444.5	6192853.4	14
NSA-OJP	T7Q8T	98.62396W	55.92842N	523496.2	6198176.3	14
NSA-YJP	T8S9T	98.28706W	55.89575N	544583.9	6194706.9	14
NSA-FEN	T7S1T	98.42072W	55.91481N	536207.9	6196749.6	14

Each flux tower site allowed for 5 to 40 individual spectral observations.

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

Observations were recorded along a transect line at marked 10-m intervals.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

Observations were made during all five BOREAS field campaigns: FFC-W, FFC-T, IFC-1, IFC-2, and IFC-3. Measurements were obtained within 2 hours of local solar noon.

7.2.2 Temporal Coverage Map

A summary of the understory data set is provided below in tabular form. This summarizes what data are available by specifying, the field campaign, the study area, the flux tower site, the instrument used for the measurements, the type of Kodak reference cards used for in-field reflectance determination, the observation date, and comments regarding the illumination conditions or the understory targets. More detailed information is provided in the spectral data headers.

Field Campaign	Study Area	Site	Instr. Used	Kodak Card Used	Observation Date	Comments
FFC-W	NSA	Fen	SE590	KGC-W	12-Feb-1994	Sun/Debris
		OJP	SE590	KGC-W	12-Feb-1994	Sun/Shade
		YJP	SE590	KGC-W	12-Feb-1994	Sun/Shade
	SSA	Fen	SE590	KGC-W	09-Feb-1994	Sun
		OBS	SE590	KGC-W	08-Feb-1994	Sun/Shade
		OJP	SE590	KGC-W	06-Feb-1994	Sun/shade
		YJP	SE590	KGC-W	09-Feb-1994	Sun/Shade
FFC-T	NSA	Fen	ASD	KGC-W	21-Apr-1994	Sun(s,v)
		OJP	ASD	KGC-W	21-Apr-1994	Sun/Shade(s)
	SSA	OBS	ASD	KGC-W	16-Apr-1994	Sun/Shade(s,v)
		OJP	ASD	KGC-W	17-Apr-1994	Sun/Shade(v)
		YJP	ASD	KGC-W	27-Apr-1994	Sun/Shade(s,v)
IFC-1	NSA	OJP	SE590	KGC-W	11(13)-Jun-1994	Sun/Shade
	SSA	OBS	SE590	KGC-W	31-May-1994	Sun/Shade
		OJP	SE590	KGC-W	26-May-1994	Sun/shade
		YJP	SE590	KGC-W	26-May-1994	Sun/Shade
IFC-2	NSA	OBS	SE590	KGC-W	16-Jul-1994	Sun/Shade
	SSA	OBS	SE590	KGC-W	23-Jul-1994	Sun/Shade
		OJP	SE590	KGC-W	21-Jul-1994	Sun/Shade
		YJP	SE590	KGC-W	20-Jul-1994	Sun/Shade
IFC-3	NSA	Fen	SE590	KGC-G	03-Sep-1994	Sun
		OBS	SE590	KGC-G	02-Sep-1994	Sun/Shade
		OJP	SE590	KGC-G	06(07)-Sep-1994	Sun/Shade
		YJP	SE590	KGC-G	01-Sep-1994	Sun/Shade
	SSA	Fen	SE590	KGC-G	12-Sep-1994	Sun/Shade
		OBS	SE590	KGC-G	13-Sep-1994	Sun/Shade
		OJP	SE590	KGC-G	12-Sep-1994	Sun/Shade
		YJP	SE590	KGC-G	12(13)(16)-Sep-1994	Sun/Shade

7.2.3 Temporal Resolution

Observations were made only once at each tower site during each field campaign. For any such flux tower site, measurements were made at 10 to 40 individual understory locations along the 100- to 300-m LAI line within a 30- to 60-minute period near solar noon, in order to minimize changes in the SZA. From these data a mean mid-day understory reflectance was calculated.

7.3 Data Characteristics

7.3.1 Parameter/Variable

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

```
         Column Name
------------------------------
SITE_NAME
SUB_SITE
START_DATE
START_TIME
END_DATE
END_TIME
INSTRUMENT
```

SOLAR_AZ_ANG
SOLAR_ZEN_ANG
ILLUMINATION_CONDTN
TARGET_DESCR
NUM_OBS
WAVELENGTH
MEAN_REFL
STD_ERR_REFL
COMMENTS
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:

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.
START_DATE	The date on which the collection of data commenced.
START_TIME	The starting Greenwich Mean Time (GMT) for the data collected.
END_DATE	The date on which the collection of the data was terminated.
END_TIME	The ending Greenwich Mean Time (GMT) for the data collected.
INSTRUMENT	The name of the device used to make the measurements.
SOLAR_AZ_ANG	Direction referred to as a circular scale of degrees read clockwise describing the position of the sun where 0=north, 90=east, 180=south and 270=west.
SOLAR_ZEN_ANG	The angle from the surface normal (straight up) to the sun during the data collection.
ILLUMINATION_CONDTN	The lighting condition when the data was collected-- e.g. sunny, shade, or combined.
TARGET_DESCR	A description of the material that is being measured.
NUM_OBS	Number of observations of the given sample used to calculate given measurements.
WAVELENGTH	Spectral wavelength at which measurement was acquired.

MEAN_REFL	The average reflectance factor.
STD_ERR_REFL	The standard error of the mean reflectance factors.
COMMENTS	Descriptive information to clarify or enhance the understanding of the other entered data.
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:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
START_DATE	[DD-MON-YY]
START_TIME	[HHMM GMT]
END_DATE	[DD-MON-YY]
END_TIME	[HHMM GMT]
INSTRUMENT	[none]
SOLAR_AZ_ANG	[degrees]
SOLAR_ZEN_ANG	[degrees]
ILLUMINATION_CONDTN	[none]
TARGET_DESCR	[none]
NUM_OBS	[counts]
WAVELENGTH	[micrometers]
MEAN_REFL	[percent]
STD_ERR_REFL	[percent]
CRTFCN_CODE	[none]
COMMENTS	[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:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS]
SUB_SITE	[Assigned by BORIS]
START_DATE	[Human observer]
START_TIME	[Human observer]
END_DATE	[Human observer]
END_TIME	[Human observer]
INSTRUMENT	[Human observer]
SOLAR_AZ_ANG	[Standard ephemeris equations]
SOLAR_ZEN_ANG	[Standard ephemeris equations]
ILLUMINATION_CONDTN	[Human observer]
TARGET_DESCR	[Human observer]
NUM_OBS	[ASD or SE-590 spectroradiometer]
WAVELENGTH	[ASD or SE-590 spectroradiometer]

MEAN_REFL	[ASD or SE-590 spectroradiometer]
STD_ERR_REFL	[ASD or SE-590 spectroradiometer]
COMMENTS	[Assigned by BORIS]
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.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	NSA-FEN-FLXTR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	RSS19-URF01	RSS19-URF01	None	None	None	None
START_DATE	06-FEB-94	13-SEP-94	None	None	None	None
START_TIME	1542	2156	None	None	None	None
END_DATE	06-FEB-94	16-SEP-94	None	None	None	None
END_TIME	1632	2212	None	None	None	None
INSTRUMENT	N/A	N/A	None	None	None	None
SOLAR_AZ_ANG	137.769	233.02	None	None	None	None
SOLAR_ZEN_ANG	33.354	80.482	None	None	None	None
ILLUMINATION_CONDTN	N/A	N/A	None	None	None	None
TARGET_DESCR	N/A	N/A	None	None	None	None
NUM_OBS	2	47	None	None	None	None
WAVELENGTH	.4	.901	None	None	None	None
MEAN_REFL	.8	98.2	None	None	None	None
STD_ERR_REFL	0	11.6	None	None	None	None
COMMENTS	N/A	N/A	None	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	04-SEP-97	26-SEP-97	None	None	None	None

Minimum Data Value -- The minimum value found in the column.
Maximum Data Value -- The maximum value found in the column.
Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.
Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be unreliable by the analysis personnel.
Below Detect Limit -- The value that indicates parameter values below the instruments detection limits. This is used to indicate that an attempt was made to determine the parameter value, but the analysis personnel determined that the parameter value was below the detection limit of the instrumentation.
Data Not Cllctd -- This value indicates that no attempt was made to determine the parameter value. This usually indicates that BORIS combined several similar but not identical data sets into the same data base table but this particular science team did not measure that parameter.

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

7.4 Sample Data Record

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

```
SITE_NAME,SUB_SITE,START_DATE,START_TIME,END_DATE,END_TIME,INSTRUMENT,
SOLAR_AZ_ANG,SOLAR_ZEN_ANG,ILLUMINATION_CONDTN,TARGET_DESCR,NUM_OBS,WAVELENGTH,
MEAN_REFL,STD_ERR_REFL,COMMENTS,CRTFCN_CODE,REVISION_DATE
'NSA-OBS-FLXTR','RSS19-URF01',02-SEP-94,1921,02-SEP-94,2040,'SE590',208.14,
51.076,'SUNNY','SUNLIT VEGETATION',14,.861,29.6,2.5,'','CPI',11-SEP-97
'NSA-OBS-FLXTR','RSS19-URF01',02-SEP-94,1921,02-SEP-94,2040,'SE590',208.14,
51.076,'SUNNY','SUNLIT VEGETATION',14,.864,29.5,2.5,'','CPI',11-SEP-97
'NSA-OBS-FLXTR','RSS19-URF01',02-SEP-94,1921,02-SEP-94,2040,'SE590',208.14,
51.076,'SUNNY','SUNLIT VEGETATION',14,.867,29.5,2.4,'','CPI',11-SEP-97
```

8. Data Organization

8.1 Data Granularity

The smallest amount of data tracked by BORIS was a file of reflectance data taken at a site on a given day.

8.2 Data Format

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

As described more fully in Peddle et al. (1995), for any particular SZA, the target reflectance is calculated from:

target_ref. = (target_signal/reference_panel_signal)*panel_reflectance_at_SZA

The panel reflectance at SZA is calculated by interpolation between laboratory panel BRDF calibrations (Soffer et al., 1995). The SZA is calculated from the local time and site longitude and latitude using standard ephemeris equations (see Peddle et al., 1995).

9.1.1 Derivation Techniques and Algorithms

It was possible to determine the SZA of each observation to a high degree of accuracy (within a few minutes of arc) using the tower flux site's latitude and longitude outlined in the BOREAS Experiment Plan Ver. 3.0, and the Local Standard Time (LST) of each observation (Observers Handbook, 1994). A fourth-order polynomial was fitted to the calibration panel BRDF data provided in Soffer et al. (1995) for each SZA and spectrally interpolated (Peddle et al., 1995). This permitted the understory radiance spectra to be converted to nadir-view reflectance.

In the data reduction, no adjustments were made for the difference in SZA between the panel and target measurements, since they were usually taken within 1 minute of each other.

9.2 Data Processing Sequence

9.2.1 Processing Steps

The processing steps to convert raw field spectrometer output spectrum to a reflectance spectrum are described above and in detail in Peddle et al. (1995). Subsequently, the observations under direct Sun illumination, for one flux tower site, during one field campaign, were simply averaged (no weighting) to provide the mean understory reflectance. The standard error was also computed as the standard error of the mean (SE), which is related to the standard deviation (SD) by:

$SE = SD/n^{1/2}$

9.2.2 Processing Changes

All reported data were collected and processed in the same way, except for IFC-1. In this case, data collection followed a modified strategy in which at each site reflectance spectra were determined for different understory vegetation types (e.g., for lichen, for moss, for labrador tea, etc.), and the aerial coverage of each vegetation type was estimated by site spatial sampling. In this case, the mean understory spectrum was calculated by weighting the reflectance of each understory type by the corresponding aerial coverage.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None.

9.3.2 Calculated Variables

Standard error.

9.4 Graphs and Plots

Summary graphs of understory reflectances are available in Miller et al. (1997).

10. Errors

10.1 Sources of Error

Although the data were collected between 350-1100 nm, noise due to low signal levels and low detector efficiency in the regions below 400 nm and above 850 nm were observed from both spectrometers and are not presented here.

10.2 Quality Assessment

Error estimate curves for the understory reflectance are provided by showing the mean reflectance curve +/- one standard error.

10.2.1 Data Validation by Source

Data validation efforts included comparisons with reflectance measurements made by Laval University scientists (unpublished) and comparisons of mean reflectance spectra for one tower site for successive field campaigns, both of which demonstrate consistent results.

10.2.2 Confidence Level/Accuracy Judgment

The seasonal variation in the tower site understory reflectances, the between-site variations as reported in Miller et al. (1997), and the reported standard errors for the spectra reported all suggest data of high quality.

10.2.3 Measurement Error for Parameters

Standard error spectra are provided along with the reflectance spectra.

10.2.4 Additional Quality Assessments

Visual review of plots and the standard error curves were used to assess data quality and to correct occasional recording errors.

10.2.5 Data Verification by Data Center

BOREAS Information System (BORIS) personnel have looked at the data and plotted the spectra for all files.

11. Notes

11.1 Limitations of the Data

There were some data gaps due to various weather and scheduling difficulties in the field. Calibrations of the panels used in the near-infrared region have not yet been completed.

11.2 Known Problems with the Data

None.

11.3 Usage Guidance

Although understory reflectance characterization on a species basis may be of interest to some BOREAS scientists, it was not pursued in this study because it would have required a substantially different measurement strategy. Furthermore, a characterization of the complete BRDF of the understory was considered outside the scope of this study.

11.4 Other Relevant Information

None given.

12. Application of the Data Set

The application of this data set is to estimate the average spectral reflectance of the understory in order to specify the boundary condition in canopy reflectance modeling for each season.

13. Future Modifications And Plans

None.

14. Software

14.1 Software Description

In-house macros were written for Microsoft Excel that ingested spectrometer spectral scans for the target and the reference panel, applied corrections for the panel BRDF according to the local SZA, and calculated the sample nadir reflectance and then the site-average reflectance spectrum and standard error. See Peddle et al. (1995) for a software and processing description.

14.2 Software Access

Because raw data files were not submitted, it is not useful to provide access to the processing software. These data were collected specifically to generate site-average understory spectra.

15. Data Access

The 1994 seasonal understory reflectance data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

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

15.2 Data Center Identification

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

15.3 Procedures for Obtaining Data

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

15.4 Data Center Status/Plans

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

16. Output Products and Availability

16.1 Tape Products

None.

16.2 Film Products
None.

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

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

ASD Personal Spectrometer II Reference Manual. 1993. Analytic Spectral Devices Inc., Boulder, Colorado, USA.

SE-590 Field-Portable Data-logging Spectroradiometer Operating Manual. Spectron Engineering, Inc., 225 Yuma Court, Denver, Co., 80223, USA.

17.2 Journal Articles and Study Reports

Chen, J. and J. Cihlar. 1994. Canadian Centre for Remote Sensing, Private Communication.

Chen, J.M., P.M. Rich, S.T. Gower, J.M. Norman, and S. Plummer. 1997. Leaf area index of boreal forests: Theory, techniques, and measurements. Journal of Geophysical Research, 102(D24): 29,429-29,443.

Miller, J.R., H.P. White, J.M. Chen, D.R. Peddle, G. McDermid, R.A. Fournier, P. Shepherd, I. Rubinstein, J. Freemantle, R. Soffer, and E. LeDrew. 1997. Seasonal change in understory reflectance of boreal forests and influence on canopy vegetation indices. Journal of Geophysical Research 102(D24): 29,475-29,482.

Milton, E.J. 1989. On the suitability of Kodak neutral test cards as reflectance standards. International Journal of Remote Sensing, Vol. 10.

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.

Observer's Handbook 1994. Editor: Roy l. Bishop, The Royal Astronomical Society of Canada.

Peddle, D.R., H.P. White, R.J. Soffer, J.R. Miller, and E.F. LeDrew. 1995. Reflectance Processing of Field Spectrometer Data in BOREAS. Proceedings: 17th Canadian Symposium on Remote Sensing, pp. 189-194, Saskatoon, Sask..

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.

Soffer, R.J., J.W. Harron, and J.R. Miller. 1995. Characterization of Kodak grey cards as reflectance reference panels in support of BOREAS field activities. Proceedings: 17th Canadian Symposium on Remote Sensing, pp. 357-362, Saskatoon, Sask.

White, H.P., J.R. Miller, J. Chen, and D.R. Peddle. 1995. Seasonal change in mean understory reflectance for BOREAS sites: Preliminary results., Proceedings: 17th Canadian Symposium on Remote Sensing, pp. 182-187, Saskatoon, Sask.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

```
ASCII    - American Standard Code for Information Interchange
ASD      - Analytic Spectral Devices, Inc. personal field spectrometer
BOREAS   - BOReal Ecosystem-Atmosphere Study
BORIS    - BOREAS Information System
BRDF     - Bidirectional Reflectance Distribution Function
CASI     - Compact Airborne Spectrographic Imager
CCRS     - Canada Centre for Remote Sensing
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
HTML     - HyperText Markup Language
IFC      - Intensive Field Campaign
ISTS     - Institute for Space and Terrestrial Science
KGC      - Kodak Grey Card
MMR      - Modular Multiband Radiometer
NASA     - National Aeronautics and Space Administration
NSA      - Northern Study Area
OBS      - Old Black Spruce
```

```
OJP      - Old Jack Pine
ORNL     - Oak Ridge National Laboratory
PANP     - Prince Albert National Park
PARABOLA - Portable Apparatus for Rapid Acquisition of Bidirectional
           Observations of the Land and Atmosphere
RSS      - Remote Sensing Science
SE-590   - Spectron Engineering field spectroradiometer
SSA      - Southern Study Area
SZA      - Solar Zenith Angle
TE       - Terrestrial Ecology
URL      - Uniform Resource Locator
UTM      - Universal Transverse Mercator
YJP      - Young Jack Pine
```

20. Document Information

20.1 Document Revision Date
Written: 07-Jan-1997
Last updated: 11-Jun-1999

20.2 Document Review Date(s)
BORIS Review: 26-May-1998
Science Review: 03-Jan-1998

20.3 Document ID

20.4 Citation
When using these data, please include the following acknowledgment as well as citations of relevant papers in Section 17.2:
If this data set is referenced by another investigator, please acknowledge the paper by Miller et al., (1997), listed in Section 17.

If using data from the BOREAS CD-ROM series, also reference the data as:
Miller, J.R., H.P. White, J. Freemantle, G. McDermid, D.R. Peddle, I. Rubinstein, P. Shepherd, R. Soffer, J. Chen, and R. Fournier, "Seasonal Change in Mean Understory Reflectance for Conifer Flux Tower Sites at BOREAS." 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.

Also, cite the BOREAS CD-ROM set as:
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. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM. NASA, 2000.

20.5 Document Curator

20.6 Document URL

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
August 2000

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)
BOREAS RSS-19 1994 Seasonal Understory Reflectance Data

5. FUNDING NUMBERS
923
RTOP: 923-462-33-01

6. AUTHOR(S)
John R. Miller, H. Peter White, Derek Peddle, Jim Freemantle
Forrest G. Hall and Jaime Nickeson, Editors

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)
Goddard Space Flight Center
Greenbelt, Maryland 20771

8. PEFORMING ORGANIZATION REPORT NUMBER
2000-03136-0

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS (ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
TM—2000–209891
Vol. 77

11. SUPPLEMENTARY NOTES
J.R. Miller, and H.P White: York University, Ontario, Canada; D. Peddle, University of Waterloo, ISTS; J. Freemantle: ISTS; J. Nickeson: Raytheon ITSS

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified–Unlimited
Subject Category: 43
Report available from the NASA Center for AeroSpace Information,
7121 Standard Drive, Hanover, MD 21076-1320. (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
The BOREAS RSS-19 team collected airborne remotely sensed images and ground reflectance data for characterizing the radiometric properties of the boreal forest landscape. One objective of BOREAS is to further the understanding of the spectral bidirectional reflectance of typical boreal ecosystem stands in the visible/near-infrared regime. An essential input for any canopy BRDF model is an accurate estimate of the average understory reflectance, both for sunlit and shaded conditions. These variables can be expected to vary seasonally because of species-dependent differences in the phenological cycle of foliar display. In response to these requirements, the average understory reflectance for the flux tower sites of both the NSA (Thompson, Manitoba) and the SSA (Candle Lake, Saskatchewan) was observed throughout the year during five field campaigns. This was done by measuring the nadir reflectance (400 to 850 nm) of sunlit and shaded understory (vegetation and snow cover) along a surveyed LAI transect line (Chen, RSS-07) at each site near solar noon and documenting an average site reflectance. Comparisons between sites reveal differences in the green and infrared regions of the spectra, because of the differing species in the understory for each site. Temporal (seasonal) variation for each site was also observed (06-Feb-1994 to 16-Sep-1994), indicating the changing flora mixtures and changing spectral signatures as the understory matures during the growing season. The data are stored in tabular ASCII files.

14. SUBJECT TERMS
BOREAS, remote sensing science, reflectance data.

15. NUMBER OF PAGES
18

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL