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
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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.

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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

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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

<table>
<thead>
<tr>
<th>Site</th>
<th>Grid Id</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Easting</th>
<th>Northing</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSA-FEN</td>
<td>F0L9T</td>
<td>104.61798W</td>
<td>53.80206N</td>
<td>525159.8</td>
<td>5961566.6</td>
<td>13</td>
</tr>
<tr>
<td>SSA-OBS</td>
<td>G8I4T</td>
<td>105.11779W</td>
<td>53.98717N</td>
<td>492276.5</td>
<td>5982100.5</td>
<td>13</td>
</tr>
<tr>
<td>SSA-OJP</td>
<td>G2L3T</td>
<td>104.69203W</td>
<td>53.91634N</td>
<td>520227.7</td>
<td>5974257.5</td>
<td>13</td>
</tr>
<tr>
<td>SSA-YJP</td>
<td>F8L6T</td>
<td>104.64529W</td>
<td>53.87581N</td>
<td>523320.2</td>
<td>5969762.5</td>
<td>13</td>
</tr>
</tbody>
</table>

### Northern Study Area:

<table>
<thead>
<tr>
<th>Site</th>
<th>Grid Id</th>
<th>Longitude</th>
<th>Latitude</th>
<th>Easting</th>
<th>Northing</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSA-OBS</td>
<td>T3R8T</td>
<td>98.48139W</td>
<td>55.88007N</td>
<td>532444.5</td>
<td>6192853.4</td>
<td>14</td>
</tr>
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<td>NSA-OJP</td>
<td>T7Q8T</td>
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<td>55.92842N</td>
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<td>NSA-YJP</td>
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<td>98.28706W</td>
<td>55.89575N</td>
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<td>6194706.9</td>
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<td>NSA-FEN</td>
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<td>55.91481N</td>
<td>536207.9</td>
<td>6196749.6</td>
<td>14</td>
</tr>
</tbody>
</table>

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.
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:

<table>
<thead>
<tr>
<th>Column Name</th>
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</thead>
<tbody>
<tr>
<td>SITE_NAME</td>
</tr>
<tr>
<td>SUB_SITE</td>
</tr>
<tr>
<td>START_DATE</td>
</tr>
<tr>
<td>START_TIME</td>
</tr>
<tr>
<td>END_DATE</td>
</tr>
<tr>
<td>END_TIME</td>
</tr>
<tr>
<td>INSTRUMENT</td>
</tr>
</tbody>
</table>


7.3.2 Variable Description/Definition

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

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE_NAME</td>
<td>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.</td>
</tr>
<tr>
<td>SUB_SITE</td>
<td>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.</td>
</tr>
<tr>
<td>START_DATE</td>
<td>The date on which the collection of data commenced.</td>
</tr>
<tr>
<td>START_TIME</td>
<td>The starting Greenwich Mean Time (GMT) for the data collected.</td>
</tr>
<tr>
<td>END_DATE</td>
<td>The date on which the collection of the data was terminated.</td>
</tr>
<tr>
<td>END_TIME</td>
<td>The ending Greenwich Mean Time (GMT) for the data collected.</td>
</tr>
<tr>
<td>INSTRUMENT</td>
<td>The name of the device used to make the measurements.</td>
</tr>
<tr>
<td>SOLAR_AZ_ANG</td>
<td>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.</td>
</tr>
<tr>
<td>SOLAR_ZEN_ANG</td>
<td>The angle from the surface normal (straight up) to the sun during the data collection.</td>
</tr>
<tr>
<td>ILLUMINATION_CONDTN</td>
<td>The lighting condition when the data was collected-- e.g. sunny, shade, or combined.</td>
</tr>
<tr>
<td>TARGET_DESCR</td>
<td>A description of the material that is being measured.</td>
</tr>
<tr>
<td>NUM_OBS</td>
<td>Number of observations of the given sample used to calculate given measurements.</td>
</tr>
<tr>
<td>WAVELENGTH</td>
<td>Spectral wavelength at which measurement was acquired.</td>
</tr>
</tbody>
</table>
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:

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

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<td>START_DATE</td>
<td>[Human observer]</td>
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<td>START_TIME</td>
<td>[Human observer]</td>
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<td>END_TIME</td>
<td>[Human observer]</td>
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<tr>
<td>INSTRUMENT</td>
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<td>[Standard ephemeris equations]</td>
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<tr>
<td>NUM_OBS</td>
<td>[ASD or SE-590 spectroradiometer]</td>
</tr>
<tr>
<td>WAVELENGTH</td>
<td>[ASD or SE-590 spectroradiometer]</td>
</tr>
</tbody>
</table>
### 7.3.5 Data Range

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

<table>
<thead>
<tr>
<th>Column Name</th>
<th>Minimum Data Value</th>
<th>Maximum Data Value</th>
<th>Missng Data Value</th>
<th>Unrel Data Value</th>
<th>Below Detect Limit</th>
<th>Data Not Cllctd</th>
</tr>
</thead>
<tbody>
<tr>
<td>SITE NAME</td>
<td>NSA-FEN-FLXTR</td>
<td>SSA-YJP-FLXTR</td>
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<td>SUB_SITE</td>
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<td>None</td>
<td>None</td>
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<td>START_DATE</td>
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<td>13-SEP-94</td>
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<td>None</td>
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<td>END_DATE</td>
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<td>16-SEP-94</td>
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<td>None</td>
<td>None</td>
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<tr>
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<td>2212</td>
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<td>None</td>
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<tr>
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<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
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<td>.901</td>
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<td>None</td>
<td>None</td>
<td>None</td>
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<tr>
<td>MEAN_REFL</td>
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<tr>
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<td>None</td>
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<td>None</td>
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<tr>
<td>COMMENTS</td>
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<td>N/A</td>
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<td>None</td>
<td>None</td>
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</tr>
<tr>
<td>CRTFCN_CODE</td>
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<td>CPI</td>
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<td>None</td>
<td>None</td>
<td>None</td>
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<tr>
<td>REVISION_DATE</td>
<td>04-SEP-97</td>
<td>26-SEP-97</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

- 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.
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_COND, 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, 'SUNNY', 14, .861, 29.6, 2.5,'', 'CPI', 11-SEP-97
'NSA-OBS-FLXTR', 'RSS19-URF01', 02-SEP-94, 1921, 02-SEP-94, 2040, 'SUNNY', 14, .864, 29.5, 2.5,'', 'CPI', 11-SEP-97
'NSA-OBS-FLXTR', 'RSS19-URF01', 02-SEP-94, 1921, 02-SEP-94, 2040, 'SUNNY', 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:

\[
\text{target_ref.} = \frac{\text{target_signal}}{\text{reference_panel_signal}} \times \text{panel_reflectance at SZA}
\]

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 Softer 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:

\[ SE = SD/\sqrt{n} \]

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


17.2 Journal Articles and Study Reports


17.3 Archive/DBMS Usage Documentation
None.

18. Glossary of Terms

None.

19. List of Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
</tr>
<tr>
<td>ASD</td>
<td>Analytic Spectral Devices, Inc. personal field spectrometer</td>
</tr>
<tr>
<td>BOREAS</td>
<td>BOReal Ecosystem-Atmosphere Study</td>
</tr>
<tr>
<td>BORIS</td>
<td>BOREAS Information System</td>
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<tr>
<td>BRDF</td>
<td>Bidirectional Reflectance Distribution Function</td>
</tr>
<tr>
<td>CASI</td>
<td>Compact Airborne Spectrographic Imager</td>
</tr>
<tr>
<td>CCRS</td>
<td>Canada Centre for Remote Sensing</td>
</tr>
<tr>
<td>CD-ROM</td>
<td>Compact Disk-Read-Only Memory</td>
</tr>
<tr>
<td>DAAC</td>
<td>Distributed Active Archive Center</td>
</tr>
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<td>EOS Data and Information System</td>
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<td>FFC-T</td>
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</tr>
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<td>FFC-W</td>
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</tr>
<tr>
<td>FOV</td>
<td>Field of View</td>
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<td>HyperText Markup Language</td>
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<tr>
<td>IFC</td>
<td>Intensive Field Campaign</td>
</tr>
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<td>ISTS</td>
<td>Institute for Space and Terrestrial Science</td>
</tr>
<tr>
<td>KGC</td>
<td>Kodak Grey Card</td>
</tr>
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<td>MMR</td>
<td>Modular Multiband Radiometer</td>
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<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
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<td>NSA</td>
<td>Northern Study Area</td>
</tr>
<tr>
<td>OBS</td>
<td>Old Black Spruce</td>
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</table>
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:

Also, cite the BOREAS CD-ROM set as:

20.5 Document Curator

20.6 Document URL
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.