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

Forrest G. Hall and Andrea Papagno, Editors

Volume 170

BOREAS TE-12 Incoming PAR
Through the Forest Canopy Data

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Goddard Space Flight Center
Greenbelt, Maryland 20771

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BOREAS TE-12 Incoming PAR Through the Forest Canopy Data
Elizabeth A. Walter-Shea, Mark A. Mesarch

Summary
The BOREAS TE-12 team collected PAR data sets in support of its efforts to characterize and interpret information on shoot geometry, leaf optical properties, leaf water potential, and leaf gas exchange. The data were collected at the SSA-OBS site from 04-Jul-1996 to 25-Jul-1996. The data are stored in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification
BOREAS TE-12 Incoming PAR Through the Forest Canopy Data

1.2 Data Set Introduction
The Terrestrial Ecology (TE)-12 team took measurements of incoming photosynthetically active radiation (PAR) as part of the BOREal Ecosystem-Atmosphere Study (BOREAS) at the Old Black Spruce (OBS) site in the Southern Study Area (SSA) from 04-Jul-1996 to 25-Jul-1996. PAR, in units of micro Einsteins per meter squared per second, from 0.4 to 0.7 microns, was measured in an array below the tree canopy, but above the understory. Ten LI-COR quantum sensors measured PAR, and minute averages are reported.

1.3 Objectives/Purpose
The objective of this research was to characterize the duration and magnitude of sun flecks under a boreal forest canopy.
1.4 **Summary of Parameters**
Minute averages of PAR, in units of micro Einstein per meter squared per minute.

1.5 **Discussion**
TE-12 took measurements of incoming PAR at SSA-OBS from 04-Jul-1996 to 25-Jul-1996. PAR, in units of micro Einsteins per meter squared per second, from 0.4 to 0.7 microns, was measured in an array below the tree canopy, but above the understory. Ten LI-COR quantum sensors measured PAR, and minute averages are reported.

1.6 **Related Data Sets**
TE-12 Shoot Geometry Data
TE-12 Leaf Gas Exchange Data

2. **Investigator(s)**

2.1 **Investigator(s) Name and Title**
Elizabeth A. Walter-Shea, Assoc. Professor

2.2 **Title of Investigation**
Radiation and Gas Exchange of Canopy Elements in a Boreal Forest

2.3 **Contact Information**

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(402) 472-6614 (fax)
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(402) 472-6614 (fax)
ewalter-sheal@unl.edu

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Andrea Papagno
Raytheon ITSS
NASA GSFC
Code 923
Greenbelt, MD 20771
(301) 286-3134
(301) 286-0239 (fax)
Andrea.Papagno@gsfc.nasa.gov
3. Theory of Measurements
Fluxes need to be measured at understory levels to relate to environmental and state variables and explain the stand scale fluxes. At the understory level, upper canopy elements shade the understory partially, creating sun flecks. These sun flecks fluctuate over time, both spatially and in intensity. An array of hemisphere sensors was placed above the understory to measure a represented area of transmitted PAR. The time frame of the measurements, 1-minute averages, provided a time scale representative of a plant's photosynthetic processes' reaction time.

4. Equipment

4.1 Sensor/Instrument Description
A LI-COR Quantum Sensor (LI-190SA) was used to detect sun flecks. A silicon photo diode with an enhanced response in the visible wavelengths was used to measure PAR, from 0.4 to 0.7 microns. A visible bandpass interference filter, in combination with color glass filters, was mounted in a cosine corrected head. Error calculations indicated that under sun-and-sky radiation, and under various natural or artificial light sources, the relative measurement errors are less than 5.0%. Therefore, this sensor can be used within or inverted over canopies and in greenhouses, controlled growth chambers, and confined laboratory conditions. Generally, this instrument measures hemispherical incoming radiation; however, when placed within a canopy, the instrument acts as a point source detector.

The quantum sensors were placed in an array surrounding a central point at varying distances from this central point. The table below describes the directions and distances from the central point for sensor.

<table>
<thead>
<tr>
<th>Sensor serial number</th>
<th>Direction</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q15566</td>
<td>North</td>
<td>15</td>
</tr>
<tr>
<td>Q9020</td>
<td>Northeast</td>
<td>16</td>
</tr>
<tr>
<td>Q15565</td>
<td>East</td>
<td>10</td>
</tr>
<tr>
<td>Q2738</td>
<td>East-Southeast</td>
<td>2.5</td>
</tr>
<tr>
<td>Q9123</td>
<td>Southeast</td>
<td>12</td>
</tr>
<tr>
<td>Q9022</td>
<td>South</td>
<td>12</td>
</tr>
<tr>
<td>Q7433</td>
<td>South-Southwest</td>
<td>1.7</td>
</tr>
<tr>
<td>Q7434</td>
<td>Southwest</td>
<td>5</td>
</tr>
<tr>
<td>Q10890</td>
<td>West</td>
<td>12</td>
</tr>
<tr>
<td>Q89085</td>
<td>Northwest</td>
<td>4.5</td>
</tr>
</tbody>
</table>

4.1.1 Collection Environment
Measurements were made onsite at the SSA-OBS site.

4.1.2 Source/Platform
Each LI-COR quantum sensor was attached to a LI-COR 2003S Mounting and Leveling Fixture. These fixtures are made of anodized aluminum with stainless steel leveling screws and a weatherproof spirit level. The fixture was attached to a wood block that was attached to the top of a pole, 0.6 m above the sphagnum surface. Once the wood block was attached to the pole, the leveling screws on the fixture were used to level the fixture holding the quantum sensor.

4.1.3 Source/Platform Mission Objectives
None given.

4.1.4 Key Variables
Incoming PAR under a tree canopy.
4.1.5 Principles of Operation
The LI-COR quantum sensor uses a silicon diode to convert sunlight to electrical energy (voltage).

4.1.6 Sensor/Instrument Measurement Geometry
The quantum sensors were placed in an array surrounding a central point at varying distances from this central point. The table below describes the directions and distances from the central point for each sensor.

<table>
<thead>
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<tr>
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<tr>
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<td>East-Southeast</td>
<td>2.5</td>
</tr>
<tr>
<td>Q9123</td>
<td>Southeast</td>
<td>12</td>
</tr>
<tr>
<td>Q9022</td>
<td>South</td>
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<tr>
<td>Q89085</td>
<td>Northwest</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Each LI-COR quantum sensor was attached to a LI-COR 2003S Mounting and Leveling Fixture. These fixtures are made of anodized aluminum with stainless steel leveling screws and a weatherproof spirit level. The fixture was attached to a wood block that was attached to the top of a pole 0.6 m above the sphagnum surface. Once the wood block was attached to the pole, the leveling screws on the fixture were used to level the fixture holding the quantum sensor.

4.1.7 Manufacturer of Sensor/Instrument
LI-COR, Inc.
Box 4425
Lincoln, NE 68504
(402) 467-3576

4.2 Calibration

4.2.1 Specifications
None given.

4.2.1.1 Tolerance
None given.

4.2.2 Frequency of Calibration
LI-COR quantum sensors were calibrated at the manufacturer in May 1996.
4.2.3 Other Calibration Information

Calibration coefficients for the sensors were in units of micro Einsteins per meter squared per second per millivolt.

<table>
<thead>
<tr>
<th>Sensor Number</th>
<th>Serial Number</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Q9020</td>
<td>-253.54</td>
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<tr>
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<td>Q9022</td>
<td>-282.05</td>
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<td>3</td>
<td>Q7434</td>
<td>-252.00</td>
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<tr>
<td>4</td>
<td>Q9123</td>
<td>-308.31</td>
</tr>
<tr>
<td>5</td>
<td>Q15566</td>
<td>-311.21</td>
</tr>
<tr>
<td>6</td>
<td>Q15565</td>
<td>-245.64</td>
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<tr>
<td>7</td>
<td>Q89085</td>
<td>-285.45</td>
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<tr>
<td>8</td>
<td>Q10890</td>
<td>-286.44</td>
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<tr>
<td>9</td>
<td>Q7433</td>
<td>-200.00</td>
</tr>
<tr>
<td>10</td>
<td>Q2734</td>
<td>-194.55</td>
</tr>
</tbody>
</table>

5. Data Acquisition Methods

The quantum sensors were placed in an array surrounding a central point at varying distances from this central point. The sensors were placed in the array to cover an area of approximately 600 m², which was representative of an area of understory under the canopy. The table below describes the directions and distances from the central point for sensor.

<table>
<thead>
<tr>
<th>Sensor serial number</th>
<th>Direction</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
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<td>North</td>
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<tr>
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<td>South</td>
<td>12</td>
</tr>
<tr>
<td>Q7433</td>
<td>South-Southwest</td>
<td>1.7</td>
</tr>
<tr>
<td>Q7434</td>
<td>Southwest</td>
<td>5</td>
</tr>
<tr>
<td>Q10890</td>
<td>West</td>
<td>12</td>
</tr>
<tr>
<td>Q89085</td>
<td>Northwest</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Each LI-COR quantum sensor was attached to a LI-COR 2003S Mounting and Leveling Fixture. These fixtures are made of anodized aluminum with stainless steel leveling screws and a weatherproof spirit level. The fixture was attached to a wood block that was attached to the top of a pole, 0.6 m above the sphagnum surface. Once the wood block was attached to the pole the leveling screws on the fixture were used to level the fixture holding the quantum sensor. Data were measured every 5 seconds and reported as 1-minute averages.

6. Observations

6.1 Data Notes
None given.

6.2 Field Notes
None given.
7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage
The SSA measurement site and its associated North American Datum of 1983 (NAD83) coordinates are:

- SSA-OBS, site id G814T, Lat/Long: 53.98717_N, 105.11779_W, Universal Transverse Mercator (UTM) Zone 13, N: 5,982,100.5, E: 492,276.5.

7.1.2 Spatial Coverage Map
Not applicable.

7.1.3 Spatial Resolution
The maximum distance between any two quantum sensors was 27 meters. The entire array covered approximately 600 m².

7.1.4 Projection
Not applicable.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
Data were collected at the OBS-SSA site from 04-Jul-1996 to 25-Jul-1996.

7.2.2 Temporal Coverage Map
Not available.

7.2.3 Temporal Resolution
Data were collected on most days from sunrise to sunset (approximately 4 a.m. to 10 p.m. local time). Measurements were made every 5 seconds and reported as 1-minute averages.

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>
</tr>
</thead>
<tbody>
<tr>
<td>SITE_NAME</td>
</tr>
<tr>
<td>SUB_SITE</td>
</tr>
<tr>
<td>DATE_OBS</td>
</tr>
<tr>
<td>TIME_OBS</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PFFD_SNSR1</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PFFD_SNSR2</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PFFD_SNSR3</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PFFD_SNSR4</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PFFD_SNSR5</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PFFD_SNSR6</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PFFD_SNSR7</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PFFD_SNSR8</td>
</tr>
</tbody>
</table>
### Variable Description/Definition

The description 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>DATE_OBS</td>
<td>The date on which the data were collected.</td>
</tr>
<tr>
<td>TIME_OBS</td>
<td>The Greenwich Mean Time (GMT) when the data were collected.</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PPFD_SNSR1</td>
<td>The one-minute mean direct downward photosynthetic photon flux density based on measurements taken below the tree canopy but above the understory using quantum sensor 1.</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PPFD_SNSR2</td>
<td>The one-minute mean direct downward photosynthetic photon flux density based on measurements taken below the tree canopy but above the understory using quantum sensor 2.</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PPFD_SNSR3</td>
<td>The one-minute mean direct downward photosynthetic photon flux density based on measurements taken below the tree canopy but above the understory using quantum sensor 3.</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PPFD_SNSR4</td>
<td>The one-minute mean direct downward photosynthetic photon flux density based on measurements taken below the tree canopy but above the understory using quantum sensor 4.</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PPFD_SNSR5</td>
<td>The one-minute mean direct downward photosynthetic photon flux density based on measurements taken below the tree canopy but above the understory using quantum sensor 5.</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PPFD_SNSR6</td>
<td>The one-minute mean direct downward photosynthetic photon flux density based on measurements taken below the tree canopy but above the understory using quantum sensor 6.</td>
</tr>
<tr>
<td>MEAN_DIR_DOWN_PPFD_SNSR7</td>
<td>The one-minute mean direct downward photosynthetic photon flux density based on measurements taken below the tree canopy but above the understory using quantum sensor 7.</td>
</tr>
</tbody>
</table>
MEAN_DIR_DOWN_PPFD_SNSR8

The one-minute mean direct downward photosynthetic photon flux density based on measurements taken below the tree canopy but above the understory using quantum sensor 8.

MEAN_DIR_DOWN_PPFD_SNSR9

The one-minute mean direct downward photosynthetic photon flux density based on measurements taken below the tree canopy but above the understory using quantum sensor 9.

MEAN_DIR_DOWN_PPFD_SNSR10

The one-minute mean direct downward photosynthetic photon flux density based on measurements taken below the tree canopy but above the understory using quantum sensor 10.

Data Not Collected -- 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 are wrapped versions of data record from a sample data file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,MEAN_DIR_DOWN_PPFD_SNSR1,MEAN_DIR_DOWN_PPFD_SNSR2,MEAN_DIR_DOWN_PPFD_SNSR3,MEAN_DIR_DOWN_PPFD_SNSR4,MEAN_DIR_DOWN_PPFD_SNSR5,MEAN_DIR_DOWN_PPFD_SNSR6,MEAN_DIR_DOWN_PPFD_SNSR7,MEAN_DIR_DOWN_PPFD_SNSR8,MEAN_DIR_DOWN_PPFD_SNSR9,MEAN_DIR_DOWN_PPFD_SNSR10,CRTFCN_CODE,REVISION_DATE
'SSA-OBS-FLXTR', '9TEI2-PAR01', 04-JUL-96, 2212, 79.8, 87.1, 246.0, 142.4, 212.3, 176.4, 84.3, 222.6, 1111.0, 75.2, 'CPI', 17-MAR-99
'SSA-OBS-FLXTR', '9TEI2-PAR01', 04-JUL-96, 2213, 71.6, 80.5, 198.6, 113.1, 299.6, 112.5, 61.91, 109.7, 1106.0, 70.5, 'CPI', 17-MAR-99
```

8. Data Organization

8.1 Data Granularity

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

8.2 Data Format(s)

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
None.

9.1.1 Derivation Techniques and Algorithms
Not applicable.

9.2 Data Processing Sequence
None given.

9.2.1 Processing Steps
None given.

9.2.2 Processing Changes
None given.

9.3 Calculations

9.3.1 Special Corrections/Adjustments
None given.

9.3.2 Calculated Variables
None given.

9.4 Graphs and Plots
None given.

10. Errors

10.1 Sources of Error
The manufacturer estimates that the LI-COR quantum sensor will measure within +/- 5.0 percent relative error of the true incoming PAR.

10.2 Quality Assessment

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
Data were examined for general consistency and clarity.
11. Notes

11.1 Limitations of the Data
None given.

11.2 Known Problems with the Data
None given.

11.3 Usage Guidance
None given.

11.4 Other Relevant Information
None given.

12. Application of the Data Set
This data set can be used to study the incoming PAR of the boreal forest.

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 incoming PAR 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 orml@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

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 given.

16.2 Film Products
None given.

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>BOREAS</td>
<td>BOREal Ecosystem-Atmosphere Study</td>
</tr>
<tr>
<td>BORIS</td>
<td>BOREAS Information System</td>
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<tr>
<td>CD-ROM</td>
<td>Compact Disk-Read-Only Memory</td>
</tr>
<tr>
<td>DAAC</td>
<td>Distributed Active Archive Center</td>
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<tr>
<td>DOY</td>
<td>Julian Day of Year</td>
</tr>
<tr>
<td>EOS</td>
<td>Earth Observing System</td>
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<td>EOSDIS</td>
<td>EOS Data and Information System</td>
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<td>Intensive Field Campaign</td>
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</tr>
<tr>
<td>PANP</td>
<td>Prince Albert National Park</td>
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<tr>
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<td>Photosynthetically Active Radiation</td>
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**BOREAS TE-12 Incoming PAR Through the Forest Canopy Data**

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**The BOREAS TE-12 team collected PAR data sets in support of its efforts to characterize and interpret information on shoot geometry, leaf optical properties, leaf water potential, and leaf gas exchange. The data were collected at the SSA-OBS site from 04-Jul-1996 to 25-Jul-1996. The data are stored in tabular ASCII files.**

**UNCLASSIFIED/UNLIMITED**

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