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BOREAS TE-12 SSA Shoot Geometry Data

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BOREAS TE-12 SSA Shoot Geometry Data

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Summary

The BOREAS TE-12 team collected shoot geometry data in 1993 and 1994 from aspen, jack pine, and black spruce trees. Collections were made at the SSA FEN, YJP, OJP, OA, YA, MIX, and OBS sites. A caliper was used to measure shoot and needle lengths and widths. A volume displacement procedure was used to measure the weight of the shoot or twig submerged in water. The data are provided in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification
BOREAS TE-12 SSA Shoot Geometry Data

1.2 Data Set Introduction
Measurements of shoot and individual needle length and width, orientation of needle to shoot axis, and number of needles per shoot were made on samples collected in 1993 and 1994 from aspen, jack pine, and black spruce trees with the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA). Calculations of shoot and twig volume, surface area, and shape factor were made based on the collected information.

1.3 Objective/Purpose
The purpose of the study was to characterize the needle and shoot geometry properties of several boreal forest tree species.

1.4 Summary of Parameters

Orientation of needles to shoot axis in three planes, volumetric displacement of the entire shoot and twig, shoot axis widths and length, sample of 10 needle lengths (and widths for the 1993 Intensive Field Campaign (IFC-93) and Focused Field Campaign - Winter (FFC-W) only). All measurements are for three age classes: growth from current year, last year, and 2 years ago.

1.5 Discussion

IFC-93: Measurements were made on samples collected at two sites in the SSA: near the Nipawin Fen (FEN) and Nipawin Jack Pine [Young-Dry] (YJP). Canopy access was limited to only ground-level collection of samples. Samples from trees could be from various heights within the tree, but were generally from the lower third of the entire canopy height. Black spruce [Picea mariana] and jack pine [Pinus banksiana] were sampled near the SSA-FEN site. Jack pine needles were sampled at the SSA-YJP site.

FFC-W: Measurements were made on samples collected in the SSA: Old Dry Jack Pine (OJP). The measurement methods described for IFC-93 were used. Jack pine trees were sampled at SSA-OJP.

FFC-Thaw (FFC-T): Measurements were made on samples collected at two sites in the SSA: OJP and Old Black Spruce (OBS). Jack pine trees were sampled at SSA-OJP and black spruce trees were sampled at SSA-OBS.

IFC-1,-2,-3: Measurements were made on samples collected at in the SSA: Mixed (MIX), YJP, and OBS. White spruce [Picea glauca] shoots were sampled at SSA-MIX. Jack pine shoots were sampled at SSA-YJP. Black spruce shoots were sampled at SSA-OBS. Measurements were made also on samples collected at SSA-Old Aspen (OA), SSA-Young Aspen (YA), SSA-FEN sites.

1.6 Related Data Sets

BOREAS TE-10 Leaf Optical Properties
BOREAS TE-12 SSA Water Potential Dataa
BOREAS TE-12 Leaf Optical Data for SSA Species

2. Investigator(s)

2.1 Investigator(s) Names and Titles

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2.2 Title of Investigation

Radiation and Gas Exchange of Canopy Elements in a Boreal Forest

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3. Theory of Measurements

Hemi-Surface Area Definition

The most desirable foliage area to use in reporting results from conifer shoots and broad leaves is to use the total surface area (SA) and one-half the total surface area, which is referred to as half the area of the surface leaf (HASL). HASL can be calculated using the shoot volume (inferred from the volume displacement measurement), the number of needles, average needle length reported here, and shape factor.

For flat leaves, the hemi-surface area is the same as the projected area, but for conifer needles or shoots, "projected area" is not even well defined and generally not used consistently. Hemi-surface area is not easy to misinterpret for any object.

Hemi-Surface Area Measurement

Surface area for conifer shoots can be measured by several methods, but the two most common are volume displacement and projected area of detached needles using an optical planimeter.

Using the optical planimeter is tedious because needles have to be carefully aligned so as to present their maximum area to the planimeter. Given the measured needle projected area of all the needles that have been detached from the shoot and a known cross-sectional shape for the needles, the surface area can be calculated and divided by two to get HSA.

A faster method that is as reliable as the planimeter method and does not require an expensive optical planimeter is the volume displacement method. This method requires a reasonably good, top-loading electronic balance; something common to any lab. The procedure is as follows:

- A container that is large enough for an intact shoot to be submerged in is filled with water and about 3-5% detergent mixed in with the water. The detergent is necessary because it prevents small air bubbles and films from accumulating on the surface of the shoot. The container has to be large enough for the shoot to be submerged without touching the walls of the container. If shoots are too large, needles can be detached and submerged in the container using a fine wire.

- The container and liquid are placed on a top-loading electronic balance and tared to provide a zero reading. An intact shoot (or a group of needles from a shoot) is submerged in the liquid with out touching the walls of the container and the weight recorded. To push the shoot into the water, a force equal to the buoyant force must be applied. The buoyant force is related to the mass of the volume of water displaced by the shoot. Thus, the volume of the intact shoot (V) in cubic centimeters is numerically equal to the weight increase indicated on the balance.
- The number of needles on the shoot (n) are counted and their averaged length (L) determined from a subsample of 10 to 20 needles spaced over the length of the shoot.
- For precise work, the needles can be removed from the shoot and the volume of the woody portion of the shoot measured by submerging it in the liquid-filled container on the balance. The needle volume is the difference between the total volume and the woody volume. The volume of the woody portion is generally 5 to 15% of the total volume.
- The shape of the cross-sectional area is determined from observations under a microscope. This shape is usually fixed for all needles of a given species and so has to be determined only once for a given species. This shape determines the coefficients in an equation that relates the above measurements to surface area (SA).

The total surface area (SA) of a group of conifer needles is given by:

$$SA = nLP \qquad (1)$$

where n is the number of needles, L is their mean length and P is the length of the perimeter of the needle cross section. The volume of the needles is:

$$V = nLA \qquad (2)$$

where A is the needle cross section. Solving for A gives:

$$A = V/(nL) \qquad (3)$$

We can define a dimensionless "shape factor" X:

$$X = P/\mathrm{sqrt}(A) \qquad (4)$$

thus

$$P = X\,\mathrm{sqrt}(A) \qquad (5)$$

Substituting this into 1) gives:

$$SA = nLX\,\mathrm{sqrt}(A) \qquad (6)$$

and from (3):

$$SA = nLX\,\mathrm{sqrt}[V/(nL)] = X\,\mathrm{sqrt}(VnL) \qquad (7)$$

This equation is valid for any arbitrary cross-sectional needle shape. Moreover, the factor will remain constant even if the needle tapers at its end, provided its shape remains the same.

Shape	Equation	Species
Square	SA = 4.00 sqrt(V n L)	Spruce
Ellipse (1:3 ratio of axes)	SA = 4.17 sqrt(V n L)	Douglas-Fir
Cylinder	SA = 3.54 sqrt(V n L)	
Hemi-Cylinder	SA = 4.10 sqrt(V n L)	Black Pine
Rectangle		
(width=length/10)	SA = 6.96 sqrt(V n L)	
(width=length/4)	SA = 5.00 sqrt(V n L)	
(width=length/3)	SA = 4.62 sqrt(V n L)	
(width=length/2)	SA = 4.24 sqrt(V n L)	

Note: sqrt means square root of the quantity in ( ).

Careful measurements of total surface area were done on several species by both the volume displacement method and optical planimeter method.

Species	Optical Planimeter (mm^2)	Volume Displacement (mm^2)
Blue Spruce	3276	3216
Douglas-Fir	9990	9705
Black Pine	4084	3900

With Douglas Fir, if detergent was not added to the water, the volume displacement method overestimated the surface area by 35% in one case and 39% in a second case because of entrapped air.

HSA is just one half the total surface area.

Proposal: Investigators using the volume displacement method should report total and half surface area (SA and HSA, respectively) along with the shape factor (X). A description of the method used to calculate the shape factor should also be provided.

4. Equipment

4.1 Sensor/Instrument Description

A Mitutoyo Digimatic Caliper (Series 500) was used to measure shoot and needle lengths and widths. The instrument has a 0.01-mm resolution and error of +/- 0.02 mm.

A Mettler (Model PL1200) top-loading scale was used in the volume displacement procedure to measure the weight of the shoot or twig submerged in water (BOREAS Experiment Plan; Appendix K.) The scale had a 0.01-g resolution and a 0- to 1200-g range.

An image analysis system was used to measure the cross-sectional area and perimeter length of needles, needed to determine the needle shape factor. The Cohu solid-state camera of the image analysis was attached to a camera mount of a microscope. Cross-sections of needles were placed on microscope slides and then placed under a Leica Wild M 3 Z microscope with a transmitting light stand, bright/dark field. The bright field of the light stand was used. The camera transmits a signal to the frame grabber board, which translates the intensity of each pixel to a gray scale from 0 (black) to 255 (white) levels. The JAVA software program (version 1.4, Jandel Corporation) was set up to count the number of pixels in a defined area of interest for a range of gray scales that represented the "black" needle cross-sections.

4.1.1 Collection Environment

All measurements were made in the controlled environment of a laboratory.

4.1.2 Source/Platform

None given.

4.1.3 Source/Platform Mission Objectives

None given.

4.1.4 Key Variables

Twig, needle and shoot element lengths, needle inclination from twig and needle surface area.

4.1.5 Principles of Operation

The Cohu solid-state camera transmits a signal to the frame grabber board, which translates the intensity of each pixel to a gray scale from 0 (black) to 255 (white) levels. The JAVA software program was set up to count the number of pixels in a defined area of interest for a range of gray scales that represent the "black" sample needle cross-sections.

4.1.6 Instrument Measurement Geometry

5.1 Sample Collection

Shoot Geometry Sampling:

For IFC-93 and IFC-1,-2,-3:

Branchlet samples (defined as a small tree limb consisting of shoots with growth from current year, previous year and two year ago) were cut from plants, covered with damp cheesecloth, sealed in a Ziploc-type storage bag, and stored and transported in a cool ice chest to the lab for processing. Generally, processing required 2 to 3 days to complete. If the samples were not measured on the same day as when they were cut from the plant, the samples were stored in a refrigerator.

For FFC-W and FFC-T:

Branchlet samples were collected from trees and placed in Ziploc-type storage bags containing damp paper towels. The samples were packed in ice and shipped to Lincoln for measurement.

Shape Factor Sampling: For IFC-1,2,3:

Samples for cross-sectional perimeter and area measurements were collected from low and high heights in the canopy (bottom third of the canopy and top third of the canopy, respectively.) Three trees were sampled each IFC, one branch from each tree. Each branch had at least three shoots with each shoot having the three most recent age classes present. Samples were stored in Ziploc-type bags and transported in cool ice chests to a nondefrosting freezer . Frozen samples were packed in coolers containing ice and shipped to Lincoln. There, the samples were stored in a nondefrosting freezer until cross-sectional measurements could be measured.

5.2 Sample Measurement

Shoot Geometry:

A soap/water mixture was created for the volume displacement procedure (BOREAS Experiment Plan, Appendix K). The mixture was 1 part liquid soap to 31 parts water. (Typically the soap/water mixture was made in bulk for several days use; 4 oz of soap and 124 oz of water.)

A shoot was selected from the cut branch that contained three ages of growth (current, past year's, and 2 years' prior growth; i.e., in 1994 the 1994, 1993, and 1992 growths were sampled). Cones were removed if present. Each year's growth was cut from the shoot and placed in a separate small Ziploc-type plastic bag until measured.

The angle between needle and shoot twig was measured for 5 randomly selected needles in each of 3 shoot cylinder planes along the shoot for a total of 15 angle measurements per shoot-age section. The angle was measured for five random needles in the horizontal plane (0 degrees) and in the top and bottom perpendicular planes (90 degrees). The protractor was moved along the shoot length and angles at five locations along the twig length were recorded. (Distinguishing the planes in jack pine was difficult due to shoot cylinder symmetry, so the protractor was arbitrarily placed for the "top" plane and the shoot was rotated 90 degrees for each of the other two planes.) If a needle was absent at the location selected for measurement, the angles were recorded as a null reading.

Bare twig length (lengths absent of needles), shoot-age section length, and the "wide" and "narrow" shoot widths were measured with the caliper. If the shoot-age section was longer than 150 mm, a meter stick was used to measure the lengths. Shoot length was measured as the length from the cut twig end to the tip of the needle.

The container was tared with the clip submerged in soap/water solution. The twig was clamped into the clip and completely submerged in the soap/water solution without contact with the side of the container. The sample and container were weighed (taring resulted in the sample weight).

The total number of needles and the number of dead needles were counted and recorded. Ten needles were randomly selected from which needle lengths were measured with the caliper. For IFC-93 and FFC-W, the widest and narrowest widths of the 10 needles were measured.

These procedures were repeated for each shoot-age class and remaining shoots.

For Shape Factor:

Needle shape factors were calculated for needles from nine shoot samples collected from three branches during each IFC. Several needles from a particular age class were sampled from each shoot. Needles were placed in a bag from which three needles were randomly sampled. The mid-needle cross-sections of three needles were placed on a microscope slide and the slide was placed on the light stand of the microscope. The image of the three cross-sections was captured and the area and perimeter of each cross-section were calculated by the image analysis system by counting the number of "blackish" pixels. The process was repeated for 32 additional needles randomly selected from the bag. A total of 35 cross-sections was measured. The areas and perimeters were used in the shape factor equation (See Section 9.1.1) and averaged to give a mean shape factor by species, age class and canopy height.

6. Observations

6.1 Data Notes

None.

6.2 Field Notes

Needle ages measured in 1993 were 1993 growth, 1992 growth and 1991 growth. Needle and twig ages measured in 1994, unless otherwise noted, are 1994 growth, 1993 growth and 1992 growth.

Sampled: August 4, 1993 (Measured: August 5, 1993)

Shoot geometry from jack pine shoots collected near SSA-FEN. 3 trees x 1 branch x 3 ages x 3 replications of shoots. Branches from tree 1 and 2 were sunlit and the branch from tree 3 was shaded.

Sampled: August 6, 1993 (Measured: August 7-10, 1993)

Coordinate measurements of leaf gas exchange; leaf optical properties and shoot geometry on black spruce near SSA-FEN. 3 trees x 4 branches x 3 ages x 3 replications of adaxial needle surface. Tree 1 was sunlit, tree 2 was lightly shaded and tree 3 was deeply shaded. All trees were about 3 to 3.5 m tall in a grove of trees about 10 m tall.

Sampled: August 16, 1993 (Measured: August 17-18, 1993)

Shoot geometry from jack pine shoots collected at SSA-YJP. 9 trees x 1 branch x 3 age x 1 replication of shoot.

Sampled: August 20, 1993 (Measured: August 21, 1993)

Coordinate measurements of leaf gas exchange, leaf optical properties and shoot geometry on black spruce shoots collected near SSA-FEN. 5 trees x 1 branch x 3 ages x 1 replication of shoot.

Sampled: February 3, 1994 (Measured: February 13, 1994)

Shoot geometry characterized from jack pine shoots collected at SSA-OJP and shipped to Lincoln, NE. 7 trees x 1 branch x 3 ages x 3 replications. Shoot age sections were from the 1993, 1992 and 1991 growth. Samples appeared somewhat flattened during shipment; needle orientation to twig and shoot diameter measurements may be invalid.

Sampled: February 7, 1994 (Measured: February 14, 1994)

Shoot geometry characterized from black spruce shoots collected at SSA-OBS and shipped to Lincoln, NE. 8 trees x 1 branch x 3 ages x 3 replications. Shoot age sections were from the 1993, 1992 and 1991 growth. Samples appeared somewhat flattened during shipping; needle orientation to twig and shoot diameter measurements may be invalid.

Sampled: April 14, 1994 (Measured: April 20-21, 1994)

Shoot geometry characterized from black spruce shoots collected at SSA-OBS and shipped to Lincoln, NE. 1 tree x 3 branch x 3 ages x 3 replications. Shoot age sections were from the 1993, 1992 and 1991 growth.

Sampled: April 15, 1994 (Measured: April 20-21, 1994)

Shoot geometry characterized on jack pine shoots collected at SSA-OJP and shipped to Lincoln, NE. 6 trees x 2 branch x 3 ages x 3 replications. Shoot ages were the 1993, 1992 and 1991 growth.

Sampled: May 26, 1994 (Measured: May 27-29, 1994)

Shoot geometry characterized from jack pine shoots collected at SSA-YJP. 9 trees x 1 branch x 3 ages x 3 replications. Trees located about 150m east of hut and 20-50m north of access road. Branches were from south side of trees and generally in full sunlight at 1230-1600 local time. Branches were collected from 2-3m from the soil surface. Shoot age sections were from the 1993, 1992 and 1991 growth.

Sampled: June 1, 1994 (Measured: June 2-4, 1994)

Sampled: August 2, 1994 (Measured: August 2, 1994)

Shoot geometry, coordinated with gas exchange measurements, was characterized from black spruce shoots collected at SSA-OBS. 3 ages x 4 replications. Samples were collected, from the canopy access tower, from high in the canopy.

Sampled: August 2, 1994 (Measured: August 2-4, 1994)

Shoot geometry was characterized from black spruce shoots collected at SSA-OBS. 3 trees x 3 branch x 3 ages x 3 replications. Samples collected from lower in the canopy (approximately 9m from the soil surface) via canopy access tower. Branches were mostly shaded.

Sampled: August 5, 1994 (Measured: August 5, 1994)

Shoot geometry, coordinated with gas exchange measurements, was characterized from jack pine shoots collected at SSA-YJP. 3 ages x 10 replications. Samples were collected from low in the canopy.

Sampled: August 9, 1994 (Measured: August 9, 1994)

Shoot geometry, coordinated with gas exchange measurements, was characterized from jack pine shoots collected at SSA-YJP. 3 ages x 3 replications. Samples were collected from low in the canopy.

Sampled: August 7, 1994 (Measured: August 7, 1994)

Shoot geometry, coordinated with gas exchange measurements, was characterized from white spruce shoots collected at SSA-MIX. 3 ages x 5 replications. Sampled were collected from middle of the canopy.

Sampled: September 4, 1994 (Measured: September 5-6, 1994)

Shoot geometry was characterized from black spruce shoots collected at SSA-OBS. 3 trees x 3 branch x 3 ages x 3 replications. Samples collected from lower in the canopy (approximately 9m from the soil surface) via canopy access tower. Tree 1 and 3 are sunlit samples and tree 2 is shaded. Measurements were not made on tree 3 branch 2.

Sampled: September 7, 1994 (Measured: September 8-11, 1994)

Shoot geometry was characterized from black spruce shoots collected at SSA-OBS. 3 trees x 3 branch x 3 ages x 3 replications. Samples collected from the top of the canopy via canopy access tower.

Sampled: September 8, 1994 (Measured: September 8, 1994)

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

Samples were collected from portions of the canopy at SSA-OBS, SSA-MIX, SSA-OA, SSA-OJP, SSA-YA, SSA-YJP, and SSA-FEN sites. The North American Datum of 1983 (NAD83) coordinates for the sites are:

	Latitude	Longitude
SSA-FEN-FLXTR	53.80206 N	104.61798 W
SSA-MIX-TETR	53.7254 N	105.20643 W
SSA-OA-FLXTR	53.62889 N	106.19779 W
SSA-OBS-FLXTR	53.98717 N	105.11779 W
SSA-OJP-FLXTR	53.91634 N	104.69203 W
SSA-YA-FLXTR	53.65601 N	105.32314 W
SSA-YJP-FLXTR	53.87581 N	104.64529 W

7.1.3 Spatial Resolution

These data represent point source measurements taken at the given locations. Shoot selection came from a branch approximately 30-70 cm long.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

Branches were collected from 1530 to 0023 Greenwich Mean Time (GMT). The shoot geometry measurement times ranged from 1340 to 0459 GMT. Measurements were not made continuously except in August 1993, May 1994, June 1994, July 1994, August 1994, and September 1994.

7.2.2 Temporal Coverage Map

The following list gives the date, site, and type of samples collected:

Date	Site	Species
04-AUG-1993	SSA-FEN	Jack Pine
04-AUG-1993	SSA-FEN	Aspen
06-AUG-1993	SSA-FEN	Black Spruce
16-AUG-1993	SSA-YJP	Jack Pine
19-AUG-1993	SSA-FEN	Aspen
19-AUG-1993	SSA-FEN	Buck Bean
19-AUG-1993	SSA-FEN	Bog Birch
20-AUG-1993	SSA-FEN	Black Spruce
26-May-1994	SSA-YJP	Jack Pine
29-May-1994	SSA-YA	Aspen
01-JUN-1994	SSA-OBS	Black Spruce
04-JUN-1994	SSA-YJP	Jack Pine
06-JUN-1994	SSA-OA	Aspen

07-JUN-1994	SSA-OBS	Black Spruce
07-JUN-1994	SSA-YA	Aspen
10-JUN-1994	SSA-YJP	Jack Pine
15-JUN-1994	SSA-YA	Aspen
21-JUL-1994	SSA-YJP	Jack Pine
25-JUL-1994	SSA-YJP	Jack Pine
30-JUL-1994	SSA-OBS	Black Spruce
02-AUG-1994	SSA-OBS	Black Spruce
04-SEP-1994	SSA-OBS	Black Spruce
04-SEP-1994	SSA-YA	Aspen
07-SEP-1994	SSA-YA	Aspen
08-SEP-1994	SSA-YJP	Jack Pine
11-SEP-1994	SSA-YJP	Jack Pine

7.2.3 Temporal Resolution

A typical shoot geometry sample (one shoot-age section from one shoot) characterization required approximately 10 to 15 minutes. (IFC93 4AUG-20AUG93; IFC1-94 26MAY-15JUN94; IFC2-94 21JUL-2AUG94; IFC3-94 4SEP-11SEP94) No consistent changes in shoot geometry were observed during the 1-3 day period following the collection of the samples from the trees.

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
DATE_OBS
TIME_OBS
DATE_COLLECTED
TIME_COLLECTED
SPECIES
CANOPY_LOCATION
SAMPLE_ID
TREE_ID
BRANCH_ID
SAMPLE_GROWTH_YEAR
REPLICATION
MEAN_ADAXIAL_NEEDLE_ANG
SDEV_ADAXIAL_NEEDLE_ANG
ADAXIAL_NEEDLE_ANG_NUM_OBS
MEAN_SIDE_NEEDLE_ANG
SDEV_SIDE_NEEDLE_ANG
SIDE_NEEDLE_ANG_NUM_OBS
MEAN_ABAXIAL_NEEDLE_ANG
SDEV_ABAXIAL_NEEDLE_ANG
ABAXIAL_NEEDLE_ANG_NUM_OBS
BARE_SHOOT_LENGTH
SHOOT_LENGTH
SHOOT_DIAMETER_WIDE
SHOOT_DIAMETER_NARROW
SHOOT_WEIGHT
```

TWIG_LENGTH
TWIG_WEIGHT
TWIG_DIAMETER
NUM_TOTAL_NEEDLES
NUM_DEAD_NEEDLES
MEAN_NEEDLE_LENGTH
SDEV_NEEDLE_LENGTH
MEAN_NEEDLE_WIDTH_WIDE
SDEV_NEEDLE_WIDTH_WIDE
MEAN_NEEDLE_WIDTH_NARROW
SDEV_NEEDLE_LENGTH_NARROW
SHAPE_FACTOR
MEAN_NEEDLE_SURFACE_AREA
SDEV_NEEDLE_SURFACE_AREA
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.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) when the data were collected.
DATE_COLLECTED	The date on which the samples were collected.
TIME_COLLECTED	The Greenwich Mean Time (GMT) when the samples were collected.
SPECIES	Botanical (Latin) name of the species (Genus species).
CANOPY_LOCATION	Location in the canopy from which the sample was taken.

The CANOPY_LOCATION parameter is a relative measure based upon the height of the sample location relative to the height of the canopy. Therefore, a sample collected from the top of a short tree in a tall canopy and a sample collected from the bottom of a short tree in a short canopy can both be designated as "low" for the HEIGHT parameter. Samples were collected from HIGH and LOW portions of the canopy at SSA-OBS and SSA-YJP. Samples were collected from LOW portions of the canopy at SSA-FEN. Canopy access at SSA-OBS was limited to the locations of the TE scaffolding towers.

SAMPLE_ID	The sample identifier used by data collectors (see documentation for a detailed description).
TREE_ID	Identifier of the mapped tree or plant stem.
BRANCH_ID	Identifier of the mapped branch (number).
SAMPLE_GROWTH_YEAR	The year in which the collected sample first grew.
REPLICATION	The number of same age samples taken from a particular shoot, branch or tree.
MEAN_ADAXIAL_NEEDLE_ANG	The mean angle of adaxial needle to the shoot axis.
SDEV_ADAXIAL_NEEDLE_ANG	The standard deviation of the angle of adaxial needles to shoot axis.
ADAXIAL_NEEDLE_ANG_NUM_OBS	The number of angles of adaxial needles to shoot axis measured.
MEAN_SIDE_NEEDLE_ANG	The mean angle of side needles to shoot axis.
SDEV_SIDE_NEEDLE_ANG	The standard deviation of the angle of side needles to shoot axis.
SIDE_NEEDLE_ANG_NUM_OBS	The number of angles of side needles to shoot axis measured.
MEAN_ABAXIAL_NEEDLE_ANG	The mean angle of abaxial needles to shoot axis.
SDEV_ABAXIAL_NEEDLE_ANG	The standard deviation of angle of the abaxial needles to shoot axis.
ABAXIAL_NEEDLE_ANG_NUM_OBS	The number of angles of abaxial needles to shoot axis measured.
BARE_SHOOT_LENGTH	The twig length not covered with needles.
SHOOT_LENGTH	The length of the shoot.
SHOOT_DIAMETER_WIDE	The diameter of the shoot at it largest point.
SHOOT_DIAMETER_NARROW	The diameter of the shoot at its smallest point.
SHOOT_WEIGHT	The weight of the shoot including both needles and twigs.
TWIG_LENGTH	The twig length.
TWIG_WEIGHT	The weight of twig portion of the sample.
TWIG_DIAMETER	The diameter of the twig measured.
NUM_TOTAL_NEEDLES	The total number of needles on the shoot.
NUM_DEAD_NEEDLES	The total number of dead needles on the shoot.
MEAN_NEEDLE_LENGTH	The mean needle length.
SDEV_NEEDLE_LENGTH	The standard deviation of the needle length.
MEAN_NEEDLE_WIDTH_WIDE	The mean of the largest needle widths.
SDEV_NEEDLE_WIDTH_WIDE	The standard deviation of the largest needle widths.
MEAN_NEEDLE_WIDTH_NARROW	The mean of the narrowest needle widths.
SDEV_NEEDLE_LENGTH_NARROW	The standard deviation of the narrowest needle widths.
SHAPE_FACTOR	The shape factor of the sample.
MEAN_NEEDLE_SURFACE_AREA	The mean of the surface area of the needles on the shoot.
SDEV_NEEDLE_SURFACE_AREA	The standard deviation of the surface area of the needles on shoot.
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]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
DATE_COLLECTED	[DD-MON-YY]
TIME_COLLECTED	[HHMM GMT]
SPECIES	[none]
CANOPY_LOCATION	[none]
SAMPLE_ID	[none]
TREE_ID	[none]
BRANCH_ID	[unitless]
SAMPLE_GROWTH_YEAR	[unitless]
REPLICATION	[unitless]
MEAN_ADAXIAL_NEEDLE_ANG	[degrees]
SDEV_ADAXIAL_NEEDLE_ANG	[degrees]
ADAXIAL_NEEDLE_ANG_NUM_OBS	[counts]
MEAN_SIDE_NEEDLE_ANG	[degrees]
SDEV_SIDE_NEEDLE_ANG	[degrees]
SIDE_NEEDLE_ANG_NUM_OBS	[counts]
MEAN_ABAXIAL_NEEDLE_ANG	[degrees]
SDEV_ABAXIAL_NEEDLE_ANG	[degrees]
ABAXIAL_NEEDLE_ANG_NUM_OBS	[counts]
BARE_SHOOT_LENGTH	[millimeters]
SHOOT_LENGTH	[millimeters]
SHOOT_DIAMETER_WIDE	[millimeters]
SHOOT_DIAMETER_NARROW	[millimeters]
SHOOT_WEIGHT	[grams]
TWIG_LENGTH	[millimeters]
TWIG_WEIGHT	[grams]
TWIG_DIAMETER	[millimeters]
NUM_TOTAL_NEEDLES	[counts]
NUM_DEAD_NEEDLES	[counts]
MEAN_NEEDLE_LENGTH	[millimeters]
SDEV_NEEDLE_LENGTH	[millimeters]
MEAN_NEEDLE_WIDTH_WIDE	[millimeters]
SDEV_NEEDLE_WIDTH_WIDE	[millimeters]
MEAN_NEEDLE_WIDTH_NARROW	[millimeters]
SDEV_NEEDLE_LENGTH_NARROW	[millimeters]
SHAPE_FACTOR	[unitless]
MEAN_NEEDLE_SURFACE_AREA	[millimeters^2]
SDEV_NEEDLE_SURFACE_AREA	[millimeters^2]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

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

Column Name	Data Source
SITE_NAME	[BORIS Designation]
SUB_SITE	[BORIS Designation]
DATE_OBS	[Human Observer]
TIME_OBS	[Human Observer]
DATE_COLLECTED	[Human Observer]
TIME_COLLECTED	[Human Observer]
SPECIES	[Human Observer]
CANOPY_LOCATION	[Human Observer]
SAMPLE_ID	[Human Observer]
TREE_ID	[Human Observer]
BRANCH_ID	[Human Observer]
SAMPLE_GROWTH_YEAR	[Human Observer]
REPLICATION	[Human Observer]
MEAN_ADAXIAL_NEEDLE_ANG	[Laboratory Equipment]
SDEV_ADAXIAL_NEEDLE_ANG	[Laboratory Equipment]
ADAXIAL_NEEDLE_ANG_NUM_OBS	[Laboratory Equipment]
MEAN_SIDE_NEEDLE_ANG	[Laboratory Equipment]
SDEV_SIDE_NEEDLE_ANG	[Laboratory Equipment]
SIDE_NEEDLE_ANG_NUM_OBS	[Laboratory Equipment]
MEAN_ABAXIAL_NEEDLE_ANG	[Laboratory Equipment]
SDEV_ABAXIAL_NEEDLE_ANG	[Laboratory Equipment]
ABAXIAL_NEEDLE_ANG_NUM_OBS	[Laboratory Equipment]
BARE_SHOOT_LENGTH	[Laboratory Equipment]
SHOOT_LENGTH	[Laboratory Equipment]
SHOOT_DIAMETER_WIDE	[Laboratory Equipment]
SHOOT_DIAMETER_NARROW	[Laboratory Equipment]
SHOOT_WEIGHT	[Laboratory Equipment]
TWIG_LENGTH	[Laboratory Equipment]
TWIG_WEIGHT	[Laboratory Equipment]
TWIG_DIAMETER	[Laboratory Equipment]
NUM_TOTAL_NEEDLES	[Laboratory Equipment]
NUM_DEAD_NEEDLES	[Laboratory Equipment]
MEAN_NEEDLE_LENGTH	[Laboratory Equipment]
SDEV_NEEDLE_LENGTH	[Laboratory Equipment]
MEAN_NEEDLE_WIDTH_WIDE	[Laboratory Equipment]
SDEV_NEEDLE_WIDTH_WIDE	[Laboratory Equipment]
MEAN_NEEDLE_WIDTH_NARROW	[Laboratory Equipment]
SDEV_NEEDLE_LENGTH_NARROW	[Laboratory Equipment]
SHAPE_FACTOR	[Laboratory Equipment]
MEAN_NEEDLE_SURFACE_AREA	[Laboratory Equipment]
SDEV_NEEDLE_SURFACE_AREA	[Laboratory Equipment]
CRTFCN_CODE	[BORIS Designation]
REVISION_DATE	[BORIS Designation]

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	SSA-9OA-FLXTR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE12-SGY01	9TE12-SGY01	None	None	None	None
DATE_OBS	04-AUG-93	15-SEP-94	None	None	None	None
TIME_OBS	0	2359	None	None	None	None
DATE_COLLECTED	04-AUG-93	14-SEP-94	None	None	None	None
TIME_COLLECTED	5	2350	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
CANOPY_LOCATION	Bottom	Top	None	None	None	None
SAMPLE_ID	940001	99999	None	None	None	None
TREE_ID	1	11	None	None	None	None
BRANCH_ID	1	7	None	None	None	None
SAMPLE_GROWTH_YEAR	1991	1994	None	None	None	None
REPLICATION	1	3	-999	None	None	None
MEAN_ADAXIAL_NEEDLE_ANG	0	90	-999	None	None	None
SDEV_ADAXIAL_NEEDLE_ANG	0	34.17	-999	None	None	None
ADAXIAL_NEEDLE_ANG_NUM_OBS	0	5	-999	None	None	None
MEAN_SIDE_NEEDLE_ANG	0	94	-999	None	None	None
SDEV_SIDE_NEEDLE_ANG	0	34.21	-999	None	None	None
SIDE_NEEDLE_ANG_NUM_OBS	0	5	-999	None	None	None
MEAN_ABAXIAL_NEEDLE_ANG	0	86.7	-999	None	None	None
SDEV_ABAXIAL_NEEDLE_ANG	0	31.14	-999	None	None	None
ABAXIAL_NEEDLE_ANG_NUM_OBS	0	5	-999	None	None	None
BARE_SHOOT_LENGTH	0	54.8	None	None	None	None
SHOOT_LENGTH	7.74	190	-999	None	None	None
SHOOT_DIAMETER_WIDE	3.17	63.15	-999	None	None	None
SHOOT_DIAMETER_NARROW	3.17	63.66	-999	None	None	None
SHOOT_WEIGHT	.01	10.66	-999	None	None	None
TWIG_LENGTH	5.63	165	-999	None	None	None
TWIG_WEIGHT	-.02	5.32	-999	None	None	None
TWIG_DIAMETER	.65	13.78	-999	None	None	None
NUM_TOTAL_NEEDLES	5	251	-999	None	None	None
NUM_DEAD_NEEDLES	0	7	-999	None	None	None
MEAN_NEEDLE_LENGTH	3.46	35.5	-999	None	None	None
SDEV_NEEDLE_LENGTH	.12	6.29	-999	None	None	None
MEAN_NEEDLE_WIDTH_WIDE	.81	1.46	-999	None	None	None
SDEV_NEEDLE_WIDTH_WIDE	.06	.19	-999	None	None	None
MEAN_NEEDLE_WIDTH_	.34	.89	-999	None	None	None

NARROW						
SDEV_NEEDLE_LENGTH_NARROW	.02	.16	-999	None	None	None
SHAPE_FACTOR	3.82	4.83	-999	None	None	None
MEAN_NEEDLE_SURFACE_AREA	3.79	1997.22	-999	None	None	None
SDEV_NEEDLE_SURFACE_AREA	28.88	542.41	-999	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	26-AUG-97	26-AUG-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 are wrapped versions of data records from a sample data file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,DATE_COLLECTED,TIME_COLLECTED,SPECIES,
CANOPY_LOCATION,SAMPLE_ID,TREE_ID,BRANCH_ID,SAMPLE_GROWTH_YEAR,REPLICATION,
MEAN_ADAXIAL_NEEDLE_ANG,SDEV_ADAXIAL_NEEDLE_ANG,ADAXIAL_NEEDLE_ANG_NUM_OBS,
MEAN_SIDE_NEEDLE_ANG,SDEV_SIDE_NEEDLE_ANG,SIDE_NEEDLE_ANG_NUM_OBS,
MEAN_ABAXIAL_NEEDLE_ANG,SDEV_ABAXIAL_NEEDLE_ANG,ABAXIAL_NEEDLE_ANG_NUM_OBS,
BARE_SHOOT_LENGTH,SHOOT_LENGTH,SHOOT_DIAMETER_WIDE,SHOOT_DIAMETER_NARROW,
SHOOT_WEIGHT,TWIG_LENGTH,TWIG_WEIGHT,TWIG_DIAMETER,NUM_TOTAL_NEEDLES,
NUM_DEAD_NEEDLES,MEAN_NEEDLE_LENGTH,SDEV_NEEDLE_LENGTH,MEAN_NEEDLE_WIDTH_WIDE,
SDEV_NEEDLE_WIDTH_WIDE,MEAN_NEEDLE_WIDTH_NARROW,SDEV_NEEDLE_LENGTH_NARROW,
SHAPE_FACTOR,MEAN_NEEDLE_SURFACE_AREA,SDEV_NEEDLE_SURFACE_AREA,CRTFCN_CODE,
REVISION_DATE
'SSA-FEN-FLXTR','9TE12-SGY01',04-AUG-93,1830,04-AUG-93,1830,
'Populus tremuloides','Bottom','99999',1,1,'1994',-999,-999.0,-999.0,-999,-999.0,
-999.0,-999,-999.0,-999.0,-999,0.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,
-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,478.22,
123.03,'CPI',26-AUG-97
'SSA-FEN-FLXTR','9TE12-SGY01',04-AUG-93,1830,04-AUG-93,1830,
'Populus tremuloides','Bottom','99999',2,1,'1993',-999,-999.0,-999.0,-999,-999.0,
-999.0,-999,-999.0,-999.0,-999,0.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,
-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,-999.0,500.67,
106.06,'CPI',26-AUG-97
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by the BOREAS Information System (BORIS) is that from a single age section of a shoot.

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

$$SA = X \, \mathrm{sqrt}(V \, n \, L) \quad [1]$$

where: SA = Total surface area of a group of conifer needles (mm^2)
X = Dimensionless Shape Factor
V = Volume of the needles (mm^3)
n = number of needles (unitless)
L = mean length of the needles (mm)

9.1.1 Derivation Techniques/Algorithms

The total surface area (SA), in mm^2, of a group of conifer needles is given by:

$$SA = n \, L \, P \quad [2]$$

where P = perimeter length of the needle cross-section (mm).

The volume (V), in mm^3, of the needles is:

$$V = n \, L \, A \quad [3]$$

where A is the needle cross-section area (mm^2).

Solving for A gives:

$$A = V / (n \, L) \quad [4]$$

A dimensionless "Shape factor" (X) is defined as:

$$X = P/\mathrm{sqrt}(A) \quad [5a]$$

thus

$$P = X \, \mathrm{sqrt}(A) \quad [5b]$$

Substituting Eq. 5b into Eq. 2 gives

$$SA = n \, L \, X \, \mathrm{sqrt}(A) \quad [6]$$

and from Eq. 4 then:

$$SA = n \, L \, X \, \mathrm{sqrt}[V/(nL)] = X \, \mathrm{sqrt}(V \, n \, L) \quad [7]$$

This equation is valid for any arbitrary cross-sectional needle shape. Moreover, the factor will remain constant even if the needle tapers at its end, provided its shape remains the same.

9.2 Data Processing Sequence

9.2.1 Processing Steps

The weight of the entire intact shoot-age section is calculated from the volume displacement procedure (BOREAS Experiment Plan; Appendix K) and converted to volume based on 1 g equals 1 cm^3. The twig volume is computed in the same manner. The total needle volume is calculated based on the difference between the shoot-age section volume and twig volume. The cross-sectional area and perimeter of the three cross-sections were measured at one time; the average area and perimeter are used in Equation 5a to calculate the a single shape factor. A total of 35 shape factor calculations was averaged to give an average shape factor for each species, canopy height, age class, and IFC. The average shape factor, average needle length, number of needles, and the corrected volume of shoot-age section are used in Equation 7 to calculate the total needle surface area.

9.2.2 Processing Changes

Not applicable.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

Not applicable.

9.3.2 Calculated Variables

None.

10. Errors

10.1 Sources of Error

Errors can occur as a result of the technique used for the volume displacement procedure. The technique involves submerging the shoot-age section or twig with an alligator clip suspended by a wire into a container of soap and water mixture. The clip must be removed from the water to clamp and unclamp the sample. Water is inadvertently removed from the container with each touch of the alligator clip. Water removal will cause an underestimation of the true volume displacement of the individual sample (approximately 0.01 g of water was removed each time the clip was touched).

The design of our submerging technique was flawed prior to 03-Jun-1994. The wire attached to the alligator clip that held the shoot submerged in the water was attached to the water container. This was corrected so the alligator clip and wire were held and lowered into the water container without touching the container. Comparison of these two methods did not show any detectable difference with respect to the sensitivity of balance (0.01 g) used to make the measurements. A 0.01-g error translates into <1 to 5% relative error in calculated surface area based on the magnitude of the volume of the needles sample. Minor errors could result in the measurements of the angle between the needle and twig as a result of sample storage. Samples were cut from the tree, wrapped in damp cheesecloth, and placed in a sealed plastic bag, which was placed in a cooler. Placing the sample in the bag and many samples in the ice chest could cause a slight "deformation" of some of the samples, but care was taken to not place too many samples in each ice chest. Flagging tape was used to denote the shoots to be used in measurement of shoot geometry, water potential, and needle optical properties. This practice could have changed the actual angle of the needle to shoot axis if the tape was placed on the needles to be measured on the shoot. The protractor was place perpendicular to the plane to be measured (i.e., parallel to the plane of the needles to be measured.) Curvature of the twigs and needles made measurements of angles, as well as length, difficult. The angle was estimated to the nearest 5 degrees. No attempt was made to straighten out the curved needles when the length was measured. The caliper could potentially squeeze the needle, thus underestimating the needle length and width measurements. Because of the above-mentioned problems, measurements with the calipers were considered to be accurate only to 0.1 mm, not the 0.01-mm resolution of the caliper. Using the image analysis system to measure the area and perimeter of the cross-sections have produced a 5-percent relative error in measurement due to user-defined thresholds of the pixel-counting methods. Natural variation in cross-section area and perimeter measurements in mid-needle sections and over the length of the needle was less than 5 percent, relative, in each case. These errors translate to less than a 5-percent relative error in shape factors. A sensitivity analysis of shape factor to other needle attributes showed that a 5-percent relative error in shape factor resulted in less than 5-percent relative error in needle surface area. (The sensitivity analysis test was conducted on samples from IFC-2 for jack pine and black spruce samples.)

10.2 Quality Assessment

Angle measurements of needles to shoot axis were approximately within 5 degrees of true orientation. Calipers for measuring shoot length and width and needle length and width measured to the nearest 0.01 mm, but due to the conditions described in Section 10.1, measurements were estimated to be accurate to the nearest 0.1 mm. The top-loading scale, used in determining shoot volume, had an accuracy of 0.01 g, but due to the water loss when attaching the sample to the clip, the weights of sample and water may be underestimated by 0.01 g for the individual measurements of the shoot and twig.

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 Data

None given.

11.2 Known Problems with the Data

Sample volumes may be underestimated by 0.01 cm^3 due to water loss as sample is attached to the clip. Missing data are coded with -999.

11.3 Usage Guidance

These data are acceptable for use with consideration of the above-mentioned known problems with the data and estimated errors.

11.4 Other Relevant Information

Acknowledgment of other research staff who assisted in measurements:
Liquang Chen, UNL graduate student Brian P. Lang, UNL undergraduate student Cynthia J. Hays, UNL Research Technologist Dr. Blaine L. Blad, Agricultural Department Head at UNL Dr. Muhammad Chaudhury, UNL Research Technologist

12. Application of the Data Set

These data should be useful to users interested canopy reflectance studies and modeling.

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 TE-12 SSA shoot geometry 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
Mitutoyo Digimatic Caliper (Series 500) Manual, Tokyo, Japan Mettler (Series PL1200) Balance, Princeton, New Jersey

17.2 Journal Articles and Study Reports
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.

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.

17.3 Archive/DBMS Usage Documentation
None.

18. Glossary of Terms

None.

19. List of Acronyms

```
ASCII    - American Standard Code for Information Interchange
BOREAS   - BOReas Ecosystem-Atmosphere Study
BORIS    - BOREAS Information System
CD-ROM   - Compact Disk-Read-Only Memory
DAAC     - Distributed Active Archive Center
EOS      - Earth Observing System
EOSDIS   - EOS Data and Information System
FC       - Field Campaign
FEN      - Nipawin Fen site
FFC      - Focused Field Campaign
FFC-T    - Focused Field Campaign - Thaw
FFC-W    - Focused Field Campaign - Winter
GIS      - Geographic Information System
GMT      - Greenwich Mean Time
GSFC     - Goddard Space Flight Center
HASL     - Half surface area of leaf
HTML     - HyperText Markup Language
IFC      - Intensive Field Campaign
MIX      - Mixed Site
NAD83    - North American Datum of 1983
NASA     - National Aeronautics and Space Administration
NSA      - Northern Study Area
OA       - Old Aspen
OBS      - Old Black Spruce
OJP      - Old Jack Pine
ORNL     - Oak Ridge National Laboratory
PANP     - Prince Albert National Park
RSS      - Remote Sensing Science
SA       - Surface area of the leaf
SSA      - Southern Study Area
TE       - Terrestrial Ecology
UNL      - University of Nebraska - Lincoln
URL      - Uniform Resource Locator
YA       - Young Aspen
YJP      - Nipawin Young-Dry Jack Pine
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20. Document Information

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20.2 Document Review Date

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Science Review: 15-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:

E.A. Walter-Shea, M.A. Mesarch, L. Chen, L. Yang from University of Nebraska at Lincoln.

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

Walter-Shea, E.A., "Radiation and Gas Exchange of Canopy Elements in a Boreal Forest." 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

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The BOREAS TE-12 team collected shoot geometry data in 1993 and 1994 from aspen, jack pine, and black spruce trees. Collections were made at the SSA FEN, YJP, OJP, OA, YA, MIX, and OBS sites. A caliper was used to measure shoot and needle lengths and widths. A volume displacement procedure was used to measure the weight of the shoot or twig submerged in water. The data are provided in tabular ASCII files.

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