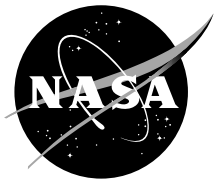
NASA/TM—2000–209891, Vol. 153



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

Forrest G. Hall and Shelaine Curd, Editors

Volume 153

BOREAS TE-9 In Situ Diurnal Gas Exchange of NSA Boreal Forest Stands

H. Margolis, M. Coyea, and Q. Dang

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

October 2000

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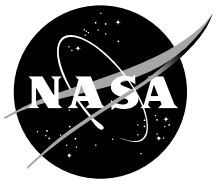

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BOREAS TE-9 In Situ Diurnal Gas Exchange of NSA Boreal Forest Stands

Hank Margolis, Marie Coyea), Qinglai Dang

Summary

The BOREAS TE-9 team collected several data sets related to chemical and photosynthetic properties of leaves in boreal forest tree species. The purpose of the BOREAS TE-09 study was threefold: 1) to provide in situ gas exchange data that will be used to validate models of photosynthetic responses to light, temperature, and carbon dioxide (CO_2); 2) to compare the photosynthetic responses of different tree crown levels (upper and lower); and 3) to characterize the diurnal water potential curves for these sites to get an indication of the extent to which soil moisture supply to leaves might be limiting photosynthesis. The gas exchange data of the BOREAS NSA were collected to characterize diurnal gas exchange and water potential of two canopy levels of five boreal canopy cover types: young jack pine, old jack pine, old aspen, lowland old black spruce, and upland black spruce. These data were collected between 27-May-1994 and 17-Sep-1994. The data are provided in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-09 In Situ Diurnal Gas Exchange of NSA Boreal Forest Stands

1.2 Data Set Introduction

The gas exchange data of the BOReal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA) were collected to characterize diurnal gas exchange and water potential of two canopy levels of five boreal canopy cover types: young and old jack pine (Pinus banksiana Lamb.), old aspen (Populus tremuloides Michx.), and lowland and upland black spruce (Picea mariana (Mill) B.S.P.). The BOREAS Terrestrial Ecology (TE)-09 team collected these data between 27-May-1994 and 17-Sep-1994.

1.3 Objective/Purpose

The purpose of this study was threefold: 1) to provide in situ gas exchange data that will be used to validate models of photosynthetic responses to light, temperature, and carbon dioxide (CO_2); 2) to compare the photosynthetic responses of different tree crown levels (upper and lower); and 3) to characterize the diurnal water potential curves for these sites to get an indication of the extent to which soil moisture supply to leaves might be limiting photosynthesis.

1.4 Summary of Parameters

Net photosynthesis, stomatal conductance to water vapor, stomatal conductance to CO_2 , transpiration, water use efficiency, mesophyll conductance, photosynthetically active radiation (PAR), air and leaf temperature, CO_2 concentration, relative humidity, vapor pressure, vapor pressure deficit (VPD), barometric pressure, and water potential.

1.5 Discussion

The gas exchange data of the BOREAS NSA were collected to characterize diurnal gas exchange and water potential of two canopy levels of five boreal canopy cover types: young and old jack pine, old aspen, lowland old and upland black spruce. These data were collected between 27-May-1994 and 17-Sept-1994.

1.6 Related Data Sets

BOREAS TE-09 PAR and Leaf Nitrogen Data for BOREAS NSA Species
BOREAS TE-09 NSA Photosynthetic Capacity and Foliage Nitrogen Data
BOREAS TE-09 NSA Leaf Chlorophyll Density
BOREAS TE-09 NSA Photosynthetic Response Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Hank Margolis, Ph.D.
Universite Laval
Faculte de foresterie et geomatique
Pavillon Abitibi-Price

2.2 Title of Investigation

Relationship Between Measures of Absorbed and Reflected Radiation and the Photosynthetic Capacity of Boreal Forest Canopies and Understories

2.3 Contact Information

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3. Theory of Measurements

The gas exchange measurements were made with a closed portable photosynthetic system (LI-COR LI-6200). As described in the LI-6200 Primer Manual, it contains three major components: a leaf chamber, within which temperature and humidity measurements are made; the LI-6250, an infrared gas analyzer (IRGA), which measures CO_2 concentration and flow rate; and a control console. Air temperature, leaf temperature, and relative humidity are measured in the leaf chamber. The pump in the LI-6250 circulates air from the chamber to the analyzer, where CO_2 concentration is measured, and returns it to the chamber. The air flow through the LI-6250 can be diverted through soda lime to remove CO_2 for purposes of calibration.

The flow valve is used to force some fraction of the flow through a tube of desiccant, which dries the air. This proportional control feature is used to help maintain a steady humidity in the chamber during a measurement. The flow rate of the air going through the desiccant is measured by a flow meter.

The IRGA can be used for absolute or differential measurement of CO_2. As used with the LI-6200, however, it is configured for absolute measurements.

The methodology for measuring leaf area is described in Appendix K of the Experiment Plan, Version 3.0. Aspen foliage is expressed as hemisurface area leaf area, while conifer foliage is expressed as total surface area leaf area.

The optical image analysis system (Decagon AgVision System) is an image analysis system that works by first looking at an object through a video camera, then processing the image into discrete numerical information with a digitizer and microcomputer, and finally displaying the image or other information on a monitor for examination.

For the measurement of Y (please note that in the text below, "Y" is the Greek symbol psi that is generally used for water potential) response at high (less negative) Y, the cut end of the stem was connected to a water reservoir. For lower (more negative) Y, the branches were taken out of water and the cut surface of the stem was dried and sealed with silicone grease. The branches were then exposed to light and permitted to transpire freely in an open space where the air was stirred continuously using an electric fan. Sealing the cut surface of the branch allowed the branch to maintain a negative pressure inside the xylem while transpiration continued. A pair of branches was chosen randomly at various times for gas exchange measurement at 20 °C. The transpiration rate of the branch being measured was kept very low by maintaining a high humidity in the cuvette (VPD < 0.8 kPa). It took from 3 to 6 hours for branches to reach their minimum Y. Immediately after the gas exchange measurement, the stem of the branch was cut and the water potential was measured with a pressure chamber (Model 610, PMS Instrument, Inc., Corvallis, OR, USA). By controlling the time interval between measurements, a range of water potentials was achieved for black spruce and jack pine during both Intensive Field Campaign (IFC)-2 and IFC-3.

4. Equipment

4.1 Sensor/Instrument Description

LI-6200 portable gas exchange system (LI-COR), pressure chamber (PMS Instrument Co.), drying oven, optical image analysis system (Decagon Devices, Inc., Pullman, WA), top loading weighing balance, IBM or compatible computer.

4.1.1 Collection Environment

Gas exchange and water potential measurements were measured by persons on the upper and lower levels of canopy access towers. In the Young Jack Pine (YJP) stand, only 3-m ladders were necessary. Leaf area measurements were determined in the lab.

4.1.2 Source/Platform

Gas exchange and water potential measurements were measured by persons on the upper and lower levels of canopy access towers. In the YJP stand, only 3-m ladders were necessary. Leaf area measurements were determined in the lab.

4.1.3 Source/Platform Mission Objectives

The purpose of this study was threefold as outlined in the BOREAS Experiment Plan, Version 3.0, Appendix N, page N-34):

- To describe the diurnal patterns of stomatal conductance, photosynthesis, and leaf water potential of the principal forest types present at the BOREAS NSA and to determine the precise nature of the environmental controls on these variables.
- To understand how these physiological properties and their environmental controls are influenced by canopy position and period of the growing season.
- To use these data for partial model validation with a model parameterized from laboratory data to be compared eventually to flux tower data from the NSA.

4.1.4 Key Variables

Diurnal water potential and net photosynthesis.

4.1.5 Principles of Operation

Gas exchange measurements were taken with a LI-COR 6200 system. Generally, a branch (bearing leaves) section was placed into the cuvette for three 20-second measurements. The same branch section was measured periodically throughout the day (approximately once every hour). At the end of the day, these branch sections were harvested and stored in a freezer until leaf area was determined.

The volume displacement method (Appendix K of BOREAS Experiment Plan, Version 3.0) was used to measure leaf area of conifer needles. The optical image analysis system was used to measure needle lengths and aspen projected leaf areas.

Water potential measurements were taken simultaneously with a pressure chamber on randomly selected branch sections at the same canopy level as the photosynthetic measurements. These samples were not kept for any further analyses.

4.1.6 Sensor/Instrument Measurement Geometry

Measurements were taken at two canopy levels: top and bottom. The heights of these samples varied according to the location of the canopy access tower; however, they reflected the average canopy as described in Section 2.2.3.1 of the BOREAS Experiment Plan, Version 3.0. Because the canopy access towers moved between IFC periods, the canopy levels were not always exactly the same. For example, the measurements at the old aspen stand ranged from approximately 13-15 m for the upper canopy and 9-11 m for the lower canopy.

4.1.7 Manufacturer of Sensor/Instrument

LI-6200 portable gas exchange system
LI-COR
P.O. Box 4425,
4421 Superior St.
Lincoln, NE 68504
(800) 447-3576

Pressure Chamber, Model 610
PMS Instrument Co.
480 SW Airport Avenue
Corvallis, OR 97333
(503) 752-7926

Leaf area measurement system/optical image analysis system (AgVision, Monochrome system, root and leaf analysis)
Decagon Devices, Inc.
P.O. Box 835
Pullman, WA 99163
(800) 755-2751

IBM DX2/486 Computer
IBM, Inc.

4.2 Calibration

The LI-COR LI-6200 was sent to the manufacturer for calibration and general maintenance in February 1994 before field work began (big mistake, see Section 10.1). The LI-6200 was examined daily for page parameters, operating parameters, and clock setting; quantum sensor calculation constant; CO_2 analyzer calculation list; flow meter calculation list; relative humidity sensor calculation list; and analyzer reference.

Each sensor was checked daily and periodically to make sure it was responding as expected: quantum sensor; air and leaf temperature match; IRGA temperature; flow meter; CO_2 concentration; and relative humidity. The zero and span for the CO_2 analyzer were set daily. The flow meter was zeroed frequently.

The LI-6250 CO_2 gas analyzer was calibrated daily according to instrument specifications (CO_2 levels), while system tests (e.g., leak tests, boundary layer resistance, soda lime test, and desiccant (k) test) were conducted periodically throughout each sampling day. Approximately every half hour, the desiccant tube was shaken.

Daily, the chambers were cleaned and the batteries recharged. The foam pads in the chamber were changed after frequent usage and any noticeable damage.

The optical image analysis system was calibrated according to instrument specifications each time the system was opened or after it was left for a period of time. A fine ruler and flat disks of known area were used in the calibration.

The pressure chamber was inspected at the manufacturer's facility prior to field use. Safety checks were conducted from time to time throughout the sampling period.

4.2.1 Specifications

The weighing balance was accurate to within 0.0001 g. The leaf area system was accurate to within 1%. The gas exchange system was accurate to 1 ppm CO_2.

The shape factor used for black spruce was 4, in accordance with the BOREAS Experiment Plan, Appendix K, Version 3.0. Based on observations of two cross-sections of two needles per fascicle for five fascicles for six jack pine trees from Thompson, Manitoba, an average shape factor of 4.59 (+/- 0.07) was calculated.

4.2.1.1 Tolerance

The acceptable range for net photosynthetic measurements is not available at this revision.

4.2.2 Frequency of Calibration

The LI-COR LI-6200 was sent to the manufacturer for calibration and general maintenance in February 1994 before field work began (big mistake, see Section 10.1). The LI-6200 was examined daily for page parameters, operating parameters, and clock setting; quantum sensor calculation constant; CO_2 analyzer calculation list; flow meter calculation list; relative humidity sensor calculation list; and analyzer reference.

Each sensor was checked daily and periodically to make sure it was responding as expected: quantum sensor; air and leaf temperature match; IRGA temperature; flow meter; CO_2 concentration; and relative humidity. The zero and SPAN for the CO_2 analyzer were set daily. The flow meter was zeroed frequently.

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The pressure chamber was inspected at the manufacturer's facility prior to field use. Safety checks were conducted from time to time throughout the sampling period.

4.2.3 Other Calibration Information

During IFC-1, the LI-6200 system had problems caused by the manufacturer's calibration. For the days when this equipment problem occurred, the data could not be treated and thus will not be stored in the BOREAS Information System (BORIS). Furthermore, the radio handsets that were distributed to the field groups caused some failure in instrument functioning. Either the instrument completely shut down or the periodic calibrations detected the influence of the handsets. These data have been cleaned and removed from the data set available in BORIS.

5. Data Acquisition Methods

Gas exchange and water potential measurements took place in five stands during daylight hours. Prior to each measurement period, instruments were calibrated and placed onsite (for example, on canopy access towers) for measurement. Five branches from randomly selected trees at a given canopy level were identified and prepared by exposing only a desirable amount of foliage for gas exchange measurement. Net photosynthesis was measured on these branches with a LI-COR LI-6200 system. Ambient conditions were also obtained once or twice within the measurement period of the five samples.

Once a canopy level was completed, another was started, which normally was within a half hour. Several cycles of measurement (upper and lower canopy) could be completed during a day. During the first IFC only, samples were harvested after four to five cycles and another five were selected. This was done to ensure that the measurement technique did not affect the sample by inducing high respiration rates from damaged tissue, for example.

A branch (bearing leaves) section was placed into the cuvette for three 20-second measurements. This period varied in the first IFC, when investigators were trying to find an ideal measurement period for the species being measured. Three 30-second measurements, or three 60-second intervals, were found to be too long. Two 20- or 30-second intervals did not always provide enough data to determine whether data errors existed. The same branch section was measured periodically throughout the day

(approximately once every hour). At the end of the day, these branch sections were harvested and stored in a freezer until leaf area was determined.

The projected leaf areas of fresh aspen leaves that were harvested following the gas exchange measurements were measured using an optical image analysis system. Projected leaf area is essentially equivalent to half the area of the surface of the leaf (HASL) for flat leaves. Leaf area of each fresh conifer sample was measured using the volume displacement method as described in Appendix K of the BOREAS Experiment Plan (Version 3.0). Because precision work was required, the needles were removed from the shoot, and the volume of the woody portion of the shoot was measured by submerging it in the liquid-filled container on the balance. The needle volume was the difference between the total volume and the woody volume. The length of all needles in the sample and the shoot silhouette were measured using the optical image analysis system. The shape factors for black spruce and jack pine respectively were 4.00 and 4.59.

The silhouette area of conifer samples was measured by age class. (In the first IFC, however, there was only one age class.) A conifer shoot was first snipped/clipped into two age classes. These two age classes included (1) 1994 needles and (2) anything produced in 1993 and earlier. Each shoot section was then randomly thrown under the camera lens and a silhouette measurement was taken. These samples were then processed under the normal procedures for measuring leaf area (volume displacement).

6. Observations

6.1 Data Notes

None given.

6.2 Field Notes

During IFC-1 only, canopy gas exchange measurements were made only in the upper canopy with the exception of 27-May in the YJP stand. On this particular day, gas exchange measurements were made on three branches per tree, for five trees for three canopy levels. (The data set will reflect this difference in numbering.) Water potential measurements were made on 01-Jun and for subsequent days. Identification errors have been corrected in the data set and are too detailed to list here.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

The data were collected from five principal sites in the NSA of Manitoba. The NSA is approximately 100 km wide by 80 km and is located 735 km north of Winnipeg. The North American Datum of 1983 (NAD83) coordinates for the sites are:

- NSA-YJP flux tower site: Lat/Long: 55.89575°N, 98.28706°W; UTM Zone 14, N:6194706.9 E:544583.9
- NSA-OJP flux tower site: Lat/Long: 55.842°N, 98.62396°W; UTM Zone 14, N:6198176.3 E:523496.2
- NSA-OA canopy access tower site (auxiliary site number T2Q6A, BOREAS Experiment Plan, Version 3.0): Lat/Long: 55.88691°N, 98.67479°W; UTM Zone 14, N: 6193540.7 E: 520342
- NSA-OBS flux tower site: Lat/Long: 55.88007°N, 98.48139°W; UTM Zone 14, N:6192853.4 E:532444.5
- NSA-UBS canopy access tower site (auxiliary site number T6R5S, BOREAS Experiment Plan, Version 3.0): Lat/Long: 55.90802°N, 98.51865°W; UTM Zone 14, N: 6195947 E:530092

Measurements were taken on the canopy access towers or, in the case of the YJP site, within 1 km of the flux tower.

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
The data represent point source measurements made at the given locations.

7.1.4 Projection
Not applicable.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
Data acquisition took place during the three IFCs, which lasted from 24-May-1994 to 19-Sept-1994.

7.2.2 Temporal Coverage Map
- During the first IFC, because of problems with the LI-6200, usable data were obtained only for four sampling days: YJP, 17-May; OJP, 30-May and 01-Jun; and OBS, 05-Jun.
- During the second IFC, usable data were obtained for seven sampling days: YJP, 01-Aug; OJP, 27-Jul and 09-Aug; OA, 29-Jul and 08-Aug; OBS, 05-Aug; and UBS, 03-Aug.
- During the third IFC, usable data were obtained for eight sampling days: YJP, 01-Sep and 10-Sep; OJP, 31-Aug and 09-Sep; OA, 03-Sep and 16-Sep; OBS, 07-Sep; and UBS, 17-Sep.

7.2.3 Temporal Resolution
None given.

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
SPECIES
SAMPLE_BRANCH_NUM
CANOPY_LOCATION
TREE_ID
WATER_POTENTIAL
PHOTOSYNTHETIC_RATE
STOMATAL_MOLAR_CONDUCT_H2O
STOMATAL_MOLAR_CONDUCT_CO2
INTERCELL_CO2_CONC
TRANSPIRATION_RATE
WATER_USE_EFF
MESOPHYL_MOLAR_CONDUCT_CO2
INTERCELL_AMB_CO2_RATIO
DOWN_PPFD
AIR_TEMP_CHAMBER
```

LEAF_TEMP
CO2_CONC
AIR_FLOW_RATE
REL_HUM_CHAMBER
VAPOR_PRESS_CHAMBER
LST_SQR_SLOPE_VAPOR_PRESS
LST_SQR_SLOPE_CO2_CONC
VAPOR_PRESS_DEFICIT
ATMOSPHERIC_PRESS
LEAF_AREA
LEAF_BOUND_LAYER_MOLAR_CONDUCT
STOMATAL_CONDUCT_RATIO
INST_WATER_ABSORB_FACTOR
NEEDLE_AREA_1994
NEEDLE_AREA_1993
NEEDLE_SILHOU_AREA_1994
NEEDLE_SILHOU_AREA_1993
TOTAL_NEEDLE_SILHOU_AREA
LICOR_VOLUME
IRGA_HOSE_VOLUME
MAX_FLOW_RATE
CRTFCN_CODE
REVISION_DATE

7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files onthe 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.
SPECIES	Botanical (Latin) name of the species (Genus species).
SAMPLE_BRANCH_NUM	The branch number sampled. When sample value is "ambient" this represents no branch and is used for a check on the ambient conditions where measurements are being taken.
CANOPY_LOCATION	Location in the canopy from which the sample was taken.
TREE_ID	Identifier of the mapped tree or plant stem.

WATER_POTENTIAL	Water Potential
PHOTOSYNTHETIC_RATE	Measured Net Photosynthesis
STOMATAL_MOLAR_CONDUCT_H2O	Stomatal conductance of water vapor.
STOMATAL_MOLAR_CONDUCT_CO2	Stomatal conductance of CO2
INTERCELL_CO2_CONC	Intercellular CO2 concentration
TRANSPIRATION_RATE	Transpiration rate
WATER_USE_EFF	Water use efficiency
MESOPHYL_MOLAR_CONDUCT_CO2	Mesophyll CO2 conductance.
INTERCELL_AMB_CO2_RATIO	The ratio of intercellular CO2 concentration and ambient CO2 concentration.
DOWN_PPFD	The downward photosynthetic photon flux density.
AIR_TEMP_CHAMBER	The temperature of the air in the chamber.
LEAF_TEMP	The leaf or shoot temperature
CO2_CONC	CO2 concentration.
AIR_FLOW_RATE	Air flow rate through the desiccant
REL_HUM_CHAMBER	The relative humidity of the air in the chamber.
VAPOR_PRESS_CHAMBER	Vapor pressure of the air in the chamber.
LST_SQR_SLOPE_VAPOR_PRESS	The calculated least squares slope of vapor pressure in relation to time for the observation.
LST_SQR_SLOPE_CO2_CONC	The calculated least squares slope of CO2 as a function of time for the observation.
VAPOR_PRESS_DEFICIT	Vapor Pressure Deficit
ATMOSPHERIC_PRESS	The atmospheric pressure.
LEAF_AREA	The area of the leaf (or needles) enclosed in the chamber, this value is always half the total surface area of the sample.
LEAF_BOUND_LAYER_MOLAR_CONDUCT	The one-sided leaf boundary layer conductance. This is a function of leaf size and type of chamber.
STOMATAL_CONDUCT_RATIO	Ratio of stomatal conductance of one side of the leaf to the other.
INST_WATER_ABSORB_FACTOR	Instrument water absorption factor
NEEDLE_AREA_1994	Leaf area for foliage that developed in 1994 based on a total leaf area basis. (This does not apply to aspen).
NEEDLE_AREA_1993	Leaf area for foliage that developed during and before 1993 based on a total leaf area basis. This does not apply to aspen foliage.
NEEDLE_SILHOU_AREA_1994	The area of the silhouette of the shoots that developed in 1994.
NEEDLE_SILHOU_AREA_1993	The area of the silhouette of the shoots that developed during and before 1993.
TOTAL_NEEDLE_SILHOU_AREA	The total area of the silhouette of all the shoots.
LICOR_VOLUME	LI-COR system volume, including LI-6250 gas analyzer, the LI-6200 console, chamber and tubing.
IRGA_HOSE_VOLUME	The volume of the IRGA and hose.
MAX_FLOW_RATE	Maximum flow rate of air.
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 onthe CD-ROM are:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
SPECIES	[none]
SAMPLE_BRANCH_NUM	[unitless]
CANOPY_LOCATION	[none]
TREE_ID	[none]
WATER_POTENTIAL	[megaPascals]
PHOTOSYNTHETIC_RATE	[micromoles CO2][meter^-2][second^-1]
STOMATAL_MOLAR_CONDUCT_H2O	[millimoles H2O][meter^-2][second^-1]
STOMATAL_MOLAR_CONDUCT_CO2	[millimoles CO2][meter^-2][second^-1]
INTERCELL_CO2_CONC	[parts per million]
TRANSPIRATION_RATE	[millimoles H2O][meter^-2][second^-1]
WATER_USE_EFF	[micromoles CO2][millimole H2O^-1]
MESOPHYL_MOLAR_CONDUCT_CO2	[millimoles CO2][meter^-2][second^-1]
INTERCELL_AMB_CO2_RATIO	[millimoles CO2][meter^-2][second^-1][parts per million CO2^-1]
DOWN_PPFD	[micromoles][meter^-2][second^-1]
AIR_TEMP_CHAMBER	[degrees Celsius]
LEAF_TEMP	[degrees Celsius]
CO2_CONC	[parts per million]
AIR_FLOW_RATE	[micromoles][second^-1]
REL_HUM_CHAMBER	[percent]
VAPOR_PRESS_CHAMBER	[millibars]
LST_SQR_SLOPE_VAPOR_PRESS	[unitless]
LST_SQR_SLOPE_CO2_CONC	[unitless]
VAPOR_PRESS_DEFICIT	[kiloPascals]
ATMOSPHERIC_PRESS	[kiloPascals]
LEAF_AREA	[millimeter^2]
LEAF_BOUND_LAYER_MOLAR_CONDUCT	[mole][meter^-2][second^-1]
STOMATAL_CONDUCT_RATIO	[unitless]
INST_WATER_ABSORB_FACTOR	[unitless]
NEEDLE_AREA_1994	[millimeter^2]
NEEDLE_AREA_1993	[millimeter^2]
NEEDLE_SILHOU_AREA_1994	[millimeter^2]
NEEDLE_SILHOU_AREA_1993	[millimeter^2]
TOTAL_NEEDLE_SILHOU_AREA	[millimeter^2]
LICOR_VOLUME	[millimeter^3]
IRGA_HOSE_VOLUME	[millimeter^3]
MAX_FLOW_RATE	[micromoles]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

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

Column Name	Data Source
SITE_NAME	[BORIS Designation]
SUB_SITE	[BORIS Designation]
DATE_OBS	[Human Observer]
TIME_OBS	[Human Observer]
SPECIES	[Human Observer]
SAMPLE_BRANCH_NUM	[Human Observer]
CANOPY_LOCATION	[Human Observer]
TREE_ID	[Human Observer]
WATER_POTENTIAL	[Laboratory Equipment]
PHOTOSYNTHETIC_RATE	[Laboratory Equipment]
STOMATAL_MOLAR_CONDUCT_H2O	[Laboratory Equipment]
STOMATAL_MOLAR_CONDUCT_CO2	[Laboratory Equipment]
INTERCELL_CO2_CONC	[Laboratory Equipment]
TRANSPIRATION_RATE	[Laboratory Equipment]
WATER_USE_EFF	[Laboratory Equipment]
MESOPHYL_MOLAR_CONDUCT_CO2	[Laboratory Equipment]
INTERCELL_AMB_CO2_RATIO	[Laboratory Equipment]
DOWN_PPFD	[Laboratory Equipment]
AIR_TEMP_CHAMBER	[Laboratory Equipment]
LEAF_TEMP	[Laboratory Equipment]
CO2_CONC	[Laboratory Equipment]
AIR_FLOW_RATE	[Laboratory Equipment]
REL_HUM_CHAMBER	[Laboratory Equipment]
VAPOR_PRESS_CHAMBER	[Laboratory Equipment]
LST_SQR_SLOPE_VAPOR_PRESS	[Laboratory Equipment]
LST_SQR_SLOPE_CO2_CONC	[Laboratory Equipment]
VAPOR_PRESS_DEFICIT	[Laboratory Equipment]
ATMOSPHERIC_PRESS	[Laboratory Equipment]
LEAF_AREA	[Laboratory Equipment]
LEAF_BOUND_LAYER_MOLAR_CONDUCT	[Laboratory Equipment]
STOMATAL_CONDUCT_RATIO	[Laboratory Equipment]
INST_WATER_ABSORB_FACTOR	[Laboratory Equipment]
NEEDLE_AREA_1994	[Laboratory Equipment]
NEEDLE_AREA_1993	[Laboratory Equipment]
NEEDLE_SILHOU_AREA_1994	[Laboratory Equipment]
NEEDLE_SILHOU_AREA_1993	[Laboratory Equipment]
TOTAL_NEEDLE_SILHOU_AREA	[Laboratory Equipment]
LICOR_VOLUME	[Laboratory Equipment]
IRGA_HOSE_VOLUME	[Laboratory Equipment]
MAX_FLOW_RATE	[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 inthe data files on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	NSA-9BS-9TETR	NSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE09-GSE01	9TE09-GSE01	None	None	None	None
DATE_OBS	27-MAY-94	14-SEP-94	None	None	None	None
TIME_OBS	746	1913	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
SAMPLE_BRANCH_NUM	1	AMBIENT	None	None	None	None
CANOPY_LOCATION	Bottom	Top	None	None	None	Blank
TREE_ID	1	4	None	None	None	Blank
WATER_POTENTIAL	0	3.7	-999	None	None	Blank
PHOTOSYNTHETIC_RATE	-22.08	27.927	None	None	None	Blank
STOMATAL_MOLAR_CONDUCT_H2O	6.03	536	None	None	None	Blank
STOMATAL_MOLAR_CONDUCT_CO2	.00388	335	None	None	None	Blank
INTERCELL_CO2_CONC	142.4667	369.3	None	None	None	Blank
TRANSPIRATION_RATE	.116267	7.3765	None	None	None	Blank
WATER_USE_EFF	-1.18598	10.12996	None	None	None	Blank
MESOPHYL_MOLAR_CONDUCT_CO2	-100.91	105.1762	-999	None	None	Blank
INTERCELL_AMB_CO2_RATIO	.397991	1.047737	None	None	None	Blank
DOWN_PPFD	16.66	1868.5	None	None	None	None
AIR_TEMP_CHAMBER	9.46	34.72	None	None	None	None
LEAF_TEMP	8.563	36.243	None	None	None	None
CO2_CONC	274.63	685.95	None	None	None	None
AIR_FLOW_RATE	174.53	600	None	None	None	None
REL_HUM_CHAMBER	15.737	70.293	None	None	None	None
VAPOR_PRESS_CHAMBER	5.584	26.65	None	None	None	None
LST_SQR_SLOPE_VAPOR_PRESS	-.03445	.14183	None	None	None	Blank
LST_SQR_SLOPE_CO2_CONC	-.99353	.1341	None	None	None	None
VAPOR_PRESS_DEFICIT	.3514	3.896	None	None	None	None
ATMOSPHERIC_PRESS	979.9	987	None	None	None	None
LEAF_AREA	1	163.9	None	None	None	None
LEAF_BOUND_LAYER_MOLAR_CONDUCT	1.3	1.6	None	None	None	None
STOMATAL_CONDUCT_RATIO	0	1	None	None	None	None
INST_WATER_ABSORB_FACTOR	1.05	2.35	None	None	None	None
NEEDLE_AREA_1994	.91	112.14	None	None	None	Blank
NEEDLE_AREA_1993	9.94	121.95	None	None	None	Blank
NEEDLE_SILHOU_AREA_1994	.7745	14.24	None	None	None	Blank
NEEDLE_SILHOU_AREA_1993	2.2826	19.0773	-999	None	None	Blank
TOTAL_NEEDLE_SILHOU_AREA	.91	66.05	-999	None	None	Blank

```
LICOR_VOLUME          414             1149            None    None    None    None
IRGA_HOSE_VOLUME      154             154             None    None    None    None
MAX_FLOW_RATE         1180            1290            None    None    None    None
CRTFCN_CODE           CPI             CPI             None    None    None    None
REVISION_DATE         10-JUL-97       12-SEP-97       None    None    None    None
-------------------------------------------------------------------------------
Minimum Data Value -- The minimum value found in the column.
Maximum Data Value -- The maximum value found in the column.
Missng Data Value  -- The value that indicates missing data. This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the attempt was unsuccessful.
Unrel Data Value   -- The value that indicates unreliable data.  This is used
                      to indicate an attempt was made to determine the
                      parameter value, but the value was deemed to be
                      unreliable by the analysis personnel.
Below Detect Limit -- The value that indicates parameter values below the
                      instruments detection limits.  This is used to
                      indicate that an attempt was made to determine the
                      parameter value, but the analysis personnel determined
                      that the parameter value was below the detection
                      limit of the instrumentation.
Data Not Cllctd    -- This value indicates that no attempt was made to
                      determine the parameter value.  This usually
                      indicates that BORIS combined several similar but
                      not identical data sets into the same data base table
                      but this particular science team did not
                      measure that parameter.

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

7.4 Sample Data Record

The following are wrapped versions of data record from a sample data fileon the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,SPECIES,SAMPLE_BRANCH_NUM,CANOPY_LOCATION,
TREE_ID,WATER_POTENTIAL,PHOTOSYNTHETIC_RATE,STOMATAL_MOLAR_CONDUCT_H2O,
STOMATAL_MOLAR_CONDUCT_CO2,INTERCELL_CO2_CONC,TRANSPIRATION_RATE,WATER_USE_EFF,
MESOPHYL_MOLAR_CONDUCT_CO2,INTERCELL_AMB_CO2_RATIO,DOWN_PPFD,AIR_TEMP_CHAMBER,
LEAF_TEMP,CO2_CONC,AIR_FLOW_RATE,REL_HUM_CHAMBER,VAPOR_PRESS_CHAMBER,
LST_SQR_SLOPE_VAPOR_PRESS,LST_SQR_SLOPE_CO2_CONC,VAPOR_PRESS_DEFICIT,
ATMOSPHERIC_PRESS,LEAF_AREA,LEAF_BOUND_LAYER_MOLAR_CONDUCT,
STOMATAL_CONDUCT_RATIO,INST_WATER_ABSORB_FACTOR,NEEDLE_AREA_1994,
NEEDLE_AREA_1993,NEEDLE_SILHOU_AREA_1994,NEEDLE_SILHOU_AREA_1993,
TOTAL_NEEDLE_SILHOU_AREA,LICOR_VOLUME,IRGA_HOSE_VOLUME,MAX_FLOW_RATE,
CRTFCN_CODE,REVISION_DATE
'NSA-9BS-9TETR','9TE09-GSE01',03-AUG-94,958,'Picea mariana','1','Top',,1.3,
1.407333,39.6,24.75,302.8,.2772,5.08947,4.657189,.830968,210.367,12.26,11.757,
364.3,288.73,48.24,6.882,.00913,-.30193,.737567,979.9,99.79,1.3,1,1.68,69.28,
30.51,11.2329,6.261,17.4939,1149,154,1290,'CPI',11-SEP-97
'NSA-9BS-9TETR','9TE09-GSE01',03-AUG-94,1003,'Picea mariana','2','Top',,1.4,
1.090333,37.53,23.45813,299.2333,.264033,4.140771,3.648057,.854651,307.233,12.25,
11.86,350.07,289.3,48.72,6.948,.0096,-.252,.730367,979.9,107.1,1.3,1,1.68,64.91,
42.19,12.339,7.7328,20.0718,1149,154,1290,'CPI',11-SEP-97
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by BORIS was that 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

During the data processing, the following formulae were used:

- water use efficiency (WUE)=(photosynthesis (µmol/m^2/s) /transpiration(mmol/m^2/s))
- mesophyll conductance (GM)=((photosynthesis (µmol/m^2/s) /Intercellular CO_2 concentration (ppm)) x 1000) (Fites and Teskey, 1988)
- Ci/Ca: CINT: Intercellular CO_2 concentration (ppm) / CO_2 concentration (ppm))

9.1.1 Derivation Techniques and Algorithms

None at this time.

9.2 Data Processing Sequence

9.2.1 Processing Steps

Data were stored in the LI-6200 system during the measurement day. Data were then downloaded/transferred from the system to an IBM or IBM-compatible computer.

When the true leaf areas for each sample were available, these values were entered into the LI-COR programming software, and all gas exchange parameters subsequently were recomputed.

Raw data for each day of data were printed and examined for anomalies in each line of data. Subsequently, any data corresponding to each line of data that showed an anomaly were removed. For example, a branch was normally placed in the cuvette for three repetitions of 20 seconds. If in one (or more) of these repetitions, a parameter output was more than 25% out of range, then the entire line of data was removed, leaving only the data corresponding to the 'clean' repetitions.

Data were recomputed using the LI-COR software if any other errors in default parameters were detected. For example, on occasion, the ratio of the stomatal conductance of one side of the leaf to the other (STMRAT) was erroneously entered in the field.

Using Excel (Version 5.0 for IBM), a program was written to process each cleaned data set. This program did the following:

- Calculated new parameters that were not part of the LI-COR software system. These parameters included water use efficiency, mesophyll conductance, and Ci:Ca ratios.
- Permitted the user to average the data depending on whether the data had been recomputed or not.
- Permitted the user to average the data depending on whether there were two or three repetitions of data, taking into account missing data.
- Formatted the data into column format.

Once the data were in a cleaned, column format, water potential values for each time period were entered into the data set. Data in imperial units were converted to standard metric units.

9.2.2 Processing Changes

See Section 9.2.1.

9.3 Calculations

During the data processing, the following formulae were used:

- water use efficiency (WUE)=(photosynthesis (µmol/m^2/s) /transpiration(µmol/m^2/s))
- mesophyll conductance (GM)=((photosynthesis (µmol/m^2/s) /Intercellular CO_2 concentration (ppm)) x 1000) (Fites and Teskey, 1988)
- Ci/Ca: CINT: Intercellular CO_2 concentration (ppm) / CO_2 concentration (ppm)

9.3.1 Special Corrections/Adjustments

Raw data for each day of data were printed and examined for anomalies in each line of data. Subsequently, any data corresponding to each line of data that showed an anomaly were removed. For example, a branch was normally placed in the cuvette for three repetitions of 20 seconds. If in one (or more) of these repetitions, a parameter output was more than 25% out of range, then the entire line of data was removed, leaving only the data corresponding to the 'clean' repetitions.

Data were recomputed using the LI-COR software if any other errors in default parameters were detected. For example, on occasion, the ratio of the stomatal conductance of one side of the leaf to the other (STMRAT) was erroneously entered in the field.

Using the software Excel (Version 5.0 for IBM), a program was written to process each cleaned data set. This program did the following:

- Calculated new parameters that were not part of the LI-COR software system. These parameters included water use efficiency, mesophyll conductance, and Ci:Ca ratios.
- Permitted the user to average the data depending on whether the data had been recomputed or not.
- Permitted the user to average the data depending on whether there were two or three repetitions of data, taking into account missing data. 4) Formatted the data into column format.

Once the data were in a cleaned, column format, water potential values for each time period were entered into the data set. Data in imperial units were converted to standard metric units.

9.3.2 Calculated Variables

water use efficiency (WUE)
mesophyll conductance (GM)
intercellular CO_2 concentration(ppm)

9.4 Graphs and Plots

None submitted.

10. Errors

10.1 Sources of Error

During IFC-1, the LI-6200 system had problems caused by the manufacturer's calibration. For days when this equipment problem occurred, the data could not be treated and thus will not be stored in BORIS. Furthermore, the radio handsets that were distributed to the field groups caused some failure in instrument functioning. Either the instrument completely shut down or the periodic calibrations detected the handset influence. These data have been cleaned and removed from the data set available in BORIS.

All erroneous default parameters were adjusted. Anomalies in each line of data were removed. For example, a branch was normally placed in the cuvette for three repetitions of 20 seconds. If in one (or more) of these repetitions, a parameter output was more than 25% out of range, then the entire line of data was removed, leaving only the data corresponding to the 'clean' repetitions. Most often these anomalies could not be explained. However, a sudden burst in light during the measurement or a poor electrical signal could cause these kinds of errors. These out-of-range errors were detected and removed. See Section 9.2.1 for additional details.

10.2 Quality Assessment

10.2.1 Data Validation by Source
All known errors were removed.

10.2.2 Confidence Level/Accuracy Judgment
All known errors were removed, yielding a high degree of confidence in this data set.

10.2.3 Measurement Error for Parameters
No measurement errors are known at this time.

10.2.4 Additional Quality Assessments
Data were compared to results observed in the laboratory, and results are within a realistic range.

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
All known problems have been removed; see Section 10.1.

11.3 Usage Guidance
Use data columns as presented.

11.4 Other Relevant Information
Not available at this time.

12. Application of the Data Set

These data can be used to characterize the diurnal water potential curves for these sites to obtain an indication of the extent to which soil moisture supply to leaves might be limiting photosynthesis.

13. Future Modifications and Plans

This is the final version of data.

14. Software

14.1 Software Description
None given.

14.2 Software Access
None given.

15. Data Access

The gas exchange 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

Decagon Devices, Inc. 1990. AgVision monochrome system, root and leaf analysis, operators manual. Pullman, WA.

LI-COR, Inc. 1990. LI-COR 6200 Condensed Reference. Software Revision 2.00 (August 1990). Lincoln, NE.

LI-COR, Inc. 1990. LI-COR 6200 Technical reference. (March 1990). Lincoln, NE.

LI-COR, Inc. 1990. The LI-COR 6200 Primer: An introduction to operating the LI-6200 portable photosynthesis system. (May 1990) Lincoln, NE.

LI-COR, Inc. 1993. LI-COR 6200 software. Lincoln, NE.

17.2 Journal Articles and Study Reports

Coyea, M.R., Q.L. Dang, H. Margolis, M. Sy, and G.J. Collatz. 1996. Canopy profiles of PAR, nitrogen, and photosynthetic capacity: implications for scaling from leaf to canopy. North American Forest Biology Workshop. June 16-20 1996. Poster presented.

Dang, Q.L., H. Margolis, M. Sy, M.R. Coyea, and G. J. Collatz. 1996. Profiles of photosynthetically active radiation, nitrogen, and photosynthetic capacity in the boreal forest: implications for scaling from leaf to canopy. Ecological Society of America. August 10-14, 1996. Providence, RI.

Dang, Q.L., H. Margolis, M. Sy, M.R. Coyea, and G.J. Collatz. 1996. Water potential and vapor pressure difference as environmental controls on branch-level gas exchange of boreal tree species in northern Manitoba. North American Forest Biology Workshop. June 16-20, 1996.

Dang, Q.L., H. Margolis, M. Sy, M.R. Coyea, G.J. Collatz, and C.L. Walthall. 1997. Profiles of photosynthetically active radiation, nitrogen and photosynthetic capacity in the boreal forest: Implications for scaling from leaf to canopy. Journal of Geophysical Research 102(D24): 28,845-28,859.

Dang, Q.L., H. Margolis, M.R. Coyea, M. Sy, and G. J. Collatz,. 1996. Regulation of branch-level gas exchange of boreal trees: role of shoot water potential and vapor pressure difference. Tree Phys. In press.

Dang, Q.L., H. Margolis, M.R. Coyea, M. Sy, G.J. Collatz and De Yue. 1995. Environmental controls on photosynthesis and stomatal conductance of boreal forest tree species. Ecological Society of America. July 31-August 4, 1995. Snowbird, UT.

Fites, J.A. and R.O. Teskey. 1988. CO_2 and water vapor exchange of Pinus in relation to stomatal behavior: test of an optimization hypothesis. Can. J. For. Res. 18:150-157.

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  - BOReal 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
FPAR    - Fraction of PAR
GIS     - Geographic Information System
GMT     - Greenwich Mean Time
GSFC    - Goddard Space Flight Center
HASL    - Half the Area of the Surface of the Leaf
HTML    - HyperText Markup Language
IFC     - Intensive Field Campaign
IRGA    - Infrared Gas Analyzer
NAD27   - North American Datum of 1927
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
```

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ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
PAR     - Photosynthetically Active Radiation
PI      - Principal Investigator
Ps      - Photosynthesis
SSA     - Southern Study Area
TE      - Terrestrial Ecology
UBS     - Upland Black Spruce
URL     - Uniform Resource Locator
UTM     - Universal Transverse Mercator
VPD     - Vapor Pressure Deficit
YA      - Young Aspen
YJP     - Young Jack Pine
```

20. Document Information

20.1 Document Revision Date

Written: 27-Feb-1997
Last Updated: 27-May-1999

20.2 Document Review Date(s)

BORIS Review: 26-Feb-1998
Science Review:06-Feb-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:

The diurnal gas exchange and water potential measurements were collected for BOREAS by the TE-09 research team from Universite Laval, Quebec, Canada, under the direction of H. Margolis. The dedicated efforts of Marie R. Coyea, Mikailou Sy, Raynald Paquin, Simon Arbour, Munyonge Abwe Wa Masabo, and Tshinkenke Vinlha in collecting and preparing these data is particularly appreciated.

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

Margolis, H., "Relationship Between Measures of Absorbed and Reflected Radiation and the Photosynthetic Capacity of Boreal Forest Canopies and Understories." 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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13. ABSTRACT *(Maximum 200 words)*

The BOREAS TE-9 team collected several data sets related to chemical and photosynthetic properties of leaves in boreal forest tree species. The purpose of the BOREAS TE-09 study was threefold: 1) to provide in situ gas exchange data that will be used to validate models of photosynthetic responses to light, temperature, and carbon dioxide (CO_2); 2) to compare the photosynthetic responses of different tree crown levels (upper and lower); and 3) to characterize the diurnal water potential curves for these sites to get an indication of the extent to which soil moisture supply to leaves might be limiting photosynthesis. The gas exchange data of the BOREAS NSA were collected to characterize diurnal gas exchange and water potential of two canopy levels of five boreal canopy cover types: young jack pine, old jack pine, old aspen, lowland old black spruce, and upland black spruce. These data were collected between 27-May-1994 and 17-Sep-1994. The data are provided in tabular ASCII files.

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