NASA/TM—2000–209891, Vol. 163

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

Forrest G. Hall and Andrea Papagno, Editors

Volume 163

BOREAS TE-10 Photosynthetic Response Data

Elizabeth Middleton, NASA Goddard Space Flight Center, Greenbelt, Maryland
Joseph Sullivan, University of Maryland, College Park

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

October 2000

Available from:

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

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

BOREAS TE-10 Photosynthetic Response Data

Elizabeth M. Middleton, Joe H. Sullivan

Summary

The BOREAS TE-10 team collected several data sets in support of its efforts to characterize and interpret information on the gas exchange, reflectance, transmittance, chlorophyll content, carbon content, hydrogen content, nitrogen content, and photosynthetic response of boreal vegetation. This data set contains measurements of quantitative parameters and leaf photosynthetic response to increases in light conducted in the SSA during the growing seasons of 1994 and 1996 using an oxygen electrode system. Leaf photosynthetic responses were not collected in 1996. The data are stored in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-10 Photo Response Data

1.2 Data Set Introduction

This data set describes the relationship between sample location, sample age, oxygen evolution measurements, and quantitative parameters in the canopies of the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) Old Black Spruce (OBS), Old Jack Pine (OJP), Young Jack Pine (YJP), Old Aspen (OA), Old Aspen-Auxiliary (OA-AUX), Young Aspen (YA), and Young Aspen-Auxiliary (YA-AUX) sites during the growing seasons of 1994 and 1996. This data set was collected and prepared to provide information on the oxygen evolution measurements and quantitative parameters of OBS (Picea mariana), OJP (Pinus banksiana and Apocynum androsaemifolium), YJP (Pinus banksiana), YA (Populus tremuloides and Corylus cornuta Marsh) OA (Populus tremuloides and Corylus cornuta Marsh), YA-AUX (Populus tremuloides, Corylus cornuta Marsh, and Picea

glauca), and OA-AUX (Populus tremuloides and Corylus cornuta Marsh). This information will be useful for assessing photosynthetic differences between different species, age classes, and canopy layers in the boreal forest.

1.3 Objective/Purpose

The purposes of the work were to:

- Obtain a canopy profile of leaf/needle growth measurements and oxygen evolution rates during photosynthesis.
- Examine interspecific and interseasonal differences in these parameters.
- Relate these differences to the photosynthetic measurements taken in the field.

1.4 Summary of Parameters

The photo response data record includes the date when the measurements were taken, quantitative parameters (color of top of leaf, color of bottom of leaf, needle count per sample, mean leaf/needle length of three needles per age class or three measurements of the same leaf, mean leaf/needle width of three needles per age class or three measurements of the same leaf, mean leaf/needle thickness of three needles per age class or three measurements of the same leaf, length/width ratio, mean hemisurface area of three needles per age class or three measurements of the same leaf, dry and fresh weights of leaf/petiole/needle, dry and fresh weights of leaf/petiole/needle/stem, fresh specific leaf weight, dry specific leaf weight, percent water content for the whole shoot including stem, percent water in the sample without stem), and oxygen evolution (maximum assimilation-Amax, dark respiration-darkresp, and stomatal limitation-stomlim).

1.5 Discussion

Samples were taken from seven forest sites in the SSA: OBS, OJP, YJP, YA-AUX, YA, OA-AUX, and OA during each of the three Intensive Field Campaigns (IFCs) in 1994 and the growing season of 1996. Measurements were taken in the laboratory. Quantitative measurements such as length, width, thickness, color, needle count/age class, and fresh weight were examined in an effort to characterize photosynthetic differences. An oxygen electrode system (Hansatech Corporation, Kingslynn, England), which measures the rate of oxygen evolution during photosynthesis, was used for photosynthesis measurements under controlled light and temperature and with saturating concentrations of carbon dioxide (CO_2) (5, 10% in air), which overcome stomatal resistances to CO_2 uptake. This information will be useful in examining differences in photosynthetic capacity between species and within canopies of the boreal forest. Measurements were taken in the laboratory.

1.6 Related Data Sets

BOREAS TE-10 Leaf Chlorophyll
BOREAS TE-10 Leaf Optical Properties

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Elizabeth Middleton Project Scientist
Dr. Joseph Sullivan Assistant Professor

2.2 Title of Investigation

CO_2 and Water Fluxes in the Boreal Forest Overstory: Relationship to fAPAR and Vegetation Indices for Needles/Leaves

2.3 Contact Information

Contact 1:
Elizabeth M. Middleton, Ph.D.
Biospheric Sciences Branch, Code 923
NASA GSFC
Greenbelt, MD 20771
(301) 286-8344
(301) 286-0239 (fax)
betsym@ltpsun.gsfc.nasa.gov

Contact 2:
Joe H. Sullivan, Ph.D.
Department of Natural Resource Sciences and Landscape Architecture
University of Maryland
College Park, MD 20742
(301) 405-1626
(301) 314-9308 (fax)
botn9@umdd.umd.edu

Contact 3:
Andrea Papagno
Raytheon ITSS
Code 923
NASA GSFC
Greenbelt, MD 20771
(301) 286-3134
(301) 286-2039 (fax)
Andrea.Papagno.gsfc.nasa.gov

Contact 4:
Shelaine Curd
Raytheon ITSS
Code 923
NASA GSFC
Greenbelt, MD 20771
(301) 286-2447
(301) 286-2039 (fax)
Shelaine.Curd@gsfc.nasa.gov

3. Theory of Measurements

An oxygen electrode system (Hansatech Corporation, Kingslynn, England), which measures the rate of oxygen evolution during photosynthesis, was used for photosynthesis measurements under controlled light and temperature and with saturating concentrations of CO_2 (5, 10% in air), which overcome stomatal resistances to CO_2 uptake. Single-leaf measurements were made using cut leaf disks having areas of 2.27 cm^2 of aspen, hazelnut, and dogbane. For full illumination by the light source, enough material was needed to fill the electrode system chamber without any overlap; thus, multiple needle samples were used to measure the coniferous species. Five needles within the same sample id and the same age class were used to measure jack pine; 15 to 20 needles within the sample id and the same needle age class were used to measure black spruce. Saturating photosynthetic photon flux density (PPFD) (2175 $\mu mol/m^2/s$) was supplied by a Bjorkman lamp connected to a Hansatech

LS-2 light source. Estimates of dark respiration (darkresp) were made after incremental light reductions (implemented for light response curves, Middleton et al. [1997] and Sullivan et al. [1996]) and acclimation to zero illumination.

Stomatal limitation is calculated using the standard equation from Farquhar and Sharkey (1982):

$$\text{stomatal limitation} = ((a_{max} - A)/a_{max}) \times 100 \quad (1)$$

Terrestrial Ecology (TE)-10 used maximum assimilation without stomatal limitations (a_{max}) from the light-saturated and CO_2-saturated O_2 measurements as an estimate of "a_{max}," and light-saturated maximum assimilation with stomatal limitations (A) from field measurements using an Infrared Gas Analyzer (IRGA) System. Amax from O_2 is without a stomatal effect because of the high CO_2 gradient overcoming any stomatal barrier to diffusion. A in the field does potentially include some other limitations in addition to stomatal closure (e.g., biochemical), but that possibility was ignored. This is an accepted way to estimate how much influence the stomates are having on gas exchange.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment

The vertical profile of the canopy was divided into three layers: top, middle, and bottom. One layer of white spruce at YA-AUX was measured during IFC-2 only. At OJP, the understory species dogbane (Apocynum androsaemifolium) was measured during IFC-2. At OA and YA, there was a hazelnut (Corylus cornuta Marsh) understory that was measured during each IFC.

Gas exchange measurements and sample collections were made from platform canopy access towers constructed onsite by the BOREAS staff at the OBS, OJP, OA, and OA-AUX sites and from the ground at the YA, YA-AUX, and YJP sites. In 1994, data were obtained during three discrete measurement periods (1 to 2 measurement days each period) designated by BOREAS as IFC-1, -2, or -3. These IFCs were selected to measure parameters at bud breaks and leaf expansion (24-May-1994 to 12-Jun-1994), midsummer or peak growing season (26-Jul-1994 to 08-Aug-1994), and the onset of dormancy and senescence in autumn (30-Aug-1994 to 15-Sep-1994). In 1996, data were obtained during three discrete measurement periods (1 to 2 measurement days each period) designated as the spring, summer, and fall seasons. These seasons were selected to measure parameters at bud breaks and leaf expansion (21-April-1996 to 24-June-1996), midsummer or peak growing season (10-July-1996 to 17-July-1996), and the onset of dormancy and senescence in autumn (20-Oct-1996 to 31-Oct-1996).

Measurements were collected from both the upper and lower canopy sections of the trees adjacent to the canopy access towers at the OJP, OBS, OA, and OA-AUX sites and on the young trees present near the flux tower sites at the YJP, YA, and YA-AUX sites. For Pinus banksiana, measurements were made on each needle class present. For Picea glauca, age classes 1 (1994) and 2 (1993) were measured during IFCs-2 and -3. For Picea mariana, the newest age was measured alone, while needles 2 and 3 years were combined in one measurement, as were 4- and 5-year-old needles. Broadleafs were measured as individual leaves with their petioles attached. At least eight replicate measurements and sample collection per IFC, canopy location, and age group were made for each species. These activities took place on trees that were accessible from the canopy access towers (approximately four trees, with two upper and lower branches measured per tree) at the OBS, OJP, OA, and OA-AUX sites and on the same number of trees each IFC at the YJP, YA, and YA-AUX sites.

Samples were sealed in plastic bags with moist towels and placed on ice for transport to the laboratory for further analysis. The laboratory was provided by BOREAS staff in Paddockwood, SK, approximately 60 km from the research sites. Each sample was divided into two components with one portion used for measurement of oxygen evolution and chlorophyll extraction and the remaining material used for analysis of leaf optical properties and carbon-hydrogen-nitrogen content.

At the laboratory, samples were stored in the dark in the refrigerator until they were measured. Laboratory measurements included quantitative properties, optical properties, and oxygen evolution. Quantitative parameters included the color of top of the leaf, the color of the bottom of the leaf, needle count per sample, mean leaf/needle length of three needles per age class or three measurements of the same leaf, mean leaf/needle width of three needles per age class or three measurements of the same leaf, mean leaf/needle thickness of three needles per age class or three measurements of the same leaf, length/width ratio, mean hemisurface area of three needles per age class or three measurements of the same leaf, dry and fresh weights of leaf/petiole/needle, and dry and fresh weights of leaf/petiole/needle/stem. A foliar disk sample of 2.27 cm^2 diameter was taken from each of the broadleaf samples for oxygen evolution. A mass of needles, 5 for jack pine and 15 to 20 for black spruce, chopped, was taken from the conifers for oxygen evolution. The foliar disk samples and chopped needles were dried and weighed following the extraction of their photosynthetic pigments. The rest of the samples were dried in an oven at 70 °F for 3 days, and their dry weights were recorded. The oxygen evolution samples were of a known weight.

4.1.2 Source/Platform

Samples were taken from towers except at YJP, YA-AUX, and YA, and were cut using knives.

4.1.3 Source/Platform Mission Objectives

Not applicable.

4.1.4 Key Variables

Oxygen evolution (maximum assimilation-Amax, dark respiration-darkresp, stomatal limitation-stomlim).

Quantitative parameters (color of top of leaf, color of bottom of leaf, needle count per sample, mean leaf/needle length of three needles per age class or three measurements of the same leaf, mean leaf/needle width of three needles per age class or three measurements of the same leaf, mean leaf/needle thickness of three needles per age class or three measurements of the same leaf, length/width ratio, mean hemisurface area of three needles per age class or three measurements of the same leaf, dry and fresh weights of leaf/petiole/needle, dry and fresh weights of leaf/petiole/needle/stem, fresh specific leaf weight, dry specific leaf weight, percent water content for the whole shoot including stem, and percent water in the sample without stem).

4.1.5 Principles of Operation

Maximum assimilation and dark respiration were obtained from the rates of oxygen evolution. An oxygen electrode system (Hansatech Corporation, Kingslynn, England), which measures the rate of oxygen evolution during photosynthesis, was used for photosynthesis measurements under controlled light and temperature and with saturating concentrations of CO_2 (5, 10% in air), which overcome stomatal resistances to CO_2 uptake. Single-leaf measurements were made using cut leaf disks having areas of 2.27 cm^2 of aspen, hazelnut, and dogbane. For full illumination by the light sources enough material was needed to fill the electrode system chamber without any overlap; thus, multiple needle samples were used to measure the coniferous species. Five needles within the same sample id and the same age class were used to measure jack pine; 15 to 20 needles within the sample id and the same needle age class were used to measure black spruce. Stomatal limitation was calculated using the standard equation from Farquhar and Sharkey (1982). Quantitative measurements enabled TE-10 to measure the percent water content and to obtain leaf/needle dimensions.

4.1.6 Sensor/Instrument Geometry

All instrumentation took place under laboratory conditions.

4.1.7 Manufacturer of Sensor/Instrument

Circulating Water Bath Set
Lauda, Model RM20B
Fisher Scientific
585 Alpha Drive
Pittsburgh, PA 15238
1 (800) 766-7000

LED Light Source
Hansatech Model LH36 Ultralight
Hansatech Corporation
Kingslynn, UK

LI-COR Area Meter
Model Number 3100
LI-COR, Inc.
4421 Superior Street
P.O. Box 4425
Lincoln, NE 68504-0425
USA
(402) 467-3576
(402) 467-2819 (fax)

Oxygen Electrode
Hansatech Corporation
Kingslynn, UK

4.2 Calibration

4.2.1 Specifications

The weighing balance was accurate to 0.01 g. The analytical balance was accurate to 0.0001 g. The leaf area meter was accurate to within 1.00%.

4.2.1.1 Tolerance

No tolerance level was set.

4.2.2 Frequency of Calibration

The oxygen evolution system was calibrated using O_2 (1 cc air) injected into the system before each sample run. The leaf area meter was calibrated before each use with a 10-cm disk. Measurements of weight (mass) were reset to zero before each sample reading.

4.2.3 Other Calibration Information

None.

5. Data Acquisition Methods

On the towers at OA, OA-AUX, OBS, YJP, and OJP, top samples were taken from the top tower level, middle samples from the middle level, and bottom samples from the bottom tower level. At YA and YA-AUX, top samples were taken from the upper third, middle samples from the middle third, and bottom samples from the lower third part of the trees. At YA-AUX, only a top layer of the white spruce (Picea glauca) canopy was sampled. At OJP, there was a dogbane (Apocynum androsaemifolium) understory during IFC-2. At OA and YA, there was a hazelnut (Corylus cornuta Marsh) understory. Stem and leaf samples were harvested from each layer and immediately placed

within a plastic bag that also contained a moist towel. For transport to the laboratory, the bags were placed in a cooler. For black spruce, age classes 1, 2, and 3 were separated from ages 4 and 5, until analysis was performed at the laboratory. For jack pine, age classes 1, 2, and 3 were separated in the field before being brought to the laboratory. For white spruce, age class 1 was separated from age classes 2 and 3, which were separated from 4 and 5. Petioles were kept on all the broadleaves. At the laboratory, samples were stored in the dark in the refrigerator until they were measured.

Laboratory measurements included quantitative properties, optical properties, and oxygen evolution. Quantitative measurements that were performed on each sample age class included fresh weight using a balance; mean leaf (hemi-surface) area using a leaf area meter; mean length, mean width, and mean thickness of leaf/needles and conifer stems using a ruler and calipers; color of top (adaxial) and bottom (abaxial) using Munsell Color Charts (Munsell Color (Firm), 1977); and needle count/age class. An oxygen electrode system (Hansatech Corporation, Kingslynn, England), which measures the rate of oxygen evolution during photosynthesis, was used for photosynthesis measurements under controlled light and temperature and with saturating concentrations of CO_2 (5, 10% in air), which overcome stomatal resistances to CO_2 uptake. Measurements were made on leaf discs or needle subsets. Single-leaf measurements were made using cut leaf disks having areas of 2.27 cm^2 of aspen, hazelnut, and dogbane. For full illumination by the light source, enough material was needed to fill the electrode system chamber without any overlap; thus, multiple needle samples were used to measure the coniferous species. Five needles within the same sample id and the same age class were used to measure jack pine; 15 to 20 needles within the sample id and the same needle age class were used to measure black spruce. The electrode was maintained at a constant temperature using a circulating water bath (Lauda, Model RM20B), reset to approximately maximum daytime air temperature per IFC (26 °C in IFC-1 and -3, 28 °C in IFC-2). Photosynthesis capacity (light-saturated photosynthesis) or Amax was determined within 2 to 24 hours after the field measurements. Saturating PPFD (2175 $\mu mol/m^2/s$) was supplied by a Bjorkman lamp connected to a Hansatech LS-2 light source. Estimates of dark respiration (darkresp) were made after incremental light reductions (implemented for light response curves, Middleton et al. [1997] and Sullivan et al. [1996]) and acclimation to zero illumination.

6. Observations

6.1 Data Notes

None.

6.2 Field Notes

None.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

At the SSA OJP, YJP, OBS, OA, and OA-AUX tower sites, branch samples were taken from trees within reach from all sides of the towers. There were no towers at the other sites. At each site, at least five trees had the required layers for that site were sampled. The SSA measurement sites and associated North American Datum of 1983 (NAD83) coordinates are:

- SSA-OA canopy access tower located 100 m up the path to the flux tower site, site id C3B7T, Lat/Long: 53.62889° N, 106.19779° W, Universal Transverse Mercator (UTM) Zone 13, N:5,942,899.9 E:420,790.5.

- SSA-OA-AUX canopy access tower located by the trailhead/parking area for the path leading to the flux tower at site id C3B7T, Lat/Long: 53.62889° N, 106.19779° W, UTM Zone 13, N:5,942,899.9 E:420,790.5. This OA-AUX site was farther up the path than SSA-OA from the flux tower site.
- SSA-OBS canopy access tower located at the flux tower site, site id G8I4T, Lat/Long: 53.98717° N, 105.11779° W, UTM Zone 13, N:5,982,100.5 E;492,276.5.
- SSA-OJP canopy access tower flux tower site, site id G2L3T, Lat/Long: 53.91634° N, 104.69203° W, UTM Zone 13, N:5,974,257.5 E:520,227.7.
- SSA-YA canopy access tower, site id D0H4T, Lat/Long: 53.65601° N, 105.32314° W, UTM Zone 13, N:5,945,298.9, E:478,644.1.
- SSA-YA-AUX, site id D6H4A, Lat/Long: 53.708° N, 105.315° W, UTM Zone 13, N:5,951,112.1, E:479,177.5.
- SSA-YJP near the flux tower site, site id F8L6T, Lat/Long: 53.87581° N, 104.64529° W, UTM Zone 13, N:5,969,762.5 E:523,320.2.

7.1.2 Spatial Coverage Map
Not applicable.

7.1.3 Spatial Resolution
These data are point measurements 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
Samples were collected from the field every day from 0900 until 1300 local time. An independent data set was taken at each of the field campaigns in 1994. The specific dates for each collection of samples are given in the data table.

7.2.2 Temporal Coverage Map

		Sample Dates (1994)		
Site	Species	IFC-1	IFC-2	IFC-3
SSA-OBS	black spruce	01-JUN	28-JUL to 01-AUG	13-SEP
SSA-OA-AUX	aspen	-	03-AUG	02-SEP
SSA-OA-AUX	hazelnut	-	03-AUG	02-SEP
SSA-OJP	jack pine	31-MAY	25-JUL	06-SEP
SSA-OJP	dogbane	-	25-JUL	-
SSA-OA	aspen	30-MAY,11-JUN	21-JUL	15-SEP
SSA-OA	hazelnut	26-MAY,11-JUN	21-JUL	15-SEP
SSA-YA-AUX	aspen	25-MAY	-	-
SSA-YJP	jack pine	26-MAY,07-JUN	22-JUL to 23-JUL	08-SEP
SSA-YA-AUX	white spruce	-	31-JUL to 01-AUG	11-SEP
SSA-YA	aspen	04-JUN	30-JUL	02-SEP,12-SEP
SSA-YA	hazelnut	04-JUN	30-JUL	02-SEP,12-SEP

		Sample Dates (1996)		
Site	Species	Spring	Summer	Fall
SSA-OBS	black spruce	10-MAY	14-JUL	11-OCT
SSA-OBS	black spruce	19-JUN	-	-
SSA-OBS	black spruce	21-JUN	-	-
SSA-OBS	tamarack	-	17-JUL	10-OCT
SSA-OJP	jack pine	18-JUN	11-JUL	13-OCT
SSA-OJP	jack pine	23-JUN	-	-
SSA-OA-AUX	aspen	24-JUN	17-JUL	-
SSA-OA-AUX	hazelnut	24-JUN	17-JUL	-
SSA-YJP	jack pine	8-MAY TO 9-MAY	12-JUL	12-OCT
SSA-YJP	jack pine	23-JUN	15-JUL	-
SSA-YA-AUX	white spruce	8-MAY	10-JUL	10-OCT
SSA-YA-AUX	white spruce	20-JUN	-	-

7.2.3 Temporal Resolution

Not applicable.

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
SPECIES
CANOPY_LOCATION
SAMPLE_GROWTH_YEAR
SAMPLE_ID
MEAN_FOLIAGE_HEMI_SURF_AREA_GY
ADAXIAL_MUNSELL_COLOR
ABAXIAL_MUNSELL_COLOR
NUM_TOTAL_NEEDLES
MEAN_LEAF_LENGTH
MEAN_LEAF_WIDTH
LEAF_LENGTH_TO_WIDTH_RATIO
MEAN_LEAF_THICKNESS
DARK_RESPIRATION
STOMATAL_LIMITATION
MAXIMUM_ASSIMILATION
TOTAL_FRESH_WEIGHT
FRESH_LEAF_WEIGHT
FRESH_LEAF_DENSITY
TOTAL_DRY_WEIGHT
DRY_LEAF_WEIGHT
DRY_WEIGHT_RATIO
DRY_LEAF_DENSITY
SHOOT_WATER_CONTENT
LEAF_WATER_CONTENT
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.
SPECIES	Botanical (Latin) name of the species (Genus species).
CANOPY_LOCATION	Location in the canopy from which the sample was taken.
SAMPLE_GROWTH_YEAR	The year in which the collected sample first grew.
SAMPLE_ID	The sample identifier used by data collectors
MEAN_FOLIAGE_HEMI_SURF_AREA_GY	The hemi-surface foliar area of the broadleaf plus its petiole or of all the needles in the needle growth year.
ADAXIAL_MUNSELL_COLOR	Munsell color code of the adaxial surface.
ABAXIAL_MUNSELL_COLOR	Munsell color code of the abaxial surface.
NUM_TOTAL_NEEDLES	The total number of needles on the shoot.
MEAN_LEAF_LENGTH	The mean lengths of three conifer needles within the same growth year or of three measurements of the same foliar broadleaf (the petiole is not included) .
MEAN_LEAF_WIDTH	The mean widths of three conifer needles within the same growth year or of three measurements of the same foliar broadleaf (the petiole is not included) .
LEAF_LENGTH_TO_WIDTH_RATIO	The ratio of the mean leaf length to the mean leaf width.
MEAN_LEAF_THICKNESS	The mean thicknesses of three conifer needles within the same growth year or of three measurements of the same foliar broadleaf (the petiole is not included) .
DARK_RESPIRATION	The lowest assimilation rate reached (negative) by a foliar broadleaf or needle sample under zero light illumination.
STOMATAL_LIMITATION	The limitation of photosynthesis by the stomates. This is calculated using the maximum photosynthesis reached under light saturating conditions with and without stomatal influence.
MAXIMUM_ASSIMILATION	The maximum assimilation reached by a plants

	leaves/needles under light saturating conditions and without stomatal limitations.
TOTAL_FRESH_WEIGHT	The total fresh weight of the broadleaf and petiole or the total of all the needles and needle stems in the needle growth year.
FRESH_LEAF_WEIGHT	The fresh weight of a single broadleaf and petiole or all of the needles (minus the needle stem) in the needle growth year.
FRESH_LEAF_DENSITY	The fresh leaf weight of the broadleaf and its petiole or all the needles in the needle growth year per their mean growth year foliar area.
TOTAL_DRY_WEIGHT	The total dry weight of the broadleaf and petiole or the total of all the needles and needle stems in the needle growth year.
DRY_LEAF_WEIGHT	The dry weight of a single broadleaf and petiole or all of the needles in the needle growth year.
DRY_WEIGHT_RATIO	The ratio of dry leaf weight to the total dry weight values.
DRY_LEAF_DENSITY	The dry leaf weight of the broadleaf and its petiole or all the needles in the needle growth year per their mean growth year foliar area.
SHOOT_WATER_CONTENT	The percentage of water in the whole conifer shoot or of the broadleaf and petiole. This is calculated as the total fresh weight minus the total dry weight divided by the total fresh weight.
LEAF_WATER_CONTENT	The percentage of water in the single broadleaf and petiole or in all of the needles in the needle growth year. This is calculated as the fresh leaf weight minus the dry leaf weight divided by the fresh leaf weight.
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]
SPECIES	[none]
CANOPY_LOCATION	[none]
SAMPLE_GROWTH_YEAR	[unitless]
SAMPLE_ID	[none]
MEAN_FOLIAGE_HEMI_SURF_AREA_GY	[millimeters^2]
ADAXIAL_MUNSELL_COLOR	[none]
ABAXIAL_MUNSELL_COLOR	[none]
NUM_TOTAL_NEEDLES	[counts]

MEAN_LEAF_LENGTH	[millimeters]
MEAN_LEAF_WIDTH	[millimeters]
LEAF_LENGTH_TO_WIDTH_RATIO	[unitless]
MEAN_LEAF_THICKNESS	[millimeters]
DARK_RESPIRATION	[micromoles O2][meter^-2][second^-1]
STOMATAL_LIMITATION	[percent]
MAXIMUM_ASSIMILATION	[micromoles O2][meter^-2][second^-1]
TOTAL_FRESH_WEIGHT	[grams]
FRESH_LEAF_WEIGHT	[grams]
FRESH_LEAF_DENSITY	[grams][millimeter^-2]
TOTAL_DRY_WEIGHT	[grams]
DRY_LEAF_WEIGHT	[grams]
DRY_WEIGHT_RATIO	[unitless]
DRY_LEAF_DENSITY	[grams][millimeter^-2]
SHOOT_WATER_CONTENT	[percent]
LEAF_WATER_CONTENT	[percent]
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]
SPECIES	[Human Observer]
CANOPY_LOCATION	[Human Observer]
SAMPLE_GROWTH_YEAR	[Human Observer]
SAMPLE_ID	[Human Observer]
MEAN_FOLIAGE_HEMI_SURF_AREA_GY	[Laboratory Equipment]
ADAXIAL_MUNSELL_COLOR	[Human Observer]
ABAXIAL_MUNSELL_COLOR	[Human Observer]
NUM_TOTAL_NEEDLES	[Human Observer]
MEAN_LEAF_LENGTH	[Laboratory Equipment]
MEAN_LEAF_WIDTH	[Laboratory Equipment]
LEAF_LENGTH_TO_WIDTH_RATIO	[Laboratory Equipment]
MEAN_LEAF_THICKNESS	[Laboratory Equipment]
DARK_RESPIRATION	[Laboratory Equipment]
STOMATAL_LIMITATION	[Laboratory Equipment]
MAXIMUM_ASSIMILATION	[Laboratory Equipment]
TOTAL_FRESH_WEIGHT	[Laboratory Equipment]
FRESH_LEAF_WEIGHT	[Laboratory Equipment]
FRESH_LEAF_DENSITY	[Laboratory Equipment]
TOTAL_DRY_WEIGHT	[Laboratory Equipment]
DRY_LEAF_WEIGHT	[Laboratory Equipment]
DRY_WEIGHT_RATIO	[Laboratory Equipment]
DRY_LEAF_DENSITY	[Laboratory Equipment]
SHOOT_WATER_CONTENT	[Laboratory Equipment]
LEAF_WATER_CONTENT	[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	9TE10-LPR01	9TE10-LPR02	None	None	None	None
DATE_OBS	25-MAY-94	13-OCT-96	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
CANOPY_LOCATION	Bottom	Top	-999	None	None	None
SAMPLE_GROWTH_YEAR	1989	1996	-999	None	None	None
SAMPLE_ID	N/A	N/A	-999	None	None	None
MEAN_FOLIAGE_HEMI_SURF_AREA_GY	113	10828	-999	None	None	Blank
ADAXIAL_MUNSELL_COLOR	.5gy4/8	7.5gy7/10	-999	None	None	Blank
ABAXIAL_MUNSELL_COLOR	2.5gy4/4	7.5gy8/6	-999	None	None	Blank
NUM_TOTAL_NEEDLES	1	219	-999	None	None	Blank
MEAN_LEAF_LENGTH	4.34	161	-999	None	None	Blank
MEAN_LEAF_WIDTH	.664	107.06	-999	None	None	Blank
LEAF_LENGTH_TO_WIDTH_RATIO	.694	25.639	-999	None	None	Blank
MEAN_LEAF_THICKNESS	.13	1.93	-999	None	None	Blank
DARK_RESPIRATION	-10.81	2.4	-999	None	None	Blank
STOMATAL_LIMITATION	1.372	268.919	-999	None	None	Blank
MAXIMUM_ASSIMILATION	-3.12	57.7	-999	None	None	Blank
TOTAL_FRESH_WEIGHT	.04	6.93	-999	None	None	Blank
FRESH_LEAF_WEIGHT	0	6.25	-999	None	None	Blank
FRESH_LEAF_DENSITY	0	10.97525	-999	None	None	Blank
TOTAL_DRY_WEIGHT	.005	2.95	-999	None	None	Blank
DRY_LEAF_WEIGHT	.005	1.908	-999	None	None	Blank
DRY_WEIGHT_RATIO	.231	1.024	-999	None	None	Blank
DRY_LEAF_DENSITY	.00001	5.36861	-999	None	None	Blank
SHOOT_WATER_CONTENT	-20	100	-999	None	None	Blank
LEAF_WATER_CONTENT	0	100	-999	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	10-SEP-98	10-SEP-98	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 file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,SPECIES,CANOPY_LOCATION,SAMPLE_GROWTH_YEAR,SAMPLE_ID,
MEAN_FOLIAGE_HEMI_SURF_AREA_GY,ADAXIAL_MUNSELL_COLOR,ABAXIAL_MUNSELL_COLOR,
NUM_TOTAL_NEEDLES,MEAN_LEAF_LENGTH,MEAN_LEAF_WIDTH,LEAF_LENGTH_TO_WIDTH_RATIO,
MEAN_LEAF_THICKNESS,DARK_RESPIRATION,STOMATAL_LIMITATION,MAXIMUM_ASSIMILATION,
TOTAL_FRESH_WEIGHT,FRESH_LEAF_WEIGHT,FRESH_LEAF_DENSITY,TOTAL_DRY_WEIGHT,
DRY_LEAF_WEIGHT,DRY_WEIGHT_RATIO,DRY_LEAF_DENSITY,SHOOT_WATER_CONTENT,
LEAF_WATER_CONTENT,CRTFCN_CODE,REVISION_DATE
'SSA-90A-FLXTR','9TE10-LPR01',26-MAY-94,'Corylus cornuta','Top','1994','14',
285.0,'2.5gy6/10','2.5gy6/8',-999.0,29.0,19.0,1.526,-999.0,-999.0,-999.0,-999.0,
.05,.05,1.75439,.049,.049,-999.0,1.7193,2.0,2.0,'CPI',10-SEP-98
'SSA-90A-FLXTR','9TE10-LPR01',26-MAY-94,'Corylus cornuta','Top','1994','15',
263.0,'2.5gy6/10','5gy5/6',-999.0,24.0,16.0,1.5,-999.0,-999.0,-999.0,-999.0,.04,
.04,1.52091,.01,.01,-999.0,.38023,75.0,75.0,'CPI',10-SEP-98
```

8. Data Organization

8.1 Data Granularity

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

8.2 Data Format(s)

The Compact Disk-Read Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of HyperText 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

stomlim = $[(a_{max}-A)/a_{max}]100$ (Farquhar and Sharkey, 1982)

9.1.1 Derivation Techniques and Algorithms

None.

9.2 Data Processing Sequence

9.2.1 Processing Steps

Oxygen evolution measurements were recorded manually. Subsequent calculations were performed using Quattro Pro 6.0 for Windows 3.1.

9.2.2 Processing Changes

None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None.

9.3.2 Calculated Variables

stomatal limitation = [(amax-A)/amax]100 (Farquhar and Sharkey, 1982)

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

Errors are primarily caused by variation in researchers' measurement techniques and in instrumentation. The data have received a quality review by TE-10 personnel, and all known sources of calculation errors have been corrected.

10.2 Quality Assessment

Data have received a quality review by TE-10 personnel.

10.2.1 Data Validation by Source

Comparisons were made with other BOREAS results and with published results.

10.2.2 Confidence Level/Accuracy Judgment

None available, but it is felt that these data are accurate.

10.2.3 Measurement Error for Parameters

Not available.

10.2.4 Additional Quality Assessments

Calculated results were plotted and the plots were compared with those from published papers.

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.

11.2 Known Problems with the Data
None.

11.3 Usage Guidance
None.

11.4 Other Relevant Information
None.

12. Application of the Data Set

These data can be used for assessing photosynthetic differences between different species, age classes, and canopy layers in the boreal forest.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description
Calculations were performed using Quattro Pro 6.0 for Windows 3.1. This document was prepared using Microsoft Word 5.1a for the Macintosh.

14.2 Software Access
None given.

15. Data Access

The photo response 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

LI-3100 LI-COR Area Meter Manual. Publication number 8805-0055, June 1988. LI-COR, Inc., 4421 Superior Street, P.O. Box 4425, Lincoln, NÈ 68504-0425.

17.2 Journal Article and Study Reports

Farquhar, G.D. and T.D. Sharkey. 1982. Stomatal conductance and photosynthesis. Annu. Rev. Plant Physiol. v33: 317-345.

Kharouk, V.I., E.M. Middleton, S.L. Spensor, B.N. Rock, and D.L. Williams. 1995. Aspen bark photosynthesis and its significance to remote sensing and carbon budget estimates in the boreal ecosystem. Water, Air and Soil Pollution. V82: 483-497.

Middleton, E.M., E.W. Chappelle, and A. DeLuca. 1995. Evaluating photosynthesis in boreal forest species with fluorescence measurements. IGARSS 1995.

Middleton, E.M., J.H. Sullivan, B.D. Bovard, A.J. DeLuca, S.S. Chan, and T.A. Cannon. 1997. Seasonal variability in foliar characteristics and physiology for boreal forest species at the five Saskatchewan tower sites during the 1994 Boreal Ecosystem-Atmosphere Study. Journal of Geophysical Research 102(D24):28,831-28,844.

Munsell Color (Firm). 1977. Munsell Color Charts for Plants Tissues. 2nd ed. Munsell Color (Firm), Baltimore, MD, 6 pp. 17 color charts.

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.

Sullivan, J.H., B.D. Bovard, and E.M. Middleton. 1996. Variability in leaf-level CO_2 and water fluxes in Pinus banksiana and Picea mariana in Saskatchewan. Tree Physiol. V17: 553-561.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

A - The maximum assimilation reached by a plant's leaves/needles under light-saturating conditions and having stomatal limitations. This was measured in the field using an IRGA system.

A_{max} - The maximum assimilation reached by a plant's leaves/needles under light-saturating conditions and without stomatal limitations. This was measured in the laboratory using an oxygen electrode system.

Darkresp - The dark respiration by a plant's leaves/needles is the lowest assimilation rate reached (negative) under zero light illumination.

Stomatal limitation - The percent by which the stomates limit photosynthesis by a plant.

19. List of Acronyms

ASCII - American Standard Code for Information Interchange
BARC - Beltsville Agricultural Research Center
BOREAS - BOReal Ecosystem-Atmosphere Study
BORIS - BOREAS Information System
CD-ROM - Compact Disk-Read-Only Memory
DAAC - Distributed Active Archive Center
db - Dogbane
EOS - Earth Observing System
EOSDIS - EOS Data and Information System
GIS - Geographic Information System
GSFC - Goddard Space Flight Center
haz - Hazelnut
HTML - HyperText Markup Language
IFC - Intensive Field Campaign
IRGA - Infrared Gas Analyzer
NAD83 - North American Datum of 1983
NASA - National Aeronautics and Space Administration
NSA - Northern Study Area
OA - Old Aspen
OA-AUX - Old Aspen-Auxiliary
OBS - Old Black Spruce
OJP - Old Jack Pine
ORNL - Oak Ridge National Laboratory
PANP - Prince Albert National Park
PPFD - Photosynthetic Photon Flux Density
SSA - Southern Study Area
TE - Terrestrial Ecology
URL - Uniform Resource Locator
USDA - United States Department of Agriculture
UTM - Universal Transverse Mercator
WS - White Spruce
YA - Young Aspen
YA-AUX - Young Aspen-Auxiliary
YJP - Young Jack Pine

20. Document Information

20.1 Revision Date

Written: 21-Aug-1997
Last Updated: 13-Aug-1999

20.2 Document Review Date(s)

BORIS Review: 14-Aug-1998
Science Review:

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:

Middleton, E.M., of the Biospheric Sciences Branch, GSFC, NASA, and Sullivan, J.H., of the Department of Department of Natural Resource Sciences and Landscape Architecture, University of Maryland, College Park.

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

Middleton, E. and J. Sullivan, "CO_2 and Water Fluxes in the Boreal Forest Overstory: Relationship to fAPAR and Vegetation Indices for Needles/Leaves." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM. NASA, 2000.

20.5 Document Curator

20.6 Document URL

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 2000	Technical Memorandum

4. TITLE AND SUBTITLE
Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)
BOREAS TE-10 Photosynthetic Response Data

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

6. AUTHOR(S)
Elizabeth Middleton and Joseph Sullivan
Forrest G. Hall and Andrea Papagno, Editors

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

8. PEFORMING ORGANIZATION REPORT NUMBER
2000-03136-0

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

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
TM—2000–209891
Vol. 163

11. SUPPLEMENTARY NOTES
J. Sullivan: University of Maryland, College Park;
A. Papagno: Raytheon ITSS, NASA Goddard Space Flight Center, Greenbelt, Maryland

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

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The BOREAS TE-10 team collected several data sets in support of its efforts to characterize and interpret information on the gas exchange, reflectance, transmittance, chlorophyll content, carbon content, hydrogen content, nitrogen content, and photosynthetic response of boreal vegetation. This data set contains measurements of quantitative parameters and leaf photosynthetic response to increases in light conducted in the SSA during the growing seasons of 1994 and 1996 using an oxygen electrode system. Leaf photosynthetic responses were not collected in 1996. The data are stored in tabular ASCII files.

14. SUBJECT TERMS
BOREAS, terrestrial ecology, boreal vegetation.

15. NUMBER OF PAGES
20

16. PRICE CODE

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