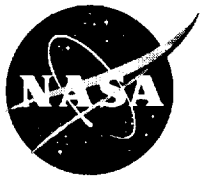
NASA/TM—2000–209891, Vol. 160



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

Forrest G. Hall and Andrea Papagno, Editors

Volume 160
BOREAS TE-10 Leaf Gas Exchange Data

E. Middleton and J. Sullivan

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

October 2000

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Joseph Sullivan, University of Maryland, College Park

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BOREAS TE-10 Leaf Gas Exchange 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 reflectance, transmittance, gas exchange, chlorophyll content, carbon content, hydrogen content, and nitrogen content of boreal vegetation. This data set contains measurements of assimilation, stomatal conductance, transpiration, internal CO_2 concentration, and water use efficiency conducted in the SSA during the growing seasons of 1994 and 1996 using a portable gas exchange system. The data are stored in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-10 Leaf Gas Exchange Data

1.2 Data Set Introduction

This data set describes the relationship between sample location, sample age, and photosynthetic parameters such as assimilation (A), stomatal conductance (Gs), transpiration (E), internal CO_2 concentration (CI), and water use efficiency (WUE) in the canopies of the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) at the Old Black Spruce (OBS), Old Jack Pine (OJP), Young Jack Pine (YJP), Old Aspen (OA), Young Aspen (YA), Auxiliary Young Aspen (YA-AUX), and the Auxiliary Old Aspen (OA-AUX) sites in 1994. In 1996, gas exchange data was taken at SSA OBS and SSA YA-AUX, where measurements of A, Gs, E, CI, WUE, and Photosynthetic Photon Flux Density (PPFD) were conducted on Picea mariana (Black Spruce) and Picea glauca (White Spruce) respectively. Photosynthetic parameters, A, Gs, E, CI, and WUE were examined as part of an effort to characterize differences between species, Intensive Field

Studies (IFCs), stand age, leaf position, and sample age in the boreal forest. This information will be useful for understanding variation in photosynthetic rates and in other data obtained during 1994. In 1994, samples were taken from seven locations in the SSA: OBS, OJP, YJP, OA, OA-AUX, YA-AUX, and YA during each of the three IFCs in 1994. These measurements were taken and recorded at the field sites using an Infrared Gas Analyzer (IRGA) system.

1.3 Objective/Purpose

The purposes of this work were to:

- Obtain a canopy profile of gas exchange parameters.
- Examine interspecific and interseasonal differences in these gas exchange parameters.

1.4 Summary of Parameters

Each data record includes the date of the measurements, A, Gs, E, CI, and WUE.

1.5 Discussion

Leaf-level gas exchange measurements were made in the field on the dominant broadleaf and coniferous woody plant species growing at the SSA OBS, YJP, OJP, YA, YA-AUX, OA, and OA-AUX sites in the boreal forest. These sites were measured during the IFCs in 1994. Measurements were also conducted at the SSA OBS and SSA YA-AUX during 1996. A single leaf on a broadleaf species was measured as a single measurement. An entire age class of needles on Pinus banksiana, Apocynum androsaemifolium, and Picea glauca was measured as a single measurement. For Picea mariana, age class 1994 was a single measurement, age classes 1993 and 1992 were a single measurement, and age classes 1991 and 1990 were a single measurement. In 1996, OBS measurements were taken from the top canopy and youngest foliage (age class 1996). In 1996, YA-AUX (Picea glauca) measurements were taken from the top canopy and 1995 and 1996 foliage.

1.6 Related Data Sets

BOREAS TE-04 Gas Exchange Data from Boreal Tree Species
BOREAS TE-05 Leaf Gas Exchange Data
BOREAS TE-10 Leaf Chlorophyll
BOREAS TE-10 Leaf Optical Properties
BOREAS TE-12 Leaf Gas Exchange Data

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

3. Theory of Measurements

Because CO_2 absorbs infrared radiation at specific wavelengths, photosynthetic CO_2 assimilation can be determined using an IRGA system. For this study, the ADC-IV Portable Photosynthesis System made by Analytical Development Corporation (ADC) was used in 1994 and 1996. In 1996 the LI 6200, another Portable Photosynthesis System made by LiCor was also used. CO_2 and H_2O fluxes were measured, and values of CO_2, A, E, and Gs were calculated, according to the equations of von Caemmerer and Farquhar (1991). Instantaneous WUE was calculated as A/E. See Sullivan and Teramura (1989).

4. Equipment

4.1 Sensor/Instrument Description

Portable photosynthesis system LCA-IV (ADC Co., LTD., Hoddesdon, England).

Portable photosynthesis system LI 6200 (LiCor, Lincon, NE).

4.1.1 Collection Environment

Gas exchange measurements and sample collections were made from platform canopy access towers constructed onsite by BOREAS staff at the OBS, OJP, OA, and OA-AUX sites and from the ground at the YA, YA-AUX, and YJP sites. Data were obtained during three discrete measurement periods (one to two measurement days each period) designated by BOREAS as IFCs (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), during midsummer or peak growing season (26-Jul-1994 to 8-Aug-1994), and at the onset of dormancy and senescence in autumn (30-Aug-1994 to 15-Sep-1994). In 1996, Picea mariana measurements were taken on the top canopy and youngest foliage (age class 1996) on 14-Jul-96 and 15-Jul-96. Picea glauca measurements were taken on the top canopy and on foliage from 1995 and 1996 on 19-Jun-96 and 09-Jul-96.

In 1994, measurements were made on intact branches from the upper, middle, 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. At OJP, measurements were made on Pinus banksiana using each needle class present (age classes 1994, 1993, 1992). At OJP, the understory species dogbane (Apocynum androsaemifolium) was measured during IFC-2. At YA-AUX, Picea glauca, age classes 1994 and 1993 of one canopy layer were measured during IFCs 2 and 3. For Picea mariana, the newest age class 1994 was measured alone, while the needles from age classes 1992 and 1993 were combined in one measurement, as were 1990 and 1991 age class needles. At the old and young aspen sites, there was a hazelnut (Corylus cornuta Marsh) understory that was measured during each IFC.

During 1994, in situ gas exchange rates were measured at each site during each IFC with an ADC-IV Portable Photosynthesis System (ADC, Hoddesdon, UK). CO_2 and H_2O fluxes were measured and values of CO_2, A, E, and Gs were calculated, according to the equations of von Caemmerer and Farquhar (1991). Single leaves and the needle age classes (as discussed) were placed inside the LCA-IV cuvette separately, and gas exchange measurements were taken. At least eight replicate measurements and sample collections 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. During 1996, in situ gas exchange rates were measured in the same manner as in 1994 using either the ADC-IV system or the LI 6200 Portable Photosynthesis System made by LiCor.

Measurements were made on relatively clear days between the hours of 0900 and 1300 local time. These days were chosen in part to coincide with other measurements (e.g., aircraft remote sensing and gas flux measurements) that were underway as part of the BOREAS project. Sampling was stratified across needle age and position to minimize variation due to time of day. All branch tips had been subjected to sunlight for several hours to ensure that photosynthetic activation had occurred before measurements began. Measurements were made under ambient temperature, relative humidity, and PPFD where possible. In 1994, artificial lighting (12-V quartz halogen lamp) was provided when ambient readings were below 1500 $\mu mol/m^2s$. Therefore, the 1994 values were considered to represent ambient light saturated gas exchange rates. In 1996, PPFD is given in the data set because the light level was not always saturating. Diurnal Picea mariana measurements were taken on 14-Jul-96 and 15-Jul-96. These gas exchange measurements were taken under ambient conditions, therefore artificial lighting was not used. Other Picea mariana measurements taken on 14-Jul-96 and the Picea glauce measurements had artificial lighting applied when the ambient light readings were below 1500 $\mu mol/m^2s$. Instantaneous WUE was calculated as A/E. Gas exchange rates were expressed on a half or hemisurface area basis standardized for the BOREAS project and obtained from the volume displacement method used by Sullivan and Teramura (1989).

4.1.2 Source/Platform

Gas exchange measurements were recorded in the field. Samples were taken from towers where available and were cut using knives.

4.1.3 Source/Platform Mission Objectives

Not applicable.

4.1.4 Key Variables

Leaf properties: assimilation, stomatal conductance, transpiration, internal CO_2 concentration, water use efficiency.

4.1.5 Principles of Operation

Gas exchange measurements and sample collections were made from platform canopy access towers constructed onsite by BOREAS staff at the OBS, OJP, OA, and OA-AUX sites and from the ground at the YA, YA-AUX, and YJP sites. Data were obtained during three discrete measurement periods (one to two measurement days each period) designated by BOREAS as IFCs (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), during midsummer or peak growing season (26-Jul-1994 to 8-Aug-1994), and at the onset of dormancy and senescence in autumn (30-Aug-1994 to 15-Sep-1994). In 1996, Picea mariana measurements were taken on the top canopy and youngest foliage (age class 1996) on 14-Jul-96 and 15-Jul-96. Picea glauca measurements were taken on the top canopy and on foliage from 1995 and 1996 on 19-Jun-96 and 09-Jul-96.

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4.1.6 Sensor/Instrument Geometry

On the towers at OA, OA-AUX, OBS, 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, YA-AUX, and YJP, 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.

4.1.7 Manufacturer of Sensor/Instrument

Portable Photosynthesis System
LCA-IV
Analytical Development Co., LTD.
Hoddesdon, England

Portable photosynthesis system LI 6200 Environmental Division
4421 Superior St.
Lincoln, NE 68504 U.S.A.
(402) 467-3576
(402) 467-2819 (fax)
1-800-447-3576 (U.S. & Canada)
envsales@env.licor.com
http://www.licor.com/ [Internet Link]

4.2 Calibration

4.2.1 Specifications

The portable photosynthetic system was accurate to within +/- 1 ppm.

4.2.1.1 Tolerance

No tolerance level was set.

4.2.2 Frequency of Calibration

The portable photosynthesis system LCA-IV and LI 6200 were calibrated at the start of each day of measurement.was calibrated at the start of each day of measurement.

4.2.3 Other Calibration Information

Calibration was completed using the BOREAS CO_2 standard of 350 ppm. This automatically reset the system to zero.

5. Data Acquisition Methods

Gas exchange measurements and sample collections were made from platform canopy access towers constructed onsite by BOREAS staff at the OBS, OJP, OA, and OA-AUX sites and from the ground at the YA, YA-AUX, and YJP sites. Data were obtained during three discrete measurement periods (one to two measurement days each period) designated by BOREAS as IFCs (IFC-1, -2, or -3). These IFCs were selected to measure parameters at bud breaks and leaf expansion (24-May-1994 to 12-June-1994), during midsummer or peak growing season (26-Jul-1994 to 8-Aug-1994), and at the onset of dormancy and senescence in autumn (30-Aug-1994 to 15-Sep-1994. In 1996, Picea mariana measurements were taken on the top canopy and youngest foliage (age class 1996) on 14-Jul-96 and 15-Jul-96. Picea glauca measurements were taken on the top canopy and on foliage from 1995 and 1996 on 19-Jun-96 and 09-Jul-96.

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6. Observations

Nothing out of the ordinary was observed.

6.1 Data Notes

TE-10 personnel note that there are low values in the data taken in 1996, and have left it up to the data users to decide where thay want to set the value limits of the data.

6.2 Field Notes

None.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

At the OJP, 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 least five trees were sampled at each site having the required layers for that site.

The SSA measurement sites and associated North American Datum of 1983 (NAD83) coordinates are:

- 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, UTM Zone 13, N:5,942,899.9 E:420,790.5.
- OA-AUX was the canopy access tower located by the trailhead/parking area for the path leading to the flux tower at the 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 OA from the flux tower site.
- OBS canopy access tower located at the flux tower site, site id G8I4T, Lat/Long: 53.98717° N, 105.11779° W, Universal Transverse Mercator (UTM) Zone 13, N:5,982,100.5 E;492,276.5.
- 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.
- YA canopy access tower, site id D0H4T, Lat/Long: 53.65601° N, 105.32314° W, Universal Transverse Mercator (UTM) Zone 13, N:5,945,298.9, E:478,644.1.
- 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.
- 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 available.

7.1.3 Spatial Resolution

These data are point source measurements at the given locations.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temperal Characteristics

7.2.1 Temperal Coverage

Gas exchange measurements 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. In 1996, Picea mariana measurements were taken on 14-Jul-96 and 15-Jul-96. Picea glauca measurements were taken on 19-Jun-96 and 09-Jul-96.

7.2.2 Temperal 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-OASP	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

In 1996, Picea mariana measurements were taken on 14-Jul-96 and 15-Jul-96. Picea glauca measurements were taken on 19-Jun-96 and 09-Jul-96.

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
TIME_OBS
SPECIES
CANOPY_LOCATION
SAMPLE_GROWTH_YEAR
SAMPLE_NUM
CO2_ASSIMILATION
STOMATAL_CONDUCT_CO2
TRANSPIRATION_RATE
INTERCELL_CO2_CONC
WATER_USE_EFF
DOWN_PPFD_CHAMBER
LEAF_AREA
COMMENTS
CRTFCN_CODE
REVISION_DATE

7.3.2 Variable Description/Definition

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

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) when the data were collected.
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_NUM	The number of the sample.
CO2_ASSIMILATION	CO2 assimilation on leaf area basis
STOMATAL_CONDUCT_CO2	Stomatal conductance of CO2
TRANSPIRATION_RATE	Transpiration rate
INTERCELL_CO2_CONC	Intercellular CO2 concentration
WATER_USE_EFF	Water use efficiency
DOWN_PPFD_CHAMBER	The incoming photosynthetic photon flux density measured in the chamber.
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.
COMMENTS	Descriptive information to clarify or enhance the understanding of the other entered data.
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
SPECIES	[none]
CANOPY_LOCATION	[none]
SAMPLE_GROWTH_YEAR	[unitless]
SAMPLE_NUM	[none]
CO2_ASSIMILATION	[micromoles CO2][meter^-2][second^-1]
STOMATAL_CONDUCT_CO2	[millimoles CO2][meter^-2][second^-1]
TRANSPIRATION_RATE	[millimoles H2O][meter^-2][second^-1]
INTERCELL_CO2_CONC	[parts per million]
WATER_USE_EFF	[micromoles CO2][millimole H2O^-1]
DOWN_PPFD_CHAMBER	[micromoles][meters^-2][second^-1]
LEAF_AREA	[millimeter^2]
COMMENTS	[none]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

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

Column Name	Data Source
SITE_NAME	[BORIS Designation]
SUB_SITE	[BORIS Designation]
DATE_OBS	[Human Observer]
TIME_OBS	[Laboratory Equipment]
SPECIES	[Human Observer]
CANOPY_LOCATION	[Human Observer]
SAMPLE_GROWTH_YEAR	[Human Observer]
SAMPLE_NUM	[Human Observer]
CO2_ASSIMILATION	[Laboratory Equipment]
STOMATAL_CONDUCT_CO2	[Laboratory Equipment]
TRANSPIRATION_RATE	[Laboratory Equipment]
INTERCELL_CO2_CONC	[Laboratory Equipment]
WATER_USE_EFF	[Laboratory Equipment]
DOWN_PPFD_CHAMBER	[Laboratory Equipment]
LEAF_AREA	[Laboratory Equipment]
COMMENTS	[Human Observer]
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-90A-FLXTR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE10-LGS01	9TE10-LGS02	None	None	None	None
DATE_OBS	25-MAY-94	15-JUL-96	None	None	None	None
TIME_OBS	0	2358	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
CANOPY_LOCATION	bottom	top	None	None	None	None
SAMPLE_GROWTH_YEAR	1991	1994	None	None	None	None
SAMPLE_NUM	1	20	None	None	None	None
CO2_ASSIMILATION	-1.92	19.9	-999	None	None	None
STOMATAL_CONDUCT_CO2	0	.64	-999	None	None	None
TRANSPIRATION_RATE	.19	6.43	-999	None	None	None
INTERCELL_CO2_CONC	0	640.1	-999	None	None	None
WATER_USE_EFF	-5.536	8.569	-999	None	None	None
DOWN_PPFD_CHAMBER	71.01	2107	None	None	None	None
LEAF_AREA	752	3921	None	None	None	None
COMMENTS	DIURNAL MEASUREMENT		None	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	30-JUL-98	07-SEP-99	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,TIME_OBS,SPECIES,CANOPY_LOCATION,SAMPLE_GROWTH_YEAR,
SAMPLE_NUM,CO2_ASSIMILATION,STOMATAL_CONDUCT_CO2,TRANSPIRATION_RATE,
INTERCELL_CO2_CONC,WATER_USE_EFF,CRTFCN_CODE,REVISION_DATE
'SSA-90A-FLXTR','9TE10-LGS01',26-MAY-94,-999,'Corylus cornuta','top','1994',18,
1.42,.07,2.71,292.1,.524,-999,-999,'','CPI',30-JUL-98
'SSA-90A-FLXTR','9TE10-LGS01',26-MAY-94,-999,'Corylus cornuta','top','1994',19,
.92,.05,1.87,299.3,.492,-999,-999,'','CPI',30-JUL-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 Formats

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

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

9. Data Manipulations

9.1 Formulae

None.

9.1.1 Derivation Techniques and Algorithms

None.

9.2 Data Processing Sequence

9.2.1 Processing Steps

Gas exchange measurements were recorded automatically by the IRGA system and later downloaded to a computer. Subsequent calculations were performed using Quattro Pro 6.0 for Windows 3.1.

9.2.2 Processing Changes

None.

9.3 Calculations

CO_2 and H_2O fluxes were measured, and values of CO_2, A, E, and were calculated, according to the equations of von Caemmerer and Farquhar (1991). WUE was calculated as A/E. Gas exchange rates were expressed on a half or hemisurface area basis standardized for the BOREAS project and obtained from the volume displacement method similar to Sullivan and Teramura (1989).

9.3.1 Special Corrections/Adjustments
None.

9.3.2 Calculated Variables
Instantaneous WUE was calculated as A/E.

9.4 Graphs and Plots
None.

10. Errors

Errors are primarily caused by variation in researchers measurement techniques and in instrumentation. The data have received a quality review by Terrestrial Ecology (TE)-10 personnel and the errors have been removed.

10.1 Sources of Errors
Errors are primarily caused by variation in researchers measurement techniques, the acquisition of measurements by multiple persons, and instrumentation variation. 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 given.

11.2 Known Problems with the Data
None.

11.3 Usage Guidance
TE-10 personnel note that there are low values in the 1996 data set, and have left it up to the data users to decide where thay want to set the value limits of the data.

11.4 Other Relevant Information
None.

12. Application of the Data Set

These data can be used to study the gas exchange of 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 and Excel 4.0 for the Macintosh. This document was prepared using Microsoft Word 5.1a for the Macintosh.

14.2 Software Access

None given.

15. Data Access

The leaf 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
Tabular American Standard Code for Information Interchange (ASCII) files.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation
LCA-IV Portable Photosynthesis System Manual, ADC Co., LTD., Hoddesdon, England.

17.2 Journal Article and Study Reports
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. IGARRS 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 (BOREAS). J. Geophys. Res. 102 (D24): 28, 831-844.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS REPORT (EXPLAN 94).

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. Boreal Ecosystem-Atmosphere Study (BOREAS):an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. V76: 1549-1577.

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS REPORT (OPS DOC 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. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS REPORT (OPS DOC 96).

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 Middleton, E.M. 1996. Variability in leaf-level CO2 and water fluxes in Pinus banksiana and Picea mariana in Saskatchewan. Tree Physiol. V17: 553-561.

Sullivan, J.H. and A.H. Teramura. 1989. The effects of ultraviolet-B radiation on loblolly pine. I. Growth, photosynthesis and pigment production in greenhouse-grown seedlings. Physiol. Plant. V77: 202-207.

von Caemmerer, S. and G.D. Farquhar. 1981. Some relationships between the biochemistry of photosynthesis and the gas exchange of leaves. Planta V153:376-387.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

A	- Assimilation
ADC	- Analytical Development Corporation
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
CI	- Internal CO2
DAAC	- Distributed Active Archive Center
db	- Dogbane
doy	- Julian Day of Year
E	- Transpiration
EOS	- Earth Observing System
EOSDIS	- EOS Data and Information System
GIS	- Geographic Information System
Gs	- Stomatal Conductance
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
NOAA	- National Oceanic and Atmospheric Administration
NSA	- Northern Study Area
OA	- Old Aspen (located 100 m from the flux tower)
OA-AUX	- Old Aspen (located 100 m from the access road)
OBS	- Old Black Spruce
OJP	- Old Jack Pine
ORNL	- Oak Ridge National Laboratory
PANP	- Prince Albert National Park
PPM	- Parts Per Million
SSA	- Southern Study Area

```
TE       - Terrestrial Ecology
URL      - Uniform Resource Locator
USDA     - United States Department of Agriculture
UTM      - Universal Transverse Mercator
WS       - White Spruce
WUE      - Water Use Efficiency
YA       - Young Aspen (located at the flux tower)
YA-AUX   - Young Aspen (near Snow Castle Lodge in the SSA)
YJP      - Young Jack Pine
```

20. Document Information

20.1 Revision Date

Written: 26-Jun-1997
Updated: 02-Mar-2000

20.2 Document Review Date(s)

BORIS Review: 12-Aug-1998
Science Review: 08-Sep-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:

Middleton, E.M., of the Biospheric Sciences Branch, GSFC, NASA and Sullivan, J. H. of the 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 Leaf Gas Exchange 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. 160

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 reflectance, transmittance, gas exchange, chlorophyll content, carbon content, hydrogen content, and nitrogen content of boreal vegetation. This data set contains measurements of assimilation, stomatal conductance, transpiration, internal CO_2 concentration, and water use efficiency conducted in the SSA during the growing seasons of 1994 and 1996 using a portable gas exchange system. The data are stored in tabular ASCII files.

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

15. NUMBER OF PAGES
18

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