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

Forrest G. Hall and Shelaine Curd, Editors

Volume 135

BOREAS TE-4 Gas Exchange Data from Boreal Tree Species

J.A. Berry, G.J. Collatz, J. Gamon, W. Fu, and A. Fredeen

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

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BOREAS TE-4 Gas Exchange Data from Boreal Tree Species

Joseph A. Berry, G. James Collatz, John Gamon, Wei Fu, Art Fredeen

Summary

The BOREAS TE-4 team collected steady-state gas exchange and reflectance data from several species in the BOREAS SSA during 1994 and in the NSA during 1996.. Measurements of light, CO_2, temperature, and humidity response curves were made by the BOREAS TE-4 team during the summers of 1994 and 1996 using intact attached leaves of boreal forest species located in the BOREAS SSA and NSA. These measurements were conducted to calibrate models used to predict photosynthesis, stomatal conductance, and leaf respiration. The 1994 and 1996 data can be used to construct plots of response functions or for parameterizing models. Parameter values are suitable for application in SiB2 (Sellers et al., 1996) or the leaf model of Collatz et al. (1991), and programs can be obtained from the investigators. The data are stored in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-04 Gas Exchange Data from Boreal Tree Species

1.2 Data Set Introduction

These data are summaries of steady-state gas exchange measurements conducted by the Terrestrial Ecology (TE)-04 team under field conditions in the summer of 1994 at the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) and during the summer of 1996 in the Northern Study Area (NSA).

1.3 Objective/Purpose

These studies were conducted to provide a basis for calibrating models of stomatal conductance, photosynthesis, and respiration used in simulating boreal ecosystem-atmosphere interactions.

1.4 Summary of Parameters

The parameters provided in each data set are intended to provide a sufficient description of the micro-environment of the leaf to permit the observations to be used for model validation. A complete list of the parameters is given in Section 4.1.4. The key measurements are the rates of net CO_2 exchange, the rate of evaporation of water from the leaf, the stomatal conductance to water vapor, and the intercellular CO_2 concentration.

1.5 Discussion

These data have been analyzed by nonlinear curve fitting programs to obtain parameter values suitable for application in SiB2 (Sellers et al., 1996) or the leaf model of Collatz et al. (1991). Validation of these calibration experiments is still in progress. Measurements of gas exchange under ambient conditions (nonsteady-state) with LI-COR 6200 instruments and studies with branch bags by the TE-11 team have been used for validation. Validation experiments for the 1994 data indicate that photosynthesis is accurately predicted by models based on these data. However, stomatal conductance of conifer species is underpredicted. The source of this problem has not been identified. Validation of the calibration experiments using the 1996 data is still in progress. Tree species measured in 1994 were black spruce (Picea mariana), aspen (Populus tremuloides), jack pine (Pinus banksiana), white spruce (Picea glauca), birch (Betula pumila), and hazel (Corylus cornuta). Tree species measured in 1996 were black spruce (Picea mariana), jack pine (Pinus banksiana), rosemary (Andromeda polifolia), bog bean (Menyanthes trifoliata), willow (Salix sp.), Carex (Carex sp.), and birch (Betula glandulosa).

1.6 Related Data Sets

BOREAS TE-05 CO2 Concentration and Stable Isotope Composition
BOREAS TE-09 NSA Photosynthetic Capacity and Foliage Nitrogen Data
BOREAS TE-09 PAR and Leaf Nitrogen Data for NSA Species
BOREAS TE-09 NSA Photosynthetic Response Data
BOREAS TE-09 NSA in situ Diurnal Gas Exchange of Boreal Forest Species
BOREAS TE-10 Leaf Optical Properties
BOREAS TE-12 Leaf Optical Data for SSA Species
BOREAS TE-12 Leaf Gas Exchange Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Joseph A. Berry
Dr. G. James Collatz
Dr. John Gamon
Dr. Wei Fu
Dr. Art Fredeen

2.2 Title of Investigation

Measurement and Prediction of CO_2 and H_2O Exchange from Boreal Forest Tree Species

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3. Theory of Measurements

The measurements reported here were made by generally accepted procedures for laboratory gas exchange. Leaves were enclosed in a cuvette that permitted precise control of the leaf environment (illumination, concentrations of CO_2 and H_2O, and temperature). Net exchange of CO_2 and H_2O was determined by infrared gas analysis of the air flowing through the stirred cuvette. See Field et al. (1989) for more information.

4. Equipment

4.1 Sensor/Instrument Description

For 1994: Gas exchange system (Model MPH-1000; Campbell Scientific, Logan, UT) Infrared Gas Analyzer (IRGA) (Model 6262; LI-COR, Inc., Lincoln, NE) Dew Point Mirror (Model Dew-10; General Eastern, Woburn, MA)

For 1996: Gas exchange system (Model LI-COR-6400, 4421 Superior Street, Lincoln, NE)

4.1.1 Collection Environment

All experiments were conducted with intact attached leaves/needles near the top of canopies in the BOREAS SSA. For specific weather conditions on experiment days, see meteorological data files.

4.1.2 Source/Platform

Equipment was located on canopy access towers.

4.1.3 Source/Platform Mission Objectives

The experiments were conducted to calibrate models of photosynthesis, stomatal regulation, and respiration for canopy leaves/needles.

4.1.4 Key Variables

atmospheric pressure boundary layer resistance ambient water vapor pressure ambient CO_2 concentration ambient temperature flux density of photosynthetically active radiation (PAR) shortwave radiation longwave radiation leaf temperature CO_2 concentration at leaf surface relative humidity at leaf surface CO_2 concentration in intercellular air spaces net photosynthetic rate stomatal conductance transpiration rate

4.1.5 Principles of Operation

The gas exchange system was an open or steady-state system. Temperature, CO_2 concentration, and H_2O vapor pressure were determined with appropriate sensors. Net CO_2 and H_2O exchange was determined by mass balance analysis of the air flowing through the cuvette. Gas exchange parameters, Ci, Gsw were calculated.

4.1.6 Sensor Instrument Measurement Geometry

Leaves/needles were enclosed in a cuvette. All measurements are expressed on a leaf area basis; for the conifers, this is reported as the hemisurface area of the needles (half of the total surface area) as determined by volume displacement (J. Norman, personal communication); the area of bilateral leaves is expressed as the single-sided area or projected area.

4.1.7 Manufacturer of Sensor/Instrument

For 1994: Gas exchange system (Model MPH-1000; Campbell Scientific, Logan, UT) IRGA (Model 6262; LI-COR, Inc., Lincoln, NE) Dew Point Mirror (Model Dew-10; General Eastern, Woburn, MA)

For 1996: Gas exchange system (Model LICOR-6400, 4421 Superior Street, Lincoln, NE)

4.2 Calibration

CO_2 concentration was referenced to standard CO_2 tanks provided by BOREAS. H_2O vapor was referenced to a dew point mirror instrument. Air flow was calibrated by volume displacement. PAR flux was referenced to a LI-COR quantum probe. The LI-COR-6400 was well-calibrated before the 1996 summer campaign.

4.2.1 Specifications

There are no published specifications for the complete system of instruments used in this study.

4.2.1.1 Tolerance

All calibrations are better than +/- 1%.

4.2.2 Frequency of Calibration

In 1994, calibration and instrument zeros were checked daily. Checks against the BOREAS gas standards occurred every week or two. In 1996, calibration and instrument zeros were checked before each experiment and when controlled CO_2 concentration or temperature was changed.

4.2.3 Other Calibration Information

No significant adjustments or drift of calibration occurred over the interval of these measurements.

5. Data Acquisition Methods

These measurements were decoupled from the ambient environment. There is no direct correspondence between the temperature, light intensity, or other environmental conditions in the cuvette during these experiments and the ambient environmental conditions at the site of the measurements.

In each gas exchange experiment, chamber CO_2 concentration (Ca), incident flux density of PAR (PFD), or chamber air temperature (Ta) was varied while other factors were held constant. Generally, it took about 30 minutes for stomatal conductance and photosynthetic rate to reach steady-state after the conditions were changed. The transient responses were monitored, but data were reported only when the leaves had reached steady-state at a new condition. CO_2 responses were measured at a high PFD (about 1000 (µmol/m^2/s) and a high chamber humidity (70%-80%) at various temperatures. For light response curves, the leaf was preconditioned to 1000 (µmol/m^2/s; light was then increased in increments of about 300 (µmol/m^2/s until saturation was evident and then decreased in steps to zero. Temperature responses were measured by increasing the chamber temperature while PFD was rate-saturating and keeping the dew point temperature of inlet air constant. The starting temperature was low (about 15 °C), and the chamber temperature was increased by about 2.5 °C per step up to the highest chamber temperature that the gas exchange system could reach in field (about 38 °C). This protocol was chosen to mimic the covariation of leaf temperature and vapor pressure deficit that occurs naturally on warm, dry days in this environment. Dark respiration was measured in CO_2-free air. These conditions were chosen to obtain maximum sensitivity and stability to resolve the small differentials of CO_2 concentration produced by respiration. The pattern of increasing chamber temperature was the same as that in the measurements of temperature response of net photosynthetic rate.

6. Observations

6.1 Data Notes

The experiments were conducted over a 2-month interval in 1994 and over a 1-month interval in 1996, spending a few consecutive days at each site. The studies were conducted with a few selected leaves at each site. TE-04 team members believe that these measurements are representative of the leaves at the site, but it was not possible to obtain a statistically representative sample. Measurements conducted with clip-on instruments such as the LI-COR 6200 photosynthesis system can be used to assess variation in leaf properties with time and location at these sites. In 1996, another sort of gas exchange measurements with approximate 1 m^2 leaf area and ambient environmental conditions was conducted at the same time for each conifer species. This provided an opportunity to check these calibrations at an intermediate scale.

6.2 Field Notes

Not available.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

In 1994:

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

- OA, site id C3B7T, Lat/Long: 53.62889°N, 106.19779°W, Universal Transverse Mercator (UTM) Zone 13, N: 5942899.9, E: 420790.5.
- OJP, site id G2L3T, Lat/Long: 53.91634°N, 104.69203°W, UTM Zone 13, N: 5974257.5, E: 520227.7.
- YJP, site id F8L6T, Lat/Long: 53.87581°N, 104.64529°W, UTM Zone 13, N: 5969762.5, E: 523320.2.
- OBS, site id G8I4T, Lat/Long: 53.98717°N, 105.11779°W, UTM Zone 13, N: 5982100.5, E: 492276.5.
- MIX, site id D9I1M, Lat/Long: 53.7254°N, 105.20643°W, UTM Zone 13, N: 5952989.7, E: 486379.7.

In 1996:

These NSA measurement sites and associated NAD83 coordinates are:

- OBS, site id T3R8T, Lat/Long: 55.88007°N, 98.48139°W, UTM Zone 14, N: 6,192,853.4, E: 532,444.5.
- OJP, site id T7Q8T, Lat/Long: 55.92842°N, 98.62396°W, UTM Zone 14, N: 6,198,176.3, E: 523,496.2.
- YJP, site id T8S9T, Lat/Long: 55.89575°N, 98.28706°W, UTM Zone 14, N: 6,194,706.9, E: 544,583.9.
- FEN, site id T7S1T, Lat/Long: 55.91481°N, 98.42072° W, UTM Zone 14, N: 6,196,749.6, E: 536,207.9.

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

The leaf area used in these measurements was typically 15-20 cm^2 on a given tree branch at the site.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

In 1994, data were collected over a 2-month interval starting on 21-Jul and ending on 01-Sep. In 1996, data were collected over a 1-month interval starting in July and ending in August.

7.2.2 Temporal Coverage Map

Not available.

7.2.3 Temporal Resolution

In most cases, data were taken during a series of days at the same site.

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
ATMOSPHERIC_PRESS
BOUND_LAYER_RESIST
AMB_WATER_VAPOR_PRESS
AMB_CO2_CONC
AMB_AIR_TEMP
DOWN_PPFD
DOWN_SHORTWAVE_RAD
DOWN_LONGWAVE_RAD
LEAF_TEMP
CO2_CONC_LEAF_SURF
REL_HUM_LEAF_SURF
INTERCELL_CO2_CONC
PHOTOSYNTHETIC_RATE
STOMATAL_MOLAR_CONDUCT_CO2
TRANSPIRATION_RATE
SPECIES
PARAM_VARIED
COMMENTS
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	The Greenwich Mean Time (GMT) when the data were collected.
ATMOSPHERIC_PRESS	The atmospheric pressure.
BOUND_LAYER_RESIST	Boundary layer resistance
AMB_WATER_VAPOR_PRESS	Ambient water vapor pressure
AMB_CO2_CONC	Ambient CO2 concentration.
AMB_AIR_TEMP	Ambient air temperature.
DOWN_PPFD	The downward photosynthetic photon flux density.
DOWN_SHORTWAVE_RAD	The total downward shortwave (solar) radiation.
DOWN_LONGWAVE_RAD	The total downward longwave radiation.
LEAF_TEMP	The leaf or shoot temperature
CO2_CONC_LEAF_SURF	CO2 concentration at leaf surface.
REL_HUM_LEAF_SURF	Relative humidity at leaf surface.
INTERCELL_CO2_CONC	Intercellular CO2 concentration
PHOTOSYNTHETIC_RATE	Measured Net Photosynthesis
STOMATAL_MOLAR_CONDUCT_CO2	Stomatal conductance of CO2
TRANSPIRATION_RATE	Transpiration rate
SPECIES	Botanical (Latin) name of the species (Genus species).
PARAM_VARIED	The parameter varied to study photosynthetic response to BOREAL tree species. i.e. CO2 CONCENTRATION = CO2 varied; LIGHT=light varied; TEMPERATURE = temperature varied; VAPOR PRESS DEFICIT = vapor pressure deficit varied; WATER POTENTIAL = Water potential varied; DARK RESPIRATION = temperature varied in dark; HIMIDITY = humidity varied; CONSTANT CONDITIONS = nothing varied; STOMATAL MODEL = many things varied for model calibration.
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 onthe CD-ROM are:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME	[HHMMSS GMT]
ATMOSPHERIC_PRESS	[kiloPascals]
BOUND_LAYER_RESIST	[meters^2][second][mole^-1]
AMB_WATER_VAPOR_PRESS	[Pascals]
AMB_CO2_CONC	[micromoles CO2][mole^-1]
AMB_AIR_TEMP	[degrees Celsius]
DOWN_PPFD	[micromoles][meter^-2][second^-1]
DOWN_SHORTWAVE_RAD	[Watts][meter^-2]
DOWN_LONGWAVE_RAD	[Watts][meter^-2]
LEAF_TEMP	[degrees Celsius]
CO2_CONC_LEAF_SURF	[micromoles CO2][mole^-1]
REL_HUM_LEAF_SURF	[percent]
INTERCELL_CO2_CONC	[parts per million]
PHOTOSYNTHETIC_RATE	[micromoles CO2][meter^-2][second^-1]
STOMATAL_MOLAR_CONDUCT_CO2	[millimoles CO2][meter^-2][second^-1]
TRANSPIRATION_RATE	[millimoles H2O][meter^-2][second^-1]
SPECIES	[none]
PARAM_VARIED	[none]
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 onthe CD-ROM are:

Column Name	Data Source
SITE_NAME	[BORIS Designation]
SUB_SITE	[BORIS Designation]
DATE_OBS	[Human Observer]
TIME	[Human Observer]
ATMOSPHERIC_PRESS	[Laboratory Equipment]
BOUND_LAYER_RESIST	[Laboratory Equipment]
AMB_WATER_VAPOR_PRESS	[Laboratory Equipment]
AMB_CO2_CONC	[Laboratory Equipment]
AMB_AIR_TEMP	[Thermometer]
DOWN_PPFD	[Laboratory Equipment]
DOWN_SHORTWAVE_RAD	[Laboratory Equipment]
DOWN_LONGWAVE_RAD	[Laboratory Equipment]
LEAF_TEMP	[Thermometer]
CO2_CONC_LEAF_SURF	[Laboratory Equipment]
REL_HUM_LEAF_SURF	[Laboratory Equipment]
INTERCELL_CO2_CONC	[Laboratory Equipment]

PHOTOSYNTHETIC_RATE	[Laboratory Equipment]
STOMATAL_MOLAR_CONDUCT_CO2	[Laboratory Equipment]
TRANSPIRATION_RATE	[Laboratory Equipment]
SPECIES	[Human Observer]
PARAM_VARIED	[Human Observer]
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 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-FEN-FLXTR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE04-GSE01	9TE04-GSE01	None	None	None	None
DATE_OBS	21-JUL-94	12-AUG-96	None	None	None	None
TIME_OBS	1	2348	None	None	None	None
ATMOSPHERIC_PRESS	93.3	98.73	None	None	None	None
BOUND_LAYER_RESIST	.2	.29	None	None	None	None
AMB_WATER_VAPOR_ PRESS	251.2	3460.9	None	None	None	None
AMB_CO2_CONC	.1	880.7	None	None	None	None
AMB_AIR_TEMP	7	41.93	None	None	None	None
DOWN_PPFD	-.3	2633	None	None	None	None
DOWN_SHORTWAVE_RAD	0	1122.33	None	None	None	None
DOWN_LONGWAVE_RAD	349	558.91	None	None	None	None
LEAF_TEMP	6.18	39.77	None	None	None	None
CO2_CONC_LEAF_SURF	.4	870.17	None	None	None	None
REL_HUM_LEAF_SURF	11.23	92	None	None	None	None
INTERCELL_CO2_CONC	-187.8	16157.5	None	None	None	None
PHOTOSYNTHETIC_RATE	-3.44	30.51	None	None	None	None
STOMATAL_MOLAR_ CONDUCT_CO2	-19402.1	3835.5	None	None	None	None
TRANSPIRATION_RATE	-.7141	4.79	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
PARAM_VARIED	N/A	N/A	None	None	None	None
COMMENTS	N/A	N/A	None	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	10-FEB-97	22-DEC-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 fileon the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,ATMOSPHERIC_PRESS,BOUND_LAYER_RESIST,
AMB_WATER_VAPOR_PRESS,AMB_CO2_CONC,AMB_AIR_TEMP,DOWN_PPFD,DOWN_SHORTWAVE_RAD,
DOWN_LONGWAVE_RAD,LEAF_TEMP,CO2_CONC_LEAF_SURF,REL_HUM_LEAF_SURF,
INTERCELL_CO2_CONC,PHOTOSYNTHETIC_RATE,STOMATAL_MOLAR_CONDUCT_CO2,
TRANSPIRATION_RATE,SPECIES,PARAM_VARIED,COMMENTS,CRTFCN_CODE,REVISION_DATE
'SSA-9OA-FLXTR','9TE04-GSE01',17-AUG-94,1017,96.5,.29,1894.1,338.8,20.24,1221.4,
266.0,420.0,20.32,330.7,81.9,255.7,20.27,447.2,2.0538,'Populus tremuloides',
'LIGHT','','CPI',10-FEB-97
'SSA-9OA-FLXTR','9TE04-GSE01',17-AUG-94,1023,96.5,.29,1865.9,339.5,20.41,861.9,
187.0,421.0,20.3,331.7,80.5,245.6,19.71,377.4,1.8563,'Populus tremuloides',
'LIGHT','','CPI',10-FEB-97
```

8. Data Organization

8.1 Data Granularity

The smallest unit of orderable data is data collected on one day at one site.

8.2 Data Format

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

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

9. Data Manipulations

9.1 Formulae

Calculation of gas exchange parameters was conducted essentially as described by Ball (1987).

9.1.1 Derivation Techniques and Algorithms

Calculation of gas exchange parameters was conducted essentially as described by Ball (1987).

9.2 Data Processing Sequence

Data were logged by a laptop computer and calculations were conducted concurrent with the measurements. All of the primary data are archived.

9.2.1 Processing Steps

The data points presented represent the mean of at least five sequential measurements.

9.2.2 Processing Changes

None given.

9.3 Calculations

The calculations are as described by Ball (1987).

9.3.1 Special Corrections/Adjustments

None given.

9.3.2 Calculated Variables

Calculation of gas exchange parameters was conducted essentially as described by Ball (1987).

9.4 Graphs and Plots

Plots of these experiments are available as PostScript files by anonymous ftp to biosphere.stanford.edu. Some of these may be found in the directory /submissions/Boreas_data/PS_files or http://biosphere.stanford.edu/ [Internet Link].

10. Errors

10.1 Sources of Error

Uncertainty in these experiments arises from instrument noise and systematic calibration errors, and because the leaf experiences somewhat different conditions in the cuvette (e.g., spectral composition or anisotropy of light) than it would in a natural environment.

10.2 Quality Assessment

10.2.1 Data Validation by Source

The calibration data sets derived from analysis of these data are being checked against observations of CO_2 and water vapor exchange taken at various scales: (a) independent leaf-scale measurements (b) branch-scale measurements made by TE-11, and (c) flux observations made at the respective towers.

10.2.2 Confidence Level/Accuracy Judgment

These data have been carefully checked and are equal in quality to measurements conducted under laboratory conditions.

10.2.3 Measurement Error for Parameters

- Gsw, stomatal conductance, +/- 5 (µmol/(m^2 sec)
- A, net CO_2 exchange, +/- 0.1 mmol m^2/s
- Ci, intercellular CO_2, +/- 5 mmol/mol

10.2.4 Additional Quality Assessments

None.

10.2.5 Data Verification by Data Center

Data were examined for general consistency and clarity.

11. Notes

11.1 Limitations of the Data

Unknown.

11.2 Known Problems with the Data

In 1994: The stomatal conductance observed with conifer species in these experiments is uniformly lower than that which occurs under similar environmental conditions in nature, possibly because the tungsten-halogen lamp used for illumination in these experiments contains less blue light than natural sunlight. The studies with aspen, hazel, and birch appear to be okay. Another problem with the conifer data sets concerns relating these measurements to the estimates of leaf area made at the canopy-scale. The measurements reported here are for actual hemispheric leaf area. The canopy-scale estimates reported by the BOREAS Remote Sensing Science (RSS)-23 team and others are an "effective leaf area" obtained by inversion of a radiation transport model. The exact correspondence between these different measures of leaf area is not known.

In 1996: The light intensities reported here were measured in the chamber perpendicular to the incident light. The light could not illuminate each needle in the chamber completely. This might cause underestimates of photosynthetic capacities of conifer species.

11.3 Usage Guidance

In 1994 data: Validation experiments indicate that the stomatal slope parameter, gradn, used in SiB2 or the Collatz et al. (1990) model should be approximately 7 for black spruce and jack pine. The effective vmax0 of needles should be increased for canopy simulations to account for clumping and self shading of needles.

In 1996 data: A problem with the conifer data sets concerns relating these measurements to the estimates of leaf area made at the canopy-scale. The measurements reported here are for actual hemispheric leaf area. The canopy-scale estimates reported by the BOREAS RSS-23 team and others are an "effective leaf area" obtained by inversion of a radiation transport model. We do not know the exact correspondence between these different measures of leaf area. Validation experiments indicate that the stomatal slope parameter, gradn, used in SiB2 or the Collatz et al. (1990) model should be approximately 7 for black spruce and jack pine. The effective vmax0 for canopy simulations should be adjusted to account for clumping and self shading of needles.

11.4 Other Relevant Information

None.

12. Application of the Data Set

The data set has been analyzed by nonlinear curve fitting programs to obtain parameters for models. These parameters will eventually be made available for distribution. Preliminary estimates can be obtained from J. Berry or http://biosphere.stanford.edu.

13. Future Modification and Plans

None.

14. Software

14.1 Software Description

SiB2 is in FORTRAN and runs in a workstation environment. The Collatz et al. (1991) model is in C and can be run on PCs or workstations.

14.2 Software Access

Copies of SiB2 or the Collatz et al. (1991) model can be obtained from J. Berry.

15. Data Access

The TE-04 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

None.

17.2 Journal Articles and Study Reports

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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.

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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
Ca - Ambient CO_2 concentration
CD-ROM - Compact Disk-Read-Only Memory
Ci - CO_2 concentration in intercellular air spaces
Cs - CO_2 concentration at leaf surface
DAAC - Distributed Active Archive Center
E - Transpiration rate
ea - ambient water vapor pressure
EOS - Earth Observing System
EOSDIS - EOS Data and Information System
GIS - Geographic Information System
GMT - Greenwich Mean Time
GSFC - Goddard Space Flight Center
Gsw - Stomatal conductance
Hs - Relative humidity at leaf surface
HTML - HyperText Markup Language
IRGA - Infrared Gas Analyzer
LW - Longwave radiation
NASA - National Aeronautics and Space Administration
NSA - Northern Study Area
OA - Old Aspen
OBS - Old Black Spruce
OJP - Old Jack Pine
ORNL - Oak Ridge National Laboratory
PANP - Prince Albert National Park
PAR - Photosynthetically Active Radiation
PFD - flux density of photosynthetically active radiation (PAR)
PFD-PAR - Flux Density
Pn - net photosynthetic rate
P0 - Atmospheric pressure
rbw - Boundary layer resistance
RSS - Remote Sensing Science
SSA - Southern Study Area
SW - Shortwave radiation

```
Ta      - Ambient temperature
TE      - Terrestrial Ecology
Tl      - Leaf temperature
URL     - Uniform Resource Locator
UTM     - Universal Transverse Mercator
YA      - Young Aspen
YJP     - Young Jack Pine
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When using these data, please include the following acknowledgment as well as citations of relevant papers in Section 17.2:

Dr. Joseph A. Berry, Carnegie Institution of Washington, Stanford, CA 94305 Dr. G. James Collatz, Code 923, NASA GSFC, Greenbelt, MD 20771 Dr. John Gamon, Department of Biology, CSU--LA, Los Angeles, CA 90032 Dr. Wei Fu, Carnegie Institution of Washington, Stanford, CA 94305 Dr. Art Fredeen, Fac. of Natural Resources and Environmental Studies, University of N.B.C., Prince George, B.C., Canada.

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13. ABSTRACT *(Maximum 200 words)*

The BOREAS TE-4 team collected steady-state gas exchange and reflectance data from several species in the BOREAS SSA during 1994 and in the NSA during 1996.. Measurements of light, CO_2, temperature, and humidity response curves were made by the BOREAS TE-4 team during the summers of 1994 and 1996 using intact attached leaves of boreal forest species located in the BOREAS SSA and NSA. These measurements were conducted to calibrate models used to predict photosynthesis, stomatal conductance, and leaf respiration. The 1994 and 1996 data can be used to construct plots of response functions or for parameterizing models. Parameter values are suitable for application in SiB2 (Sellers et al., 1996) or the leaf model of Collatz et al. (1991), and programs can be obtained from the investigators. The data are stored in tabular ASCII files.

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