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BOREAS TE-12 Leaf Gas Exchange Data

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BOREAS TE-12 Leaf Gas Exchange Data

Timothy J. Arkebauer, Litao Yang

Summary

The BOREAS TE-12 team collected several data sets in support of its efforts to characterize and interpret information on the reflectance, transmittance, and gas exchange of boreal vegetation. This data set contains measurements of leaf gas exchange conducted in the SSA during the growing seasons of 1994 and 1995 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-12 Leaf Gas Exchange Data

1.2 Data Set Introduction

Field studies of single leaf gas exchange properties of dominant vascular plant species were conducted at the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) in 1994 and 1995 using a portable gas exchange system.

1.3 Objective/Purpose

The purposes of the work were to:

- Quantify the response of leaf gas exchange properties (e.g., net CO_2 assimilation rate and stomatal conductance) to environmental conditions in the field.
- Determine diurnal and seasonal changes in leaf gas exchange properties.

1.4 Summary of Parameters

Each data record includes the date and time of measurements, leaf properties (species, leaf area, boundary layer conductance, leaf temperature, net CO_2 assimilation rate, stomatal conductance, internal CO_2 concentration), and environmental conditions (Photosynthetic Photon Flux Density (PPFD), air temperature, CO_2 concentration, relative humidity, air vapor pressure).

1.5 Discussion

The overall project goal was to investigate the interactions between single leaf (or shoot) gas exchange properties and leaf (or shoot) optical properties. Leaf-level gas exchange measurements were made in the field on the dominant broadleaf and coniferous woody plant species growing in the SSA. The primary focus was on Populus tremuloides (aspen) at the SSA Young Aspen (YA) site and Pinus banksiana (jack pine) at the SSA Young Jack Pine (YJP) site. Measurements were also obtained from Picea mariana (black spruce) at the SSA Old Black Spruce (OBS) site, old Populus tremuloides (old aspen) and Picea glauca (white spruce) at the SSA Mixed site (MIX), old aspen and Corylus cornuta Marsh (hazelnut) from the SSA Old Aspen (OA) site, and hazelnut and Populus balsamifera (balsam-poplar) from the SSA-YA site.

1.6 Related Data Sets

BOREAS TE-04 Gas Exchange Data from Boreal Tree Species
BOREAS TE-05 Leaf Gas Exchange Data
BOREAS TE-12 Leaf Optical Data for SSA Species
BOREAS TE-12 SSA Water Potential Data
BOREAS TE-12 SSA Shoot Geometry Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Timothy J. Arkebauer, Associate Professor

2.2 Title of Investigation

Radiation and Gas Exchange of Canopy Elements in a Boreal Forest

2.3 Contact Information

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3. Theory of Measurements

Gas exchange measurements were made using an LI-6200 CO_2 Infrared Gas Analyzer (IRGA) system in the closed-circuit mode. The net CO_2 assimilation rate is calculated via the change in CO_2 concentration in the sample chamber with time. Stomatal conductance is calculated from the rate of change of water vapor concentration with time, the fraction of the total system flow through the desiccant, and the (previously determined) boundary layer conductance of the leaf. Further details can be found in the LI-6200 Technical Reference Manual (LI-COR, Inc., 1990).

Internal CO_2 concentrations of the leaves were calculated based on the measured net CO_2 assimilation rates and leaf conductances. Additional information on the theory related to leaf gas exchange measurements can be found in Ball (1987).

4. Equipment

4.1 Instrument Description

4.1.1 Collection Environment

All gas exchange measurements were made on intact plants in the field at the various SSA sites mentioned in Section 1.5.

4.1.2 Source/Platform

In most cases, measurements were made from the ground. At the SSA-OA, SSA-MIX, and SSA-OBS sites, measurements were made at the top of the Terrestrial Ecology (TE) scaffold towers.

4.1.3 Source/Platform Mission Objectives

Not applicable.

4.1.4 Key Variables

Leaf properties: net CO_2 assimilation rate, stomatal conductance, internal CO_2 concentration, leaf temperature. Environmental conditions: air temperature, air vapor pressure, incident PPFD, air CO_2 concentration.

4.1.5 Principles of Operation

Measurements were made with an LI-6200 Portable Photosynthesis System operated in the closed mode. Net CO_2 assimilation rate was determined from the time rate of change of CO_2 concentration in the sample chamber. Stomatal conductance was determined from the time rate of change of water vapor concentration in the chamber, in conjunction with the fraction of the system flow diverted through the desiccant and the (previously determined) leaf boundary layer conductance. CO_2 concentrations are measured with an IRGA. A pump circulates the air from the sample chamber, through the analyzer, and back into the sample chamber. Water vapor concentrations in the sample chamber are determined by a Vaisala humidity chip and a thermistor sensing the air temperature. Leaf temperatures are

determined by a thermocouple pair that measures the temperature difference between the air thermistor and a thermocouple appressed to the leaf. Additional information is found in the LI-COR LI-6200 Technical Reference Manual.

4.1.6 Sensor/Instrument Measurement Geometry

None.

4.1.7 Manufacturer of Instrument

LI-6200 CO2 Gas IRGA
LI-COR, Inc.
P.O. Box 4425
4421 Superior Street
Lincoln, NE 68504 USA
(402) 467-3576
(402) 467-2819 (fax)

4.2 Calibration

4.2.1 Specifications

The IRGAs, the humidity chips, the flow meters, and the quantum sensors were calibrated by the manufacturer prior to each field season. The zero and span of the LI-6200 CO_2 analyzer were calibrated against known standard gases in the field.

4.2.1.1 Tolerance

None.

4.2.2 Frequency of Calibration

Annual calibration of the IRGAs, the humidity chips, the flow meters, and the quantum sensors was done by the manufacturer. Daily calibration of the zero and span of the IRGAs was performed in the field. The CO_2 zero and the flow meter zero were checked and adjusted several times daily.

4.2.3 Other Calibration Information

Calibration gases for the IRGAs were obtained from Acklands, 1042 Quebec Ave., Saskatoon, Saskatchewan CANADA, S7K 1V5 (Primary supplier: Linde Gas, Alberta, CANADA). These gases were calibrated against gases of known concentration traceable to the National Oceanic and Atmospheric Administration (NOAA), Boulder, CO.

5. Data Acquisition Methods

Samples from the coniferous species (e.g., Pinus banksiana, Picea mariana) were excised immediately after gas exchange measurements for leaf area determination. Leaf areas (i.e., surface areas of the needles enclosed in the gas exchange cuvette) were determined at the Paddockwood School Laboratory in the evening following the daily field work.

A positive net CO_2 assimilation rate (e.g., photosynthesis) means that the net flux of CO_2 is into the leaf. A negative net CO_2 assimilation rate (e.g., respiration) indicates that the net flux of CO_2 is out of the leaf.

Measurements of leaves from the broadleaf species (Populus tremuloides, Populus balsamifera, and Corylus cornuta) were made by enclosing entire leaves, or portions thereof, inside the sample cuvette. Small shoots of the coniferous species (Pinus banksiana, Picea mariana, Picea glauca), consisting of a number of needles, were placed into the sample cuvette for gas exchange determination. The coniferous samples consisted of needles from one age class only. The other age class needles were either excluded from the cuvette or were clipped off from the branch.

The LI-6200 measurements were made with either a 0.25-liter or a 1-liter sample chamber. Most measurements were made under natural illumination (sunlight); however, a limited number of measurements were made with an incandescent light source in conjunction with a dichroic mirror. Leaves to be measured were placed in the sample chamber without altering their original orientation. The sample chamber was held with a tripod standing on the soil (or scaffold) surface. Light response curves were usually made by attenuating natural illumination with neutral density filters. Respiration rates were determined after enclosing leaves in an opaque film-changing bag.

Assimilation rate versus internal CO_2 concentration responses were determined using a transient technique. The net CO_2 assimilation rate and the internal CO_2 concentrations for these studies were corrected for chamber leaks, and an external fan was used to moderate chamber temperatures (for details see McDermitt et al., 1989).

Leaf areas for the broadleaf species were determined by tracing the leaf outline on ruled graph paper. Leaf areas for the coniferous species were determined by the volume displacement method. Shoots were submerged in a water-filled container (containing 3-5% detergent in order to wet all surfaces) and the volume of water they displaced was recorded. The displaced volume was proportional to the total surface area of the shoot (see below). All gas exchange values are expressed on half the total surface area of the sample (for the broadleaf species this is the area projected normal to the leaf surface).

6. Observations

6.1 Data Notes

None.

6.2 Field Notes

A limited set of field notes and observations is available by request from T.J. Arkebauer.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

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

- SSA-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
- 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, UTM Zone 13, N:5,942,899.9 E:420,790.5
- SSA-OBS canopy access tower located at flux tower site, site id G8I4T, Lat/Long: 53.98717°N, 105.11779°W, UTM Zone 13, N:5,982,100.5E;492,276.5
- SSA-MIX canopy access tower, site id D9I1M, Lat/Long: 53.7254°N, 105.20643°W, UTM Zone 13, N:5,952,989.7, E:486,379.7
- SSA-YJP near 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 Temporal Characteristics

7.2.1 Temporal Coverage
Measurements were made from 29-May-1994 through 08-Sep-1994 and from 01-Jul-1995 through 07-Aug-1995. For each species and each year, data are arranged chronologically in the data file.

7.2.2 Temporal Coverage Map
None given.

7.2.3 Temporal Resolution
Multiple measurements were made at the SSA-YA, SSA-OA, SSA-OBS, SSA-MIX, and SSA-YJP sites on several days per month from 29-May-1994 through 08-Sep-1994 and from 01-Jul-1995 through 07-Aug-1995.

7.3 Data Characteristics

7.3.1 Parameter/Variable
The parameters contained in the data files on the CD-ROM are:

```
         Column Name
------------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
SPECIES
SAMPLE_GROWTH_YEAR
SAMPLE_ID
DOWN_PPFD
LEAF_TEMP
AIR_TEMP_CHAMBER
CO2_CONC_CHAMBER
AIR_FLOW_CHAMBER
REL_HUM_CHAMBER
VAPOR_PRESS_CHAMBER
BOUND_LAYER_MOLAR_CONDUCT_H2O
LEAF_AREA
PHOTOSYNTHETIC_RATE
STOMATAL_MOLAR_CONDUCT_H2O
INTERCELL_CO2_CONC
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).
SAMPLE_GROWTH_YEAR	The year in which the collected sample first grew.
SAMPLE_ID	The sample identifier used by data collectors (see documentation for a detailed description).
DOWN_PPFD	The downward photosynthetic photon flux density.
LEAF_TEMP	The leaf or shoot temperature
AIR_TEMP_CHAMBER	The temperature of the air in the chamber.
CO2_CONC_CHAMBER	The CO2 concentration in the chamber.
AIR_FLOW_CHAMBER	The total air flow rate through the system.
REL_HUM_CHAMBER	The relative humidity of the air in the chamber.
VAPOR_PRESS_CHAMBER	Vapor pressure of the air in the chamber.
BOUND_LAYER_MOLAR_CONDUCT_H2O	The boundary layer conductance for water vapor of the sample.
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.
PHOTOSYNTHETIC_RATE	Measured Net Photosynthesis
STOMATAL_MOLAR_CONDUCT_H2O	Stomatal conductance of water vapor.
INTERCELL_CO2_CONC	Intercellular CO2 concentration
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]
SAMPLE_GROWTH_YEAR	[unitless]
SAMPLE_ID	[none]
DOWN_PPFD	[micromoles][meter^-2][second^-1]
LEAF_TEMP	[degrees Celsius]
AIR_TEMP_CHAMBER	[degrees Celsius]
CO2_CONC_CHAMBER	[parts per million]
AIR_FLOW_CHAMBER	[micromoles][second ^-1]
REL_HUM_CHAMBER	[percent]
VAPOR_PRESS_CHAMBER	[millibars]
BOUND_LAYER_MOLAR_CONDUCT_H2O	[mole H2O][meter^-2][second^-1]
LEAF_AREA	[millimeter^2]
PHOTOSYNTHETIC_RATE	[micromoles CO2][meter^-2][second^-1]
STOMATAL_MOLAR_CONDUCT_H2O	[millimoles H2O][meter^-2][second^-1]
INTERCELL_CO2_CONC	[parts per million]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

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

Column Name	Data Source
SITE_NAME	[BORIS Designation]
SUB_SITE	[BORIS Designation]
DATE_OBS	[Human Observer]
TIME_OBS	[Human Observer]
SPECIES	[Human Observer]
SAMPLE_GROWTH_YEAR	[Human Observer]
SAMPLE_ID	[Human Observer]
DOWN_PPFD	[Field Equipment]
LEAF_TEMP	[Thermometer]
AIR_TEMP_CHAMBER	[Laboratory Equipment]
CO2_CONC_CHAMBER	[Laboratory Equipment]
AIR_FLOW_CHAMBER	[Laboratory Equipment]
REL_HUM_CHAMBER	[Laboratory Equipment]
VAPOR_PRESS_CHAMBER	[Laboratory Equipment]
BOUND_LAYER_MOLAR_CONDUCT_H2O	[Laboratory Equipment]
LEAF_AREA	[Laboratory Equipment]
PHOTOSYNTHETIC_RATE	[Laboratory Equipment]
STOMATAL_MOLAR_CONDUCT_H2O	[Laboratory Equipment]
INTERCELL_CO2_CONC	[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-90A-FLXTR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE12-LGS01	9TE12-LGS01	None	None	None	None
DATE_OBS	29-MAY-94	07-AUG-95	None	None	None	None
TIME_OBS	515	2010	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
SAMPLE_GROWTH_YEAR	1992	1995	None	None	None	None
SAMPLE_ID	1	9	None	None	None	None
DOWN_PPFD	-2.232	3998	None	None	None	None
LEAF_TEMP	3.846	42.62	None	None	None	None
AIR_TEMP_CHAMBER	3.8	41.47	None	None	None	Blank
CO2_CONC_CHAMBER	46.32	899.5	None	None	None	None
AIR_FLOW_CHAMBER	11.09	90.73	None	None	None	None
REL_HUM_CHAMBER	1.326	60.25	None	None	None	None
VAPOR_PRESS_CHAMBER	4.417	44.69	None	None	None	None
BOUND_LAYER_MOLAR_CONDUCT_H2O	1.4	9.99	None	None	None	None
LEAF_AREA	1.74	39.84	None	None	None	None
PHOTOSYNTHETIC_RATE	-39.59	31.53	None	None	None	None
STOMATAL_MOLAR_CONDUCT_H2O	-.15	3.46	None	None	None	None
INTERCELL_CO2_CONC	-3983	7427	None	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	24-NOV-97	24-NOV-97	None	None	None	None

Minimum Data Value -- The minimum value found in the column.
Maximum Data Value -- The maximum value found in the column.
Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.
Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be unreliable by the analysis personnel.
Below Detect Limit -- The value that indicates parameter values below the instruments detection limits. This is used to indicate that an attempt was made to determine the parameter value, but the analysis personnel determined that the parameter value was below the detection limit of the instrumentation.
Data Not Cllctd -- This value indicates that no attempt was made to determine the parameter value. This usually indicates that BORIS combined several similar but not identical data sets into the same data base table but this particular science team did not measure that parameter.

Blank -- Indicates that blank spaces are used to denote that type of value.

10.1 Sources of Error

```
N/A   -- Indicates that the value is not applicable to the respective column.
None  -- Indicates that no values of that sort were found in the column.
------------------------------------------------------------------------------
```

7.4 Sample Data Record

The following are wrapped versions of data recordS from a sample data file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,SPECIES,SAMPLE_GROWTH_YEAR,SAMPLE_ID,
DOWN_PPFD,LEAF_TEMP,AIR_TEMP_CHAMBER,CO2_CONC_CHAMBER,AIR_FLOW_CHAMBER,
REL_HUM_CHAMBER,VAPOR_PRESS_CHAMBER,BOUND_LAYER_MOLAR_CONDUCT_H2O,LEAF_AREA,
PHOTOSYNTHETIC_RATE,STOMATAL_MOLAR_CONDUCT_H2O,INTERCELL_CO2_CONC,CRTFCN_CODE,
REVISION_DATE
'SSA-90A-FLXTR','9TE12-LGS01',06-JUN-94,1228,'Populus tremuloides','1994','1',
1962.0,27.05,25.61,328.4,45.66,17.84,15.0,1.965,17.81,6.88,.11,216.7,'CPI',
24-NOV-97
'SSA-90A-FLXTR','9TE12-LGS01',06-JUN-94,1234,'Populus tremuloides','1994','2',
1110.0,25.77,24.65,357.3,41.77,18.05,12.96,1.965,14.0,10.89,.14,218.4,'CPI',
24-NOV-97
```

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 [illegible] (ASCII) numerical and character fields of varying length separated by

11. Notes

11.1 Limitations of the Data

None given.

11.2 Known Problems with the Data

Other than the few times measurements were made on moist leaves (as discussed above), there are no known problems with the data set.

11.3 Usage Guidance

The normal caveat of 'use at your own risk' applies. Correspondence with T.J. Arkebauer is encouraged when questions arise.

11.4 Other Relevant Information

Ms. Litao Yang was responsible for most of the day-to-day coordination of the field measurements. Mr. Runsheng Xu assisted with field data collection in 1994. Their assistance was greatly appreciated.

12. Application of the Data Set

These data can be used to study the gas exchange of boreal vegetation.

13. Future Modifications and Plans

None given.

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-6200 Technical Reference Manual, LI-COR, Inc., Lincoln, NE, USA, March 1990.

17.2 Journal Articles and Study Reports

Ball, J.T. 1987. Calculations related to gas exchange. In: Stomatal Function. E. Zeiger, G.D. Farquhar and I.R. Cowan (eds), Stanford University Press, Stanford, CA, pp. 446-475.

McDermitt, D.K., J.M. Norman, J.T. Davis, T.M. Ball, T.J. Arkebauer, J.M. Welles, and S.R. Roemer. 1989. CO_2 response curves can be measured with a field-portable closed-loop photosynthesis system. Ann. Sci. For. 46:416s-420s.

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).

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13. ABSTRACT *(Maximum 200 words)*

The BOREAS TE-12 team collected several data sets in support of its efforts to characterize and interpret information on the reflectance, transmittance, and gas exchange of boreal vegetation. This data set contains measurements of leaf gas exchange conducted in the SSA during the growing seasons of 1994 and 1995 using a portable gas exchange system. The data are stored in tabular ASCII files.

14. SUBJECT TERMS
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