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

Forrest G. Hall and Andrea Papagno, Editors

Volume 164

BOREAS TE-11 Leaf Gas Exchange Measurements

B. Saugier and J.Y. Pontailler

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

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BOREAS TE-11 Leaf Gas Exchange Measurements

Bernhard Saugier, J.Y. Pontailler

Summary

The BOREAS TE-11 team collected several data sets in support of its efforts to characterize and interpret information on the sap flow, gas exchange, and lichen photosynthesis of boreal vegetation and meteorological data of the area studied. This data set contains measurements of assimilation and transpiration conducted at the OJP site during the growing seasons of 1993 and 1994. The data are stored in ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-11 Leaf Gas Exchange Measurements

1.2 Data Set Introduction

This data set includes gas exchange measurements of Old Jack Pine (OJP) needles taken during the growing seasons of 1993 and 1994. Assimilation and transpiration measurements were taken continuously from 27-Aug-1993 to 02-Sep-1993 during 1993 and on 25-Jul-1994 and 26-Jul-1994.

1.3 Objective/Purpose

The purpose of the work was to measure the gas exchanges (CO_2 and H_2O) of an attached branch using a large cuvette operating in a closed system. Both CO_2 assimilation and transpiration were monitored together with several microclimatological parameters. The experiment was performed in August-September 1993 and July 1994 at the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) OJP site.

1.4 Summary of Parameters

In the data file, assimilation and transpiration data are expressed per unit leaf area. Air temperature, relative humidity, and photosynthetically active radiation (PAR) are also measured in the cuvette. Time step is 30 minutes.

1.5 Discussion

These data were extrapolated using leaf area index (LAI) measurements performed by other teams on the same site, and a comparison was performed using a micromet estimate of the whole-stand transpiration/assimilation. The water-use efficiency (assimilation/transpiration) at the branch level was computed and then multiplied by the transpiration of the trees (derived from sap flow measurements) to obtain the net assimilation at the tree level.

1.6 Related Data Sets

BOREAS RSS-04 1994 Southern Study Area Jack Pine LAI and fPAR Data
BOREAS RSS-07 LAI, Gap Fraction, and fPAR Data
BOREAS TE-04 Gas Exchange Data from Boreal Tree Species
BOREAS TE-05 Leaf Gas Exchange Data
BOREAS TE-10 Leaf Gas Exchange Data
BOREAS TE-11 Sapflow Data
BOREAS TE-12 Leaf Gas Exchange Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Bernard Saugier, Professor
Jean-Yves Pontailler, Technical Manager

2.2 Title of Investigation

Seasonal Variations of Net Photosynthesis and Transpiration at the Branch Level

2.3 Contact Information

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Shelaine.Curd@gsfc.nasa.gov

3. Theory of Measurements

A whole branch was enclosed in a large cuvette located in the top of the canopy. Between measurements, a fan blew air from the outside through the chamber at a high flow rate (0.045 m^3/s) to prevent overheating. Every 30 minutes, the cuvette was closed for 5 minutes in order to allow a measurement of both CO_2 assimilation and transpiration using the closed system method. CO_2 concentration was measured using an Infrared Gas Analyzer (IRGA) system, and air humidity was measured by a capacitive sensor.

Gas exchange was computed as:

$$A = (V/Sf) * (Dc/Dt) * (1/p)$$

$$E = (V/Sf) * (De/Dt) * (1/p)$$

Where V is the cuvette volume (moles of air); Sf is the leaf area (m^2); c and e are the CO_2 and H_2O partial pressures (µb or mb), respectively; Dx/Dt is the derivative of x with respect to time t (sec); and p is the atmospheric pressure (mb or hPa).

Thus, A is in the units of $\mu mol/m^2s$, and E is in $mmol/m^2s$.

4. Equipment

4.1 Sensor/Instrument Description

The big cuvette is referred to as a branch bag, which is a 0.25-m^3 transparent chamber made of an acrylic frame covered with a 75-µm-thick polypropylene film. A turbine, located on the scaffolding, injected air at a high flow rate into the bag through a flexible pipe (45 dm^3 per second). At the bag level, the air inlet and outlet were fitted with thin, light Perspex shutters: the air flow opened it up, and it closed hermetically when the flow stopped. When a gas exchange measurement was required, a relay, activated by a Campbell 21X data logger, shifted the main power supply from the turbine to a couple of fans located in the bag. This caused the branch bag shutters to close immediately. The decrease in CO_2 and H_2O concentration inside the bag was then monitored for 5 minutes. A CID CI-301 gas analyzer was used to monitor CO_2 and a Vaisala capacitive probe model HMB30YB

measured air temperature and humidity. PAR was measured inside the bag using a laboratory-made, cosine-corrected, blue-enhanced gallium arsenide sensor.

4.1.1 Collection Environment

Gas exchange measurements took place at the SSA-OJP site.

4.1.2 Source/Platform

None given.

4.1.3 Source/Platform Mission Objectives

None given.

4.1.4 Key Variables

Assimilation and transpiration.

4.1.5 Principles of Operation

None given.

4.1.6 Sensor/Instrument Measurement Geometry

None given.

4.1.7 Manufacturer of Sensor/Instrument

HMB30YB Capacitive Probe:
Vaisala Oyj.
Helsinki, Finland
http://www.vaisala.com/ [Internet Link]

LI-190SB PAR Sensor:
LI-COR, Inc.
Box 4425
Lincoln, NE 68504
(402) 467-3576

CI-301PS Portable Photosynthesis System:
CID, Inc.
4018 NE 112th Avenue
Suite D-8
Vancouver, WA 98682
1 (800) 767-0119
(360) 254-7923 (fax)
http://www.cid-inc.com/ [Internet Link]

4.2 Calibration

The IRGA was calibrated using cylinders. The Vaisala probe was calibrated using a laboratory-made air supply system offering an accurate dewpoint regulation (using a condenser). The PAR sensor was calibrated in daylight conditions against two new LI-COR sensors model LI-190 SB.

4.2.1 Specifications

None given.

4.2.1.1 Tolerance

None given.

4.2.2 Frequency of Calibration

None given.

4.2.3 Other Calibration Information

None given.

5. Data Acquisition Methods

A Campbell 21X data logger, with four input channels and one relay output per bag, was used to collect the data. One bag was used in 1993 for 1 week, and two were used for 1 month in 1994.

6. Observations

6.1 Data Notes

None given.

6.2 Field Notes

The team came from France with a branch bag made of unassembled parts. It took 2 days to assemble it and install it on the top of the canopy access tower. The team had hoped for a good clear day, but the best days had periods of sunshine and scattered clouds. Data seemed of good quality; transpiration rates were lower than expected, with maximum values of 0.8 mmol H_2O/m^2s, leading to estimates of the canopy transpiration close to those obtained using the sap flow method. At night, the system was able to measure low respiration rates.

At the end of the experiment, the branch was harvested in order to measure leaf area (HASL) using the displacement method suggested for conifer shoots in the BOREAS Experiment Plan (Sellers and Hall, 1994, Appendix K).

7. Data Description

7.1 Spatial Characteristics

A dominant branch was chosen. In 1994, the two branches were close to each other, but located on different trees.

7.1.1 Spatial Coverage

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

- OJP, site id G2L3T, Lat/Long: 53.91634 N, 104.69203 W, Universal Transverse Mercator (UTM) Zone 13, N: 5974257.5 E: 520227.7

7.1.2 Spatial Coverage Map

None available.

7.1.3 Spatial Resolution

None given.

7.1.4 Projection

None given.

7.1.5 Grid Description

None given.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

The data were collected at varying periods from 27-Aug-1993 to 10-Aug-1994.

7.2.2 Temporal Coverage Map

None given.

7.2.3 Temporal Resolution

Measurements were taken every 30 minutes, for about 6 days in 1993 (27-Aug-1993 to 02-Sep-1993, night and day) and from 25-Jul-1994to 10-Aug-1994. For various reasons (distance between chamber and IRGA, stomatal response, etc.), assimilation and transpiration were not computed according to the same durations: CO_2 assimilation was computed on a 4-minute basis, while transpiration calculations used the first 1.5 minutes of every experiment.

7.3 Data Characteristics

7.3.1 Parameter/Variable

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

```
         Column Name
------------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
SPECIES
SAMPLE_BRANCH_NUM
VAPOR_PRESS_DEFICIT
CO2_ASSIMILATION
TRANSPIRATION_RATE
DOWN_PPFD
AIR_TEMP_CHAMBER
REL_HUM_CHAMBER
CO2_CONC_CHAMBER
INITIAL_CO2_CONC_CHAMBER
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_BRANCH_NUM	The branch number sampled. When sample value is "ambient" this represents no branch and is used for a check on the ambient conditions where measurements are being taken.
VAPOR_PRESS_DEFICIT	Vapor Pressure Deficit
CO2_ASSIMILATION	CO2 assimilation on leaf area basis
TRANSPIRATION_RATE	Transpiration rate
DOWN_PPFD	The downward photosynthetic photon flux density.
AIR_TEMP_CHAMBER	The temperature of the air in the chamber.
REL_HUM_CHAMBER	The relative humidity of the air in the chamber.
CO2_CONC_CHAMBER	The CO2 concentration in the chamber.
INITIAL_CO2_CONC_CHAMBER	The ambient CO2 concentration (at the beginning of the measurements, vpm).
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_BRANCH_NUM	[unitless]
VAPOR_PRESS_DEFICIT	[kiloPascals]
CO2_ASSIMILATION	[micromoles CO2][meter^-2][second^-1]
TRANSPIRATION_RATE	[millimoles H2O][meter^-2][second^-1]
DOWN_PPFD	[micromoles][meter^-2][second^-1]
AIR_TEMP_CHAMBER	[degrees Celsius]
REL_HUM_CHAMBER	[percent]
CO2_CONC_CHAMBER	[parts per million]
INITIAL_CO2_CONC_CHAMBER	[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_BRANCH_NUM	[Human Observer]
VAPOR_PRESS_DEFICIT	[Laboratory Equipment]
CO2_ASSIMILATION	[Laboratory Equipment]
TRANSPIRATION_RATE	[Laboratory Equipment]
DOWN_PPFD	[Laboratory Equipment]
AIR_TEMP_CHAMBER	[Laboratory Equipment]
REL_HUM_CHAMBER	[Laboratory Equipment]
CO2_CONC_CHAMBER	[Laboratory Equipment]
INITIAL_CO2_CONC_CHAMBER	[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-OJP-FLXTR	SSA-OJP-FLXTR	None	None	None	None
SUB_SITE	9TE11-LGS01	9TE11-LGS01	None	None	None	None
DATE_OBS	27-AUG-93	10-AUG-94	None	None	None	None
TIME_OBS	1	2354	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
SAMPLE_BRANCH_NUM	1	2	None	None	None	Blank
VAPOR_PRESS_DEFICIT	.1	4.02	None	None	None	Blank
CO2_ASSIMILATION	-5.54	99.99	None	None	None	None
TRANSPIRATION_RATE	-.136	99.99	None	None	None	None
DOWN_PPFD	-10	1783	-999	None	None	None
AIR_TEMP_CHAMBER	0	35.7	None	None	None	None
REL_HUM_CHAMBER	0	92	None	None	None	None
CO2_CONC_CHAMBER	-16	978	-999	None	None	None
INITIAL_CO2_CONC_CHAMBER	-30	1364	-999	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	26-AUG-98	27-AUG-98	None	None	None	None

Minimum Data Value -- The minimum value found in the column.
Maximum Data Value -- The maximum value found in the column.
Missng Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.
Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the

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

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

7.4 Sample Data Record

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

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,SPECIES,SAMPLE_BRANCH_NUM,
VAPOR_PRESS_DEFICIT,CO2_ASSIMILATION,TRANSPIRATION_RATE,DOWN_PPFD,
AIR_TEMP_CHAMBER,REL_HUM_CHAMBER,CO2_CONC_CHAMBER,INITIAL_CO2_CONC_CHAMBER,
CRTFCN_CODE,REVISION_DATE
'SSA-OJP-FLXTR','9TE11-LGS01',27-AUG-93,1702,'Pinus banksiana','',,5.37,.676,
1430.0,21.0,43.4,288.0,318.0,'CPI',26-AUG-98
'SSA-OJP-FLXTR','9TE11-LGS01',27-AUG-93,1732,'Pinus banksiana','',,7.12,.715,
1440.0,21.7,41.6,283.0,312.0,'CPI',26-AUG-98
```

8. Data Organization

8.1 Data Granularity

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

8.2 Data Format(s)

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

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

9.1.1 Derivation Techniques and Algorithms

All signals, Volts (IRGA and Vaisala), or millivolts (PAR), were treated and stored by the data logger.

CO_2 assimilation was computed according to the formula:

$$A = ((CO_2i-CO_2f)/sec)*(Vol/Sf)*(0.044642*(273/(273+Ta)))$$

where: CO_2i: Initial CO_2 concentration (vpm)
CO_2f: Final CO_2 concentration (vpm)
sec: Time interval (s)
Vol: Volume of the system (dm^3)
Sf: Leaf area (HASF, m^2)
Ta: Air temperature (°C)

Transpiration was computed according to the formula:

$$E = (Vol/Sf)*((Xf-Xi)/sec)*0.05555$$

where: Xi: Initial water content (g/m^3)
Xf: Final water content (g/m^3)

Time interval "Sec" is equal to 90 seconds for the transpiration estimation and to 250 seconds for CO_2 assimilation. This resulted from a careful examination of the plots of CO_2 and absolute humidity versus time and selection of linear sections of both plots. Thus, seconds 0 to 90 were used for humidity and seconds 30 to 280 were used for CO_2.

9.2 Data Processing Sequence

9.2.1 Processing Steps

See Sections 3 and 4.1.

9.2.2 Processing Changes

None given.

9.3 Calculations

See Section 9.1.1.

9.3.1 Special Corrections/Adjustments

None given.

9.3.2 Calculated Variables

Transpiration and assimilation.

9.4 Graphs and Plots

None given.

10. Errors

10.1 Sources of Error

The accuracy of the gas analyzer in absolute mode and the eventuality of leaks, especially during windy periods, are probably two limiting factors.

10.2 Quality Assessment

The system appeared able to measure very low respiration rates at night.

10.2.1 Data Validation by Source

None given.

10.2.2 Confidence Level/Accuracy Judgment

None given.

10.2.3 Measurement Error for Parameters

None given.

10.2.4 Additional Quality Assessments

None given.

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

There are some missing data:

- Day 240, 14:00 to 18:30 (power failure)
- Day 245, 02:00 to end (IRGA malfunction)

11.3 Usage Guidance

None given.

11.4 Other Relevant Information

None given.

12. Application of the Data Set

This data set can be used to examine the gas exchange of OJP in the boreal forest.

13. Future Modifications and Plans

None given.

14. Software

14.1 Software Description

None given.

14.2 Software Access

None given.

15. Data Access

The TE-11 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

These data are available on the BOREAS CD-ROM series.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

None given.

17.2 Journal Articles and Study Reports

Dufrene E, J.Y. Pontailler, and B. Saugier. 1993. A branch bag technique for simultaneous CO_2 enrichment and assimilation measurement on beech (Fagus sylvatica). Plant, Cell and Environment 16, 1131-1138.

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

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

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

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Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

```
A       - Assimilation
ASCII   - American Standard Code for Information Interchange
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
CD-ROM  - Compact Disk-Read-Only Memory
DAAC    - Distributed Active Archive Center
E       - Transpiration
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
FPAR    - Fraction of Photosynthetically Active Radiation
GIS     - Geographic Information System
GMT     - Greenwich Mean Time
GSFC    - Goddard Space Flight Center
HASL    - Leaf Area
HTML    - HyperText Markup Language
IRGA    - Infrared Gas Analyzer
LAI     - Leaf Area Index
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NSA     - Northern Study Area
OJP     - Old Jack Pine
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
PAR     - Photosynthetically Active Radiation
RSS     - Remote Sensing Science
SSA     - Southern Study Area
TE      - Terrestrial Ecology
URL     - Uniform Resource Locator
UTM     - Universal Transverse Mercator
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The BOREAS TE-11 team collected several data sets in support of its efforts to characterize and interpret information on the sap flow, gas exchange, and lichen photosynthesis of boreal vegetation and meteorological data of the area studied. This data set contains measurements of assimilation and transpiration conducted at the OJP site during the growing seasons of 1993 and 1994. The data are stored in ASCII files.

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