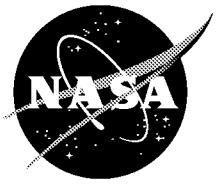
NASA/TM—2000–209891, Vol. 196



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

Forrest G. Hall and Sara Conrad, Editors

Volume 196

BOREAS TF-3 Automated Chamber CO_2 Flux Data from the NSA-OBS

Michael L. Goulden, University of California, Irvine
Patrick M. Crill, University of New Hampshire, Durham

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

October 2000

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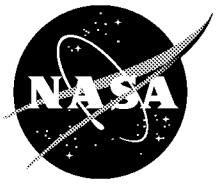

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October 2000

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BOREAS TF-3 Automated Chamber CO_2 Flux Data from the NSA-OBS

Michael L. Goulden, Patrick M. Crill

Summary

The BOREAS TF-3 and TGB-1 teams collected automated CO_2 chamber flux data in their efforts to fully describe the CO_2 flux at the NSA-OBS site. This data set contains fluxes of CO_2 at the NSA-OBS site measured using automated chambers. In addition to reporting the CO_2 flux, it reports chamber air temperature, moss temperature, and light levels during each measurement. The data set covers the period from 23-Sep-1995 through 26-Oct-1995 and from 28-May-1996 through 21-Oct-1996. The data are stored in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TF-03 Automated Chamber CO_2 Flux Data from the NSA-OBS

1.2 Data Set Introduction

This data set contains fluxes of carbon dioxide (CO_2) at the BOReal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA) Old Black Spruce (OBS) site measured using automated chambers. In addition to reporting the CO_2 flux, it reports chamber air temperature, moss temperature, and light levels during each measurement. The data set covers the period from 23-Sep-1995 through 26-Oct-1995 and from 28-May-1996 through 21-Oct-1996. The data are stored in tabular American Standard Code for Information Interchange (ASCII) files.

1.3 Objective/Purpose

Black spruce forests with a continuous carpet of feather moss in shaded dry areas and sphagnum moss in open wet areas dominate much of the North American boreal zone. The exchange of CO_2 between these forests and the atmosphere is complex, with important contributions by five physiological processes: black spruce photosynthesis, black spruce respiration, moss photosynthesis, moss respiration, and heterotrophic respiration. Information on the rates of and controls on each of these processes is needed to improve understanding of the current and future carbon balance of boreal forests. An automated, multiplexing gas-exchange system was used to make continuous, unattended measurements of the net exchange of CO_2 at the moss surface at the NSA-OBS site.

1.4 Summary of Parameters

The primary focus is on the net fluxes of CO_2 measured. The data set also includes chamber air temperature, moss temperature, and light levels during each measurement.

1.5 Discussion

Measurements were made at the NSA-OBS site. The system operated continuously and was visited every 2 weeks. The site was heterogeneous with large changes in vegetation over small gradients in elevation. Upland areas were dominated by dense, 10-m-tall, 120-year-old black spruce, with a minor shrub layer and continuous feather moss. Lower areas were dominated by sparse, 1- to 6-m-tall spruce and continuous sphagnum moss. For 1994, chambers 1-3 were placed in an upland area of well-developed feather moss, while chambers 8-10 were placed in a lower area dominated by sphagnum moss. The other chambers were placed at intermediate or lichen-covered locations.

1.6 Related Data Sets

BOREAS TGB-01/TGB-03 CH4 Chamber Flux Data over the NSA Fen
BOREAS TGB-03 Plant Species Composition Data over the NSA Fen
BOREAS TGB-01/TGB-03 NEE Data over the NSA Fen
BOREAS TGB-03 CH4 and CO2 Chamber Flux Data over NSA Upland Sites
BOREAS TGB-01 NSA CH4 and CO2 Chamber Flux Data
BOREAS TGB-01 CH4 Concentration and Flux Data from NSA Tower Sites
BOREAS TGB-01 NSA SF6 Chamber Flux Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Michael L. Goulden
University of California

Dr. Patrick M. Crill
Research Associate Professor
University of New Hampshire

2.2 Title of Investigation

Automated Measurements of CO_2 Exchange at the Moss Surface of a Black Spruce Forest

2.3 Contact Information

Contact 1:
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Jeffrey.Newcomer@gsfc.nasa.gov

3. Theory of Measurements

Net exchange of CO_2 above the moss surface reflects the sum of moss photosynthesis and moss, root, and heterotrophic respiration during daylight, and moss, root, and heterotrophic respiration at night. Long-term in situ measurements of CO_2 exchange over diel courses should allow partial separation of these processes and permit an analysis of the associated environmental controls. However, investigations of this type have been limited by the difficulty of obtaining reliable field measurements in remote, inclement regions.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment

Data were collected under all environmental conditions.

4.1.2 Source/Platform

Ground.

4.1.3 Source/Platform Mission Objectives
Support investigators and chambers.

4.1.4 Key Variables
CO_2 flux.

4.1.5 Principles of Operation
Data were recorded and the system was managed with a datalogger. The raw CO_2 and H_2O signals were sampled every 2 seconds and averaged every minute. The other signals were sampled every 2 seconds and averaged every 9 minutes.

4.1.6 Sensor/Instrument Measurement Geometry
Not applicable.

4.1.7 Manufacturer of Sensor/Instrument
The chambers were 38- x 38.5- x 25-cm boxes built of clear lexan and aluminum angle.

Thermocouple
Omega Engineering
Stamford, CT

Datalogger
Campbell Scientific
Logan, UT

Infrared gas analyzer (IRGA)
IRGA, Model 6262
LI-COR, Inc
Lincoln, NE

4.2 Calibration

4.2.1 Specifications
None given.

4.2.1.1 Tolerance
None given.

4.2.2 Frequency of Calibration
Each chamber was calibrated at least once a day by standard addition. Every 21 hours, the system added 0.08 cm^3/sec of 10% CO_2 to the return flow throughout a 3-hour circuit.

4.2.3 Other Calibration Information
None given.

5. Data Acquisition Methods

Measurements were made at the NSA-OBS site. The system operated continuously and was visited every 2 weeks. The site was heterogeneous with large changes in vegetation over small gradients in elevation. Upland areas were dominated by dense, 10-m-tall, 120-year-old black spruce, with a minor shrub layer and continuous feather moss. Lower areas were dominated by sparse, 1- to 6-m-tall spruce and continuous sphagnum moss. For 1994, chambers 1-3 were placed in an upland area of well-developed feather moss, while chambers 8-10 were placed in a lower area dominated by sphagnum moss. The other chambers were placed at intermediate or lichen-covered locations.

Measurements of CO_2 exchange above moss surfaces are sensitive to errors that are not usually encountered when working above bare soil. Moss is extremely porous, creating uncertainty in chamber volume and also increasing the risk of mass flow. Transient changes in moss physiology and in the direction of CO_2 movement may confound dark respiration measurements made by shading during daytime. Because the physiological activity of moss is sensitive to water content, chambers that remain in place for extended periods must not alter evaporation or precipitation. Finally, the CO_2 exchange above moss is complex, and therefore many measurements may be required to separate the environmental controls on photosynthesis and respiration. As a result of these and other uncertainties, discrepancies among methods used to measure moss-surface exchange in BOREAS have been large, and it is unclear which, if any, chamber design provides accurate results.

The Tower Flux (TF)-03 team designed an automated gas-exchange system to circumvent most of these problems. The system sequentially sampled 10 clear, closed-type chambers, completing a circuit every 3 hours. Power consumption was less than 300 W at 115 VAC. The system was shipped and operated in three weather-tight boxes that sat on the forest floor within 15 m of the chambers.

The tubing and mixing volume were flushed and allowed to equilibrate during the first 8 minutes of each run. The selected chamber was then closed slowly, and the change in CO_2 monitored for the next 10 minutes. Chamber closure had no discernible effect on the temperature within a chamber during the fall of 1995. Subsequent measurements in midsummer 1996 revealed some warming (1-2 °C), which occasionally resulted in condensation on the walls of chambers exposed to direct sun.

Air was drawn from the chamber throughout the run and passed through a CO_2 and H_2O IRGA operated in absolute mode. The flow through the IRGA was controlled at 80 cm^3/second. The pressure of the sample flow was measured with a pressure transducer immediately after it had exited the IRGA and was assumed equal to the pressure in the sample cell.

Soil temperature at 5 cm beneath the moss surface and air temperature were measured in each chamber with type-T thermocouples. Horizontal photosynthetically active photon flux density (PPFD) was measured at each chamber with a gallium arsenide phosphide photodiode.

Data were recorded and the system managed with a datalogger. The raw CO_2 and H_2O signals were sampled every 2 seconds and averaged every minute. The other signals were sampled every 2 seconds and averaged every 9 minutes. The solenoids used for chamber selection, chamber closure, and calibration were controlled with a pair of 16-channel control modules. The set points for the mass flow controllers were provided by a four-channel analog output module. The signals from the thermocouples and light sensors were multiplexed with a thermally insulated 32-channel multiplexer. The data were transferred to a storage module every 3 hours and subsequently transferred to a computer every 2 weeks.

6. Observations

6.1 Data Notes

None given.

6.2 Field Notes

None given.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

All measurements were made at the NSA-OBS site. The North American Datum of 1983 (NAD83) coordinates at the site are 55.8798° N, 98.4848° W.

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

These are point measurements made 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

The data set covers the period from 23-Sep-1995 through 26-Oct-1995 and from 28-May-1996 through 21-Oct-1996.

7.2.2 Temporal Coverage Map

Not available.

7.2.3 Temporal Resolution

The CO_2 and H_2O signals were sampled every 2 seconds and averaged every minute.

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
CHAMBER_NUM
CO2_FLUX
CALIBRATION
MOSS_TEMP
AIR_TEMP
DOWN_PPFD_CHAMBER
REVISION_DATE
CRTFCN_CODE
```

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.
CHAMBER_NUM	Identifier assigned to the chamber measured.
CO2_FLUX	Carbon Dioxide flux.
CALIBRATION	Binary code to indicate whether the system is calibrating. If a 1 is present then the system is calibrating.
MOSS_TEMP	Temperature of the moss within the chamber.
AIR_TEMP	The air temperature.
DOWN_PPFD_CHAMBER	The incoming photosynthetic photon flux density measured in the chamber.
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.
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).

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]
CHAMBER_NUM	[unitless]
CO2_FLUX	[micromoles][meter^-2][second^-1]
CALIBRATION	[none]
MOSS_TEMP	[degrees Celsius]
AIR_TEMP	[degrees Celsius]
DOWN_PPFD_CHAMBER	[micromoles][meters^-2][second^-1]
REVISION_DATE	[DD-MON-YY]
CRTFCN_CODE	[none]

7.3.4 Data Source

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

Column Name	Data Source
SITE_NAME	[Assigned by BORIS Staff]
SUB_SITE	[Assigned by BORIS Staff]
DATE_OBS	[Investigator]
TIME_OBS	[Investigator]
CHAMBER_NUM	[Investigator]
CO2_FLUX	[IRGA]
CALIBRATION	[Investigator]
MOSS_TEMP	[type-T thermocouples]
AIR_TEMP	[type-T thermocouples]
DOWN_PPFD_CHAMBER	[Investigator]
REVISION_DATE	[Assigned by BORIS Staff]
CRTFCN_CODE	[Assigned by BORIS Staff]

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	NSA-OBS-FLXTR	NSA-OBS-FLXTR	None	None	None	None
SUB_SITE	9TF03-FLX10	9TF03-FLXC9	None	None	None	None
DATE_OBS	23-SEP-95	21-OCT-96	None	None	None	None
TIME_OBS	14	2356	None	None	None	None
CHAMBER_NUM	1	10	None	None	None	None
CO2_FLUX	-26.18502	206.2905	-999	None	None	None
CALIBRATION	0	1	None	None	None	None
MOSS_TEMP	-11.10693	51.89928	-999	None	None	None
AIR_TEMP	-12.46	46.67	-999	None	None	None
DOWN_PPFD_CHAMBER	-.72	1853.657	-999	None	None	None
REVISION_DATE	09-OCT-98	09-OCT-98	None	None	None	None
CRTFCN_CODE	CPI	CPI	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,CHAMBER_NUM,CO2_FLUX,CALIBRATION,
MOSS_TEMP,AIR_TEMP,DOWN_PPFD_CHAMBER,REVISION_DATE,CRTFCN_CODE
'NSA-OBS-FLXTR','9TF03-FLX10',23-SEP-95,2356,10,5.16147,1,6.55583,8.14,
-.72,09-OCT-98,'CPI'
'NSA-OBS-FLXTR','9TF03-FLX10',24-SEP-95,256,10,1.009062,0,6.74634,7.98,
-.72,09-OCT-98,'CPI'
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by the BOREAS Information System (BORIS) is the measurement(s) made for a given site during a given day.

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

None given.

9.2 Data Processing Sequence

9.2.1 Processing Steps

None given

9.2.2 Processing Changes
None given.

9.3 Calculations

9.3.1 Special Corrections/Adjustments
None given.

9.3.2 Calculated Variables
None given.

9.4 Graphs and Plots
None given.

10. Errors

10.1 Sources of Error
Measurements of CO_2 exchange above moss surfaces are sensitive to errors that are not usually encountered when working above bare soil. Moss is extremely porous, creating uncertainty in chamber volume and also increasing the risk of mass flow. Transient changes in moss physiology and in the direction of CO_2 movement may confound dark respiration measurements made by shading during daytime. Because the physiological activity of moss is sensitive to water content, chambers that remain in place for extended periods must not alter evaporation or precipitation. Finally, the CO_2 exchange above moss is complex, and therefore many measurements may be required to separate the environmental controls on photosynthesis and respiration. As a result of these and other uncertainties, discrepancies among methods used to measure moss-surface exchange in BOREAS have been large, and it is unclear which, if any, chamber design provides accurate results.

10.2 Quality Assessment

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
See Section 10.1.

11.3 Usage Guidance
See Section 10.1.

11.4 Other Relevant Information
None given.

12. Application of the Data Set

None given.

13. Future Modifications and Plans

None given.

14. Software

14.1 Software Description
None given.

14.2 Software Access
Not applicable.

15. Data Access

The NSA-OBS automated chamber CO_2 flux 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

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

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

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

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

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

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

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

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
CD-ROM  - Compact Disk-Read-Only Memory
DAAC    - Distributed Active Archive Center
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
GIS     - Geographic Information System
GMT     - Greenwich Mean Time
GSFC    - Goddard Space Flight Center
HTML    - HyperText Markup Language
IRGA    - Infrared Gas Analyzer
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NSA     - Northern Study Area
OBS     - Old Black Spruce
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
PPFD    - Photosynthetically Active Photon Flux Density
SSA     - Southern Study Area
TF      - Tower Flux
TGB     - Trace Gas Biochemistry
URL     - Uniform Resource Locator
```

20. Document Information

20.1 Document Revision Date

Written: 08-Oct-1998
Last Updated: 17-Aug-1999

20.2 Document Review Date(s)

BORIS Review: 15-Oct-1998
Science Review:

20.3 Document ID

20.4 Citation

When using these data, please include the following acknowledgment as well as citations of relevant papers in Section 17.2:

Goulden, M.L. and Crill, P.M. 1997. Automated measurements of CO_2 exchange at the moss surface of a black spruce forest. Tree Physiology. 17:537-542.

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

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The BOREAS TF-3 and TGB-1 teams collected automated CO_2 chamber flux data in their efforts to fully describe the CO_2 flux at the NSA-OBS site. This data set contains fluxes of CO_2 at the NSA-OBS site measured using automated chambers. In addition to reporting the CO_2 flux, it reports chamber air temperature, moss temperature, and light levels during each measurement. The data set covers the period from 23-Sep-1995 through 26-Oct-1995 and from 28-May-1996 through 21-Oct-1996. The data are stored in tabular ASCII files.

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