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

Forrest G. Hall and Sara K. Conrad, Editors

Volume 226

BOREAS TGB-1 CH_4 and CO_2 Chamber Flux Data over NSA Upland Sites

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Tim R. Moore, McGill University, Montreal, Quebec

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

November 2000

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BOREAS TGB-3 CH_4 and CO_2 Chamber Flux Data over NSA Upland

Kathleen Savage, Tim R. Moore

Summary

The BOREAS TGB-3 team collected methane and carbon dioxide (CH_4, CO_2) chamber flux measurements at the NSA Fen, OBS, YJP, and auxiliary sites along Gillam Road and the 1989 burn site. Gas samples were extracted from chambers and analyzed at the NSA lab facility approximately every 7 days during May to September 1994 and June to October 1996. The data are provided in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS TGB-03 CH_4 and CO_2 Chamber Flux Data over NSA Upland Sites

1.2 Data Set Introduction

The Trace Gas Biogeochemistry (TGB)-03 team took chamber flux measurements at upland sites in the BOReal Ecosystem Atmosphere Study (BOREAS) Northern Study Area (NSA) from late May to early September 1994 and early June to late October 1996.

1.3 Objective/Purpose

The objectives of these measurements were:

- To examine the trace gas exchange between the atmosphere and the boreal upland soils.
- To identify environmental controls on CH_4 and CO_2 flux and the spatial and temporal variability associated with those controls in order to improve the process models that describe exchanges of trace gases between the boreal ecosystem and the atmosphere.

1.4 Summary of Parameters

In the 1994 sampling season, CH_4 and CO_2 chamber flux measurements were taken from 11 sites. These sites were designated as 1989 burn moss, 1989 burn spruce, palsa moss, palsa birch, Gillam aspen, Gillam pine, Gillam spruce, Young Jack Pine (YJP) wet, YJP dry, Old Black Spruce (OBS) aspen, OBS spruce.

In the 1996 sampling season, CH_4 and CO_2 chamber fluxes were measured at YJP wet, YJP dry, OBS aspen, OBS spruce, Old Jack Pine (OJP) moss, OJP aspen, and OJP pine (note OJP sites sampled by Patrick Crill in 1994).

1.5 Discussion

In 1994, CH_4 and CO_2 chamber flux measurements were taken at the 11 sites within the NSA to determine the soil surface exchange rate of CH_4 and CO_2 at these locations. The locations represent both a hydraulic and disturbance gradient. The sampling collars were installed in the spring of 1994 by the McGill researchers (TGB-03), and measurements of CH_4 and CO_2 flux were made during and between the 1994 and 1996 Intensive Field Campaigns (IFCs).

1.6 Related Data Sets

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/TGB-03 CH4 Chamber Flux Data over the NSA Fen

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Tim R. Moore
Professor
McGill University

Kathleen Savage
McGill University

2.2 Title of Investigation

Environmental Controls on Methane Consumption and Carbon Dioxide Emissions in Upland Boreal Forest Soil

2.3 Contact Information

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3. Theory of Measurements

Chamber fluxes measure the changes in mixing ratio of trace gases (CH_4 and CO_2) in a closed headspace over a period of time. This headspace is isolated from the atmosphere; therefore, the exchange of material between the covered soil and the headspace can be quantified.

4. Equipment

4.1 Sensor/Instrument Description

The CH_4 and CO_2 flux measurements were taken with PVC collars (26 cm in diameter) and chambers made from polycarbonate bottles (26 cm in diameter; 40 cm tall; area of exposure 0.053 m^2; Moore and Roulet, 1991). Bottles were covered with aluminum foil to reduce heating. The neck of each bottle was sealed with a rubber stopper that contained a glass tube with a rubber septum with a 1-m length of Tygon tubing attached to the top to minimize disturbance. Syringes were made of polypropylene.

CH_4 and CO_2 were quantified with a Shimadzu 14A Gas Chromatograph (GC) equipped with a flame ionization detector (FID) for CH_4 and thermal conductivity Detector (TCD) for CO_2. A HayeSepQ column was used, the GC temperature was set at 40 °C, and ultra-pure (99.999%) N_2 was used as the carrier gas flowing at 30 mL/min. The detectors were operated at 125 °C. Analog signals (0-1 V) from the detectors were digitized at 10 Hz with a Hewlett Packard (HP) 35000D A/D board and quantified and logged using HP ChemStation software.

Chamber fluxes were accomplished with aluminum chambers manufactured at the University of New Hampshire (UNH) and designed by Patrick Crill.

4.1.1 Collection Environment

The chamber fluxes were collected under ambient environmental conditions.

4.1.2 Source/Platform

Ground.

4.1.3 Source/Platform Mission Objectives

The ground supported the collars and chambers.

4.1.4 Key Variables

The key variable measured during the sampling period was CH_4 and CO_2 flux. Soil temperature, moisture, and soil gas profile concentrations were also measured.

4.1.5 Principles of Operation

The Shimadzu GC-14A is equipped with a FID and a TCD. The FID is used to detect CH_4; the TCD is used to detect CO_2. The FID uses a hydrogen flame in an air atmosphere to burn components as they exit the column. In the flame, carbon-carbon bonds are fragmented so that various organic ions and free electrons exist. Application of a voltage across a collector electrode over the flame causes an ion current to flow that is amplified and then measured as the output signal. The TCD detects CO_2 by passing a sample in a helium carrier gas past metallic filaments with current flowing through them. The sample components with lower thermal conductivity than the helium carrier gas raise the filament temperature when they pass through. The signal output from the TCD is a measurement of the change in filament resistance caused by the temperature rise. The signal output from both the FID and TCD is for a data processor, integrator, recorder, or computer (Instruction Manual: GC-14A; Shimadzu Corporation, Kyoto, Japan).

4.1.6 Sensor/Instrument Measurement Geometry

Not applicable.

4.1.7 Manufacturer of Sensor/Instrument

The investigator manufactured collar and chambers.

Manufacturer of GC-14A FID/TCD and GC-MINI2:
Shimadzu Scientific Instruments, Inc.
7102 Riverwood Drive
Columbia, MD 21046
(410) 381-1227

4.2 Calibration

4.2.1 Specifications

Analyses were conducted with a Shimadzu GC with a FID (FID-GC) using a Porapak Q column. Nitrogen was used as the carrier gas, and CH_4 standards of 2.349 ppmv were used to calibrate. Precision of the analysis (standard deviation as percent of the mean of 10-15 daily repetitions of the standard) was less than 1% of the standards. Fluxes between 0.1 and -0.1 $mg/m^2/d$ were not detectable.

Signal peaks from the detectors were quantified with working standards calibrated against Canadian Atmospheric Environment Services (AES) certified primary standards acquired by the BOREAS project and a CO_2/CH_4 standard of Niwot Ridge air prepared by the National Oceanic and Atmospheric Administration (NOAA) Climate Monitoring and Diagnostics Laboratory (CMDL). Uncertainty in the standards' analyses on a given day ranged from 0.1 to 0.2%.

4.2.1.1 Tolerance

The sensitivity of the TCD is approximately 6,000 mV mL/mg. The FID's maximum sensitivity is 3 x 10-12 g/s for diphenyl.

4.2.2 Frequency of Calibration

The instrument is calibrated on a daily basis. Standards are run generally before and after samples on a given day of analysis.

4.2.3 Other Calibration Information

None given.

5. Data Acquisition Methods

A total of 66 PVC collars were placed along the moisture and disturbance gradients in the NSA and sampled in 1994. CH_4 and CO_2 were sampled at each of the collars once a week from early May through mid-September 1994 using a static chamber technique (Crill et al., 1988). Water was added to the groove in each collar before inserting the chamber in order to make an airtight seal. Air samples were obtained from each chamber by inserting a polypropylene syringe into the Tygon tubing equipped with a three-way stopcock and pumping the piston four or five times to mix air in the chamber before a 60-mL sample was drawn. A 10-mL sample was taken from the 60-mL syringe using the three-way stopcock. Four 10-mL samples were taken at 5-minute intervals over a 20-minute period. Samples were returned to a laboratory in Thompson and analyzed for CH_4 and CO_2 within 4-6 hours of collection.

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

The North American Datum of 1983 (NAD83) coordinates for the sites are:

Burn Moss:	BM:	55.906° N,	98.947° W
Burn Spruce:	BS:	55.906° N,	98.949° W
Palsa Moss:	PM:	55.902° N,	98.418° W
Old Black Spruce, spruce stand:	OBSS:	55.902° N,	97.497° W
Gillam Road Spruce:	GS:	55.904° N,	97.706° W
Gillam Road Pine:	GP:	55.901° N,	97.709° W
Old Black Spruce, aspen stand:	OBSA:	55.906° N,	98.5° W
Gillam Road Aspen:	GA:	53.901° N,	97.712° W
Palsa Bog:	PB:	55.902° N,	98.419° W
Fen Tower site:	FEN:	55.91481° N,	98.42072° W
Old Black Spruce Tower site:	OBS:	55.88007° N,	98.48139° W
Old Jack Pine Tower site:	OJP:	55.92842° N,	98.62396° W
Young Jack Pine Tower site:	YJP:	55.89575° N,	98.28706° W
Young Jack Pine dry site:	YJPD:	55.896° N,	98.298° W
Young Jack Pine wet site:	YJPW:	55.883° N,	98.286° W

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

These are point source data made from the enclosed areas.

7.1.4 Projection
Not applicable.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
CH_4 and CO_2 flux, temperature, moisture, and profile concentration measurements were made from mid-May through mid-September 1994.

7.2.2 Temporal Coverage Map
Not available.

7.2.3 Temporal Resolution
CH_4 and CO_2 flux measurements were made once a week at each of the 66 collars throughout the season.

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
COLLAR_ID
AIR_TEMP
CO2_FLUX
CH4_FLUX
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.
COLLAR_ID	A TGB designation for the chamber collar sites.
AIR_TEMP	The air temperature.
CO2_FLUX	Carbon Dioxide flux.
CH4_FLUX	Methane flux.
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]
COLLAR_ID	[none]
AIR_TEMP	[degrees Celsius]
CO2_FLUX	[micromoles][meter^-2][second^-1]
CH4_FLUX	[micromoles][meter^-2][second^-1]
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	Assigned by BORIS
SUB_SITE	Assigned by BORIS
DATE_OBS	Investigator
COLLAR_ID	Investigator
AIR_TEMP	[PLEASE COMPLETE]
CO2_FLUX	Shimadzu GC
CH4_FLUX	Shimadzu GC
CRTFCN_CODE	Assigned by BORIS
REVISION_DATE	Assigned by BORIS

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-9BS-T03BS	NSA-YJP-T03JP	None	None	None	None
SUB_SITE	TGB03-FLX01	TGB03-FYJPW	None	None	None	None
DATE_OBS	16-MAY-94	22-OCT-96	None	None	None	None
COLLAR_ID	BM-01	YJPW-06	None	None	None	None
AIR_TEMP	-1	33	None	None	None	Blank

```
CO2_FLUX            -39.547454     257.517361     -999    -888   None    Blank
CH4_FLUX            -.00683        .10096956      -999    -888   None    Blank
CRTFCN_CODE         CPI            CPI            None    None   None    None
REVISION_DATE       14-APR-97      17-APR-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 sample data records from a selected file on the CD-ROM:

```
SITE_NAME,SUB_SITE,DATE_OBS,COLLAR_ID,AIR_TEMP,CO2_FLUX,CH4_FLUX,CRTFCN_CODE,
REVISION_DATE
'NSA-9BS-T03BS','TGB03-FLXBM',07-JUN-94,'BM-04',84.834838, -.00242,'CPI',
16-APR-98
'NSA-9BS-T03BS','TGB03-FLXBM',07-JUN-94,'BM-05',9.04900463,0,'CPI',16-APR-98
```

8. Data Organization

8.1 Data Granularity

The smallest set of CH_4 and CO_2 flux measurements tracked by BOREAS was the data collected at a given site on 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

$R_f = C_{std} / A_{std}$
$C_s = R_f * A_s$
R_f = Response factor
A_{std} = Standard peak area
C_{std} = Concentration of the standard
C_s = Concentration of the sample
A_s = Peak area of sample

CH_4 concentrations were calculated from the average of 10 peak areas of known CH_4 standards. The response factor was calculated as the concentration of the known standard divided by the average of 10 standard peak areas. The peak area of the unknown sample was multiplied by the response factor.

The flux calculations were made by fitting a regression curve to the time series of CH_4 concentrations. The flux rate of a gas is calculated using the following equation:

$$\text{Flux}(mg/m^2/d) = \text{ppmv/min} * (P/R*g/\text{mol of the gas}) * (1/T)*V_c/A_c * (1000mg/g*1440min/d)$$

where: P = pressure in atmospheres
R = 8.2054×10^{-5} m^3 atm/mol/K

gases: CH_4 = 16 g/mol
T = degrees K of the chamber
V_c = chamber volume in m^3
A_c = chamber area in m^2

$$V_c=((E/100 \times 0.047 \times 1000) + V_t$$

V_c = volume of the chamber
V_t = volume of the top narrow part of chamber = 1.4
E = height of cylindrical part of chamber in cm

9.2 Data Processing Sequence

9.2.1 Processing Steps

The peak areas were taken directly from the HP ChemStation reports from the GC. They were entered into spreadsheets, and the concentrations were calculated using the formulas in Section 9.1. The spreadsheets then automatically calculated the flux using the formulas in Section 9.1.

The flux equation included the slope of the regression line of the five samples the height and volume of the chamber and air temperature (see above). Fluxes were calculated by linear regression of the concentration change in the five samples. If one sample deviated from the line, the flux was recalculated without the outlier. The correlation coefficient of the regression had to be significant to the 95% confidence limit for n=4 or 5 ($r^2 = 0.95$ or 0.87); otherwise, the sample was rejected. Sites with ebullition were kept in the data set even if a large increase was observed between two of the samples as long as the correlation coefficient was still significant at $p < 0.05$.

9.2.2 Processing Changes

None given.

9.3 Calculations

Not applicable.

9.3.2 Calculated Variables

Refer to Section 9.1.1.

9.4 Graphs and Plots

None given.

10. Errors

10.1 Sources of Error

Field sampling error could account for some error in the concentration of the syringe samples:

- Not flushing the sampling line from the chamber before sampling could cause dilution of the sample with air from the last sampling time.
- Not completely closing the syringes or allowing them to come open during transport will cause dilution from ambient air.

Errors such as these would have been written down in the lab/field books, and these data have been edited out. The analytical precision of the GCs is 0.2% for CH_4.

10.2 Quality Assessment

10.2.1 Data Validation by Source

Each flux measurement has been verified by checking the calculations in the spreadsheets and assessing the slope and intercept for the linear regression.

10.2.2 Confidence Level/Accuracy Judgment

None given.

10.2.3 Measurement Error for Parameters

The analytical precision of the GCs is 0.2% for CH_4.

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

The analytical precision of the GCs is 0.2% for CH_4.

11.2 Known Problems with the Data

None given.

11.3 Usage Guidance

None given.

11.4 Other Relevant Information

None given.

12. Application of the Data Set

The chamber flux data can be used in connection with the tower flux data to determine the CH_4 and CO_2 exchange between the atmosphere and the boreal soils.

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 TGB-03 upland 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

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17.3 Archive/DBMS Usage Documentation

None given.

18. Glossary of Terms

None given.

19. List of Acronyms

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AES     - Atmospheric Environment Services, Canada
ASCII   - American Standard Code for Information Interchange
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
CD-ROM  - Compact Disk-Read-Only Memory
CMDL    - Climate Monitoring and Diagnostics Laboratory
DAAC    - Distributed Active Archive Center
ECD     - Electron Capture Detector
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
FID     - Flame Ionization Detector
GC      - Gas Chromatograph
GIS     - Geographic Information System
GSFC    - Goddard Space Flight Center
HP      - Hewlett Packard
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HTML    - HyperText Markup Language
IFC     - Intensive Field Campaign
IRGA    - Infrared Gas Analyzer
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NOAA    - National Oceanic and Atmospheric Administration
NSA     - Northern Study Area
OBS     - Old Black Spruce
OJP     - Old Jack Pine
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
SSA     - Southern Study Area
TCD     - Thermal Conductivity Detector
TGB     - Trace Gas Biogeochemistry
UNH     - University of New Hampshire
URL     - Uniform Resource Locator
YJP     - Young Jack Pine
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The BOREAS TGB-3 team collected methane and carbon dioxide (CH_4, CO_2) chamber flux measurements at the NSA Fen, OBS, YJP, and auxiliary sites along Gillam Road and the 1989 burn site. Gas samples were extracted from chambers and analyzed at the NSA lab facility approximately every 7 days during May to September 1994 and June to October 1996. The data are provided in tabular ASCII files.

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