NASA/TM—2000–209891, Vol. 229

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

Forrest G. Hall and Sara K. Conrad, Editors

Volume 229

BOREAS TGB-5 CO_2, CH_4, and CO Chamber Flux Data over the NSA

R. Burke and R. Zepp

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

November 2000

The NASA STI Program Office … in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.
- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.
- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at http://www.sti.nasa.gov/STI-homepage.html
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320

NASA/TM—2000–209891, Vol. 229

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

Forrest G. Hall and Sara K. Conrad, Editors

Volume 229

BOREAS TGB-5 CO_2, CH_4, and CO Chamber Flux Data over the NSA

Roger Burke and Richard Zepp
U.S. Environmental Protection Agency, Athens, Georgia

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

November 2000

Available from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076-1320
Price Code: A17

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Price Code: A10

BOREAS TGB-5 CO_2, CH_4, and CO Chamber Flux Data over the NSA

Roger Burke, Richard G. Zepp

Summary

The BOREAS TGB-5 team collected a variety of trace gas concentration and flux measurements at several NSA sites. This data set contains carbon dioxide (CO_2), methane (CH_4), and carbon monoxide (CO) chamber flux measurements conducted in 1994 at upland forest sites that experienced stand-replacement fires. These measurements were acquired to understand the impact of fires on soil biogeochemistry and related changes in trace gas exchange in boreal forest soils. Relevant ancillary data, including data concerning the soil temperature, solar irradiance, and information from nearby unburned control sites, are included to provide a basis for modeling the regional impacts of fire and climate changes on trace gas biogeochemistry. The data are provided in tabular ASCII files.

Table of Contents

1) Data Set Overview
2) Investigator(s)
3) Theory of Measurements
4) Equipment
5) Data Acquisition Methods
6) Observations
7) Data Description
8) Data Organization
9) Data Manipulations
10) Errors
11) Notes
12) Application of the Data Set
13) Future Modifications and Plans
14) Software
15) Data Access
16) Output Products and Availability
17) References
18) Glossary of Terms
19) List of Acronyms
20) Document Information

1. Data Set Overview

1.1 Data Set Identification

BOREAS TGB-05 CO_2, CH_4, and CO Chamber Flux Data over the NSA

1.2 Data Set Introduction

These measurements are required to understand the impact of fires on soil biogeochemistry and related changes in trace gas exchange in boreal forest soils. Relevant ancillary data, including data concerning the soil temperature and solar irradiance, are included to provide a basis for modeling the regional impacts of fire and climate changes on trace gas biogeochemistry.

1.3 Objective/Purpose

The objective of this study is to examine the effects of fire on soil-atmosphere fluxes of trace carbon gases (carbon dioxide [CO_2], methane [CH_4] and carbon monoxide [CO]) in upland black spruce and jack pine ecosystems located within the BOReal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA) near Thompson, Manitoba.

1.4 Summary of Parameters

This data set contains measurements of ambient CO_2, CH_4, and CO)concentrations; CO_2, CH_4, and CO fluxes; ambient and soil temperatures; and solar irradiance.

1.5 Discussion

The soil-atmosphere exchange of CO_2 is an important component of the carbon budget of the boreal forest biome. Soil-atmosphere exchange of CH_4 and CO in the boreal biome has major effects on the atmospheric content of these radiatively and chemically important trace gases. Closed chamber techniques with gas chromatography were used to determine the soil surface flux of CO_2, CH_4, and CO at five BOREAS auxiliary sites in the NSA that were exposed to intense stand-replacement fires during the 7-year period prior to 1994. Flux data were also obtained at nearby control sites. Relevant ancillary data were simultaneously obtained at the sites. The experiments were conducted from the beginning of June through the end of August 1995.

The results from this study indicate that upland soils in burned boreal forests are generally net sources of both CO_2 and CO, but net sinks of atmospheric CH_4. Soil temperatures in these burned sites were generally higher than those observed in nearby unburned controls. Soil respiration includes both root respiration and decomposition of soil organic matter (SOM). Despite the loss of root respiration in the burn sites, soil respiration was nearly the same in the burn sites as in unburned controls. This indicates that enhancement of SOM decomposition by the warming of the soil offset the reduction in root respiration. In sites exposed to the most intense fires, however, where surface organic matter was considerably reduced and converted to charcoal by fire, soil respiration was significantly reduced compared to other sites that were investigated. CH_4 sinks were generally greater in the well-drained jack pine stands than in black spruce stands. CO fluxes are affected by thermal and photochemical production at the soil surface and by microbial consumption deeper in the soil. Thus, CO fluxes in the open burn sites were positive during daylight, whereas the fluxes were negative in the unburned forest soils.

1.6 Related Data Sets

BOREAS TGB-01 Soil CH4 and CO2 Profile Data over NSA Tower Sites
BOREAS TGB-01 CH4 and CO2 Chamber Flux Data from NSA Tower Sites
BOREAS TGB-01 CH4 Concentration and Flux Data from NSA Tower Sites
BOREAS TGB-01 SF6 Chamber Flux Data over NSA Jack Pine Sites
BOREAS TGB-03 CO2 and CH4 Chamber Flux Data over the NSA

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Richard G. Zepp and Dr. Roger A. Burke
U.S. Environmental Protection Agency (EPA)
Athens, GA

2.2 Title of Investigation

Trace Gas Exchange in the Boreal Forest Biome: Effects of Fire and Beaver Activity

2.3 Contact Information

Contact 1:
Dr. Richard G. Zepp
U.S. EPA
960 College Station Road
Athens, GA 30605
(706) 355-8117
zepp.richard@epamail.epa.gov

Contact 2:
Jeffrey A. Newcomer
Raytheon ITSS
Code 923
NASA GSFC
Greenbelt, MD 20771
(301) 286-7858
(301) 286-0239 (fax)
Jeffrey.Newcomer@gsfc.nasa.gov

3. Theory of Measurements

The CO_2, CH_4, and CO fluxes at the surface of the soil are important components of the carbon budget of the boreal forest. Stand-replacement fires may affect the soil-surface fluxes of these gases. Fire removes the canopy and part of the moss, lichen, and shrub cover, thus altering soil temperature, moisture, and nutrient composition. Models of trace gas biogeochemistry in the boreal forest, such as CENTURY, require field measurements of these fluxes in order to calibrate the models and test their predicted fluxes. In order to understand and quantify the carbon gas exchange in these systems, it is necessary to measure their exchange under a variety of conditions in unburned plots and burned plots of various postburn ages.

In particular, CO exchange from the forest ecosystem floor is a poorly understood process that may exhibit a significant effect on the ambient CO levels. The forest floor may act as both a source and sink for CO. Sink activity is believed to be the result of consumption of CO by microbial activity, while production is primarily the result of thermal and photochemical decomposition of living and dead organic matter. The net exchange from the forest floor will therefore be determined by the relative source and sink strengths of these processes. Some parameters that are believed to be important in CO exchange are temperature, moisture content, soil nutrient levels, SOM content, and light intensity.

4. Equipment

4.1 Sensor/Instrument Description

- CH_4 and CO_2 were measured using a Karl Gas Chromatograph (GC) equipped with flame-ionization detector (FID) (for CH_4) and thermal conductivity detector (TCD) (for CO_2). CO was measured using a Trace Analytical (Menlo Park, CA) RGA-3 GC. This instrument isolates CO, and reacts with HgO, producing Hg vapor. The Hg vapor is detected by atomic absorbance. Samples are injected through an injection loop (0.5 or 1 mL).
- Aluminum chamber bases (0.215-m inner diameter [i.d.]) were used for isolating a section of the forest floor. The chambers were anchored with three or four spikes that were 0.20 m in length. The chambers were also equipped with a cylindrical skirt to prevent lateral diffusion of gases. Three skirt sizes were used depending on the ecosystem type: 5 cm, 10 cm, and 20 cm. The opening of the base had a trough filled with water to provide support and seal the chamber top.

- Light measurements were made with an International Light IL1700 radiometer using probes for various light regions (SED 623 for visible, SED 240 for ultraviolet [UV]-A, and SED 033 for UV-B).
- Soil temperature was measured with a portable temperature probe (Cole-Palmer thermistor thermometer L-08110-20).
- Soil water content was measured using a 1502B Time Domain Reflectometer (TDR) [Topp et al., 1980].

4.1.1 Collection Environment

Measurements were made at open sites that had experienced stand-replacement fires within the prior 7 years or at nearby shaded control forest sites that had not burned for at least 70 years. The soil temperatures and solar irradiance were typically much higher at the burned sites than at the control sites. Data were collected under a variety of ambient temperatures ranging from near 0 °C to near 28 °C.

4.1.2 Source/Platform

All measurements were made on the ground.

4.1.3 Source/Platform Mission Objectives

The mission objective was to measure soil surface CO_2, CH_4, and CO fluxes and relevant ancillary data in fire scars and nearby controls.

4.1.4 Key Variables

CO_2, CH_4, and CO flux; soil temperature; soil moisture content; and light intensity (total, UV-A, and UV-B).

4.1.5 Principles of Operation

The chamber assays for CO, CO_2, and CH_4 followed the methods established by Hutchinson and Livingston [1993]. Analysis of CH_4 [Crill, 1991] was conducted with 0.5% precision.

4.1.6 Sensor/Instrument Measurement Geometry

Not applicable.

4.1.7 Manufacturer of Sensor/Instrument

RGA-3 Chromatograph
Trace Analytical
3517-A Edison Way
Menlo Park, CA 94025

IL-1700 Radiometer
International Light, Inc.
17 Graf Road
Newburyport, MA 01950

Temperature Probe
Cole-Palmer Instrument Company
7425 North Oak Park Avenue
Niles, IL 60714

TDR
Tektronix, Inc.
Beaverton, OR

4.2 Calibration

4.2.1 Specifications

Instruments were configured and maintained according to manufacturers' specifications noted in the instruction manuals and were calibrated routinely according to standards.

4.2.1.1 Tolerance

The precision of fluxes for the trace gas measurements, computed from three replicates, is expected to be 15% for CO_2 and CH_4, and 5-10% for CO. The precision is judged by the standard deviation of the three measurements.

4.2.2 Frequency of Calibration

Calibration was performed immediately before measuring each day's samples. Correlation coefficients of 0.99 or better were achieved in all cases. A secondary standard of near atmospheric CO_2, CH_4, or CO concentration was injected periodically during analysis to ensure that no instrumental drift occurred.

4.2.3 Other Calibration Information

CH_4 and CO_2 concentrations were calculated by comparing sample peak areas obtained with a Shimadzu CR501 dual channel integrator to those resulting from repeated analysis of two CH_4 standards and two CO_2 standards. The CH_4 standards contained 0.90-ppm and 2.05-ppm CH_4, and the CO_2 standards contained 356.1-ppm and 397.4-ppm CO_2. The standard gases were supplied by the BOREAS project and calibrated by the Atmospheric Environment Service (AES) of Canada. Based on 10 to 15 daily measurements of these standards, the precision of analysis (standard deviation divided by the mean value expressed in percentage) was 0.7 ± 0.3% for CH_4 and 1.7 ± 0.4% for CO_2. For CO calibration, a standard curve was generated each day by injecting calibrated volumes of a 9.5 ± 0.14-ppm CO primary standard (National Institute of Standards and Technology, Gaithersburg, MD).

5. Data Acquisition Methods

A static chamber technique [such as that described by Whalen and Reeburgh, 1988] was used to estimate soil/atmosphere CH_4 and CO_2 exchange. The chamber consists of a permanently deployed circular aluminum collar, with a water seal and skirt, and an opaque lid. The collars were ~10, 25, or 30 cm deep in areas with significant moss, lichen, or burned vegetation cover, and ~5 cm deep in areas in which the vegetation had burned to the mineral layer. The lid is constructed of aluminum and is equipped with a septum for syringe sampling and a small hole to equalize pressure. The total enclosed area is 0.036 m^2, and the enclosed volume is about 8.7 liters.

CH_4 and CO_2 flux samples were collected at 5-minute intervals over the course of 20 minutes in 60-mL polypropylene syringes with siliconized polypropylene plungers and nylon three-way stopcocks. Syringes were stored in the dark at ambient temperature until analysis. Concentration determinations were made using a Carle AGC GC equipped with a TCD and a FID. Gas samples were introduced to the GC via a 10-port gas sampling valve plumbed for the simultaneous filling of two sample loops and then injection into two columns. Separation of CH_4 and CO_2 was accomplished with 1/8-inch outer diameter (o.d.) stainless steel Hayesep-D (3 m for the FID side and 2 m for the TCD side) analytical columns.

Soil-atmosphere CO exchange was measured using transparent, static soil chambers. These chambers consisted of two parts: a semipermanent base installed into the ground and a removable glass cover that isolated the atmosphere immediately above the base. The aluminum chamber bases consisted of an open-ended, 0.215-m i.d. cylinder (the skirt). The bottom edge of the skirt was beveled to aid insertion into the soil. Skirt lengths were either 0.5 or 0.10 m, depending upon the thickness of the organic layer above the mineral soil. A concentric trough (~30 cm i.d. and 4 cm deep) was welded to

the top of the chamber. This trough, when filled with water, provided an airtight seal with the top. Three or four 0.5-cm-o.d. x 10-cm-long aluminum spikes were attached symmetrically around the circumference of the skirt to provide a secure installation. The glass chamber tops were Kimax (Kimble, Vineland, NJ) borosilicate jars (25 cm deep, ~24 cm i.d., volume ~12 liters). These jars were transparent to visible (400-700 nm) and UV-A (315-400 nm) light, but filtered out a part of UV-B (280-315 nm) radiation. Two 1/4-inch holes were drilled in the side of each glass jar with a 90-degree radial displacement and ~15 cm vertical displacement between each hole. These holes were used as sampling and vent ports. The holes were plugged with small corks, and needles were inserted through the corks. The vent consisted of a 1-inch-long, 22-gauge needle, and the sampling port consisted of a 4- to 6-inch-long, 18-gauge needle. Both needles were left open to the atmosphere during sampling, thereby preventing pressure differentials during experiments.

Soil-atmosphere CO exchange was measured in the following manner. First, the trough of the chamber base was filled with enough water to ensure an airtight seal with the chamber top. Then, the top was quickly but gently placed in the trough and a gas sample of ~20 mL was removed from the chamber. Additional samples were collected (usually at 7-minute intervals) for a total of at least four samples. For each sample, the syringe was connected to the sampling needle and pumped three times to ensure a well-mixed chamber. Approximately 20 mL of sample was collected, and the syringe stopcock was closed. The back of the syringe barrel was sealed with a minimum amount of distilled water and stored in a plastic ziplock bag on ice until analysis. The all-glass syringes (Popper & Sons, New Hyde Park, NY) were fitted with gas-tight Teflon stopcocks (Alltech Associates, Deerfield, IL) and encased in black heat-shrink tubing to keep their contents dark. Sampling was conducted between the hours of 1000 and 1500 local time with the exception of two diurnal studies.

Air and soil temperatures (at a depth of 10 cm for CO_2 and CH_4; 1.0 cm for CO) were measured with a thermocouple probe. Volumetric soil moisture content was measured with a TDR as described by Topp et al. [1984]. Total solar irradiance was measured during the CO flux measurements with the light probe placed close to the environmental chamber.

6. Observations

6.1 Data Notes

None given.

6.2 Field Notes

Date	Location	Activity
July 19		Arrive Thompson
July 20	Lab	Set up laboratory
July 21	Gillam Road: 94GR, CGR	CH4, CO2, CO fluxes
July 22	Gillam Road: 92GR, 87GR	CH4, CO2, CO fluxes
July 23	Leaf Rapids Road: 89JP, CJP	CH4, CO2, CO fluxes
July 24	Leaf Rapids Road: 89FR, CFR	CH4, CO2, CO fluxes
July 25	Gillam Road: 94GR	CH4, CO2, CO fluxes; process studies
July 26	Gillam Road: 94GR, 87GR	CH4, CO2, CO fluxes
July 27	Gillam Road: CGR, 92GR	CH4, CO2, CO fluxes
July 28	Gillam Road: CGR, 92GR	CH4, CO2, CO fluxes; process studies
July 29	Tower Beaver Pond	CO flux from pond
July 30		Off
July 31		Off
Aug 1	Gillam Road: 94GR, 92GR	CH4, CO2, CO fluxes
Aug 2	Gillam Road: CGR, 87GR	CH4, CO2, CO fluxes
Aug 3	Leaf Rapids Rd: 89JP, CJP	CH4, CO2, CO fluxes
Aug 4	Gillam Road: 92GR	CH4, CO2, CO fluxes; diurnal
Aug 5	Gillam Road: 92GR	CH4, CO2, CO fluxes; diurnal continued

Aug 6	Gillam Road: CGR, 87GR	CH4, CO2, CO fluxes
Aug 7	Gillam Road: 94GR, 92GR	CH4, CO2, CO fluxes
Aug 8	Lab	Shut down equipment; ship soil samples
Aug 14	Arrive Thompson	
Aug 15	Lab	Set up lab
Aug 16	Gillam Road: CGR, 94GR	CH4, CO2, CO fluxes
	94GR #6 dug up by animal;.	re-install in another location about 10 ft toward Thompson
Aug 17	Gillam Road: 92GR, 87GR	CH4, CO2, CO fluxes
Aug 18	Gillam Road: CGR	CH4, CO2, CO fluxes; diurnal
Aug 19	Gillam Road: CGR	CH4, CO2, CO fluxes; diurnal continued
Aug 20		Off
Aug 21	Leaf Rapids Road: 89FR, CFR	CH4, CO2, CO fluxes
Aug 22	Leaf Rapids Road: 89JP, CJP	CH4, CO2, CO fluxes
		Four chamber bases missing from 89 Jack Pine site - presumed stolen; remove remaining bases to prevent additional theft and remove some chambers from CJP site for placement in new control site on Gillam Road
Aug 23	Gillam Road: CGR, 92GR	CH4, CO2, CO fluxes
Aug 24	Gillam Road: 87GR, 94GR	CH4, CO2, CO fluxes
Aug 25	Gillam Road: NGRC, CGR	CH4, CO2, CO fluxes; SF6 at 87GR
	87GR	Place three chamber bases in New Gillam Road Control (two medium skirt, one deep skirt)
Aug 26	Gillam Road: CGR, 92GR,	Simul. rain event at CGR, 92GR, 87GR,
	87GR, 94GR, NCGR	94GR; CH4, CO2, CO fluxes at NCGR
Aug 27		Off
Aug 28	Gillam Road: CGR, 92GR	CH4, CO2, CO fluxes
Aug 29	Gillam Road: 87GR, 94GR	CH4, CO2, CO fluxes
Aug 30	Gillam Road: 92GR, 94GR,	SF6 diffusion studies
	87GR	
Aug 31	Lab; Leaf Rapids Road:	SF6 analysis; SF6 diffusion and CH4/CO2
	89FR, CFR	at 89FR and CFR
Sept 1	Gillam Road: 92GR, 94GR	SF6 diffusion studies
Sept 2	Lab	Pack and ship equipment
Sept 2	Leave Thompson	

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

Measurements were performed on upland black spruce (Picea mariana) and jack pine (Pinus banksiana) forest sites in the vicinity of the BOREAS NSA, which is located near Thompson, Manitoba. The North American Datum of 1983 (NAD83) latitude and longitude coordinates of Thompson, Manitoba are 55° 91' N, 98° 42' W. Four black spruce sites, three burned and one control, were selected about 100 km northeast of Thompson, Manitoba. The sites were located at 56° 09' N, 96° 44' W; 56° 08' N, 96° 42' W. All four black spruce sites, which were located within 5 km of each other, were exposed to very similar climatic conditions. The jack pine burn site was located in a large burn site (115,643 ha; summer 1989) on Hwy 391 near Leaf Rapids, Manitoba, 140 km west-northwest of Thompson, Manitoba. A jack pine stand located 133 km west-northwest of Thompson, unburned for at least 80 years, served as the control for the jack pine burn site. At each site, the environmental chambers were used to measure fluxes within an area that was approximately 10,000 m^2.

7.1.2 Spatial Coverage Map

A map showing site locations is included.

7.1.3 Spatial Resolution

The environmental chambers used to measure soil fluxes of CO_2, CO, and CH_4 covered an area about 0.036 m^2. Flux measurements for CO_2, CO, and CH_4 were at six locations within the site.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

The environmental chambers were used to measure soil surface fluxes between June and September 1994. Data were obtained during Intensive Field Campaign (IFC)-1, IFC-2, August 1994, and the first week of IFC-3.

7.2.2 Temporal Coverage Map

See section 6.2 Field Notes.

7.2.3 Temporal Resolution

Individual flux measurements generally were made over a period of 20 to 30 minutes. Flux experiments were routinely conducted between the hours of 1000 and 1600. local time with selected diurnal studies during August 1994 conducted throughout the day and night.

The flux and ancillary data at a given black spruce site were obtained with a sampling frequency of 2-3 days during the periods noted in Section 7.2.1. Data at the jack pine sites were obtained on a weekly basis.

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
STATION_ID
CO2_FLUX
CH4_FLUX
CO_FLUX
AIR_TEMP
SOIL_TEMP_1CM
SOIL_TEMP_10CM
CALC_DOWN_SHORTWAVE_RAD
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 Information System (BORIS) staff, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, or TRN; TTT identifies the cover type for the site (999 if unknown); and CCCCC is the identifier for the site (exactly what it means will vary with site type).
SUB_SITE	The identifier assigned to the subsite by BORIS, 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 the subsite (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.
STATION_ID	The station identifier from which the measurement came.
CO2_FLUX	Carbon dioxide flux.
CH4_FLUX	Methane flux.
CO_FLUX	Carbon monoxide flux.
AIR_TEMP	The measured air temperature.
SOIL_TEMP_1CM	Soil temperature at 1 cm depth.
SOIL_TEMP_10CM	Soil temperature at 10 cm depth.
CALC_DOWN_SHORTWAVE_RAD	Calculated total irradiance encompassing wavelengths from 200-4200 nanometers.
REVISION_DATE	The most recent date that the information in the referenced data base table record was revised.
CRTFCN_CODE	The BOREAS certification level of the data. Examples are Checked by PI (CPI), Certified by Group (CGR), Preliminary (PRE), and CPI but questionable (CPI-???).

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]
STATION_ID	[none]
CO2_FLUX	[micromoles][meter-2][second-1]
CH4_FLUX	[micromoles][meter-2][second-1]
CO_FLUX	[micromoles][meter-2][second-1]
AIR_TEMP	[degrees Celsius]
SOIL_TEMP_1CM	[degrees Celsius]

SOIL_TEMP_10CM	[degrees Celsius]
CALC_DOWN_SHORTWAVE_RAD	[Watts][meter^-2]
REVISION_DATE	[DD-MON-YY]
CRTFCN_CODE	[none]

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
TIME_OBS	Investigator
STATION_ID	Investigator
CO2_FLUX	RGA-3 Chromatograph
CH4_FLUX	RGA-3 Chromatograph
CO_FLUX	RGA-3 Chromatograph
AIR_TEMP	Thermometer
SOIL_TEMP_1CM	Temperature probe
SOIL_TEMP_10CM	Temperature probe
CALC_DOWN_SHORTWAVE_RAD	IL-1700 Radiometer
REVISION_DATE	Assigned by BORIS
CRTFCN_CODE	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-T05GR	NSA-9JP-T5391	None	None	None	None
SUB_SITE	TGB05-F87GR	TGB05-FXCJP	None	None	None	None
DATE_OBS	08-MAR-94	17-OCT-96	None	None	None	None
TIME_OBS	0	2300	None	None	None	None
STATION_ID	1	6	None	None	None	None
CO2_FLUX	0.0281	4.47	-999	-888	None	Blank
CH4_FLUX	-11.5625	0.00083	-999	-888	None	Blank
CO_FLUX	-0.0262	0.057	None	-888	None	Blank
AIR_TEMP	-0.6	91	-999	None	None	Blank
SOIL_TEMP_1CM	-0.2	58.2	-999	None	None	Blank
SOIL_TEMP_10CM	-0.3	20	-999	None	None	Blank
CALC_DOWN_SHORTWAVE_RAD	21	967	-999	None	None	Blank
REVISION_DATE	26-SEP-97	26-SEP-97	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 that an attempt was made to determine the

```
                        parameter value, but the analysis personnel deemed the
                        value to be unreliable.
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 staff 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 records from a sample data file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,STATION_ID,CO2_FLUX,CH4_FLUX,CO_FLUX,AIR_TEMP,
SOIL_TEMP_1CM,SOIL_TEMP_10CM,DOWN_SHORTWAVE_RAD,REVISION_DATE,CRTFCN_CODE
'NSA-9JP-T5391','TGB05-F89JP',08-MAR-94,1615,'5',.994,-.0013773,,19.7,,15.0,,
26-SEP-97,'CPI'
'NSA-9JP-T5391','TGB05-F89JP',08-MAR-94,1615,'6',.745,-.0013889,,19.7,,15.0,,
26-SEP-97,'CPI'
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by BORIS was the flux measurement from 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

None.

9.2 Data Processing Sequence

9.2.1 Processing Steps

Gas samples were collected from the environmental chambers at the field sites, transferred to the laboratory, and analyzed by gas chromatography. The fluxes were then calculated from measured concentrations of the gases vs. time.

9.2.2 Processing Changes

None given.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

For each chamber experiment, the concentration of CO within the chamber was plotted as a function of time after sealing the chamber top over the base. These plots showed three different patterns: (1) linear changes with time, (2) first-order decay with time, and (3) initial linear increase followed by a diminished rate of increase, often yielding a steady state. Concentration vs. time plots were initially plotted to determine the curve shape, and the data analysis was determined based on curve shape. Data were analyzed by performing linear regression (slope = CO exchange rate), by performing log-linear regression (slope = first-order rate constant), or by determining the initial slope.

9.3.2 Calculated Variables

Fluxes of CO_2 and CH_4 were calculated by linear regression of the measured concentrations of samples (typically five) collected during each chamber deployment. CO fluxes were calculated as described in Section 9.3.1.

9.4 Graphs and Plots

Data were plotted using Lotus Freelance, Lotus 123, and Quattro Pro.

10. Errors

10.1 Sources of Error

A few flux measurements were rejected because of various problems such as loss of one or more time points, contaminated or leaky syringes, GC problems, or disturbance of the site during sampling. These problems usually became apparent when either: (1) the initial concentration was not close to the ambient concentration, or (2) the correlation coefficient of the linear regression was not significant at the 90% confidence level ($r^2 = 0.810$ for $n = 4$; $r^2 = 0.648$ for $n = 5$).

10.2 Quality Assessment

Based on the actual performance of the flux measurement system during this study, the minimum detectable flux of CH_4 is estimated to be about 0.3 mg CH_4-C/m^2/d, and the minimum detectable flux of CO_2 to be 0.1 g CO_2-C/m^2/d.

10.2.1 Data Validation by Source

Calibrations and instrumentation ranges were checked, and data were checked for values that were not in expected ranges.

10.2.2 Confidence Level/Accuracy Judgment

For all of the CO_2 and CH_4 data analyzed with regressions, data sets were rejected if the correlation coefficient of the linear regression was not significant at the 90% confidence level ($r^2 = 0.810$ for $n = 4$; $r^2 = 0.648$ for $n = 5$). For CO measurements that exhibited decreasing CO concentrations vs. time, the data sets were rejected if the correlation coefficient of the linear regression of log concentration vs. time was not significant at the 90% confidence level.

10.2.3 Measurement Error for Parameters

Typically, replicate measurements of the same gas sample are within 10% RSD for CO_2, CH_4, and CO.

10.2.4 Additional Quality Assessments

Multiple comparison procedures were performed with the software package SigmaStat (Jandel Scientific, San Rafael, CA) to test for statistically significant differences in gas fluxes and volumetric water content among sets of samples grouped by site or by date within a given site. Each data group was tested for normality (Kolmogorov-Smirnov test) and equal variance (Levene median test) with the SigmaStat package. For comparisons of data groups with normal distributions and equal variances, a One Way Analysis of Variance (ANOVA) was performed to test for differences in mean values of the different groups. If significant differences in the means were found, then a Student-Newman-Keuls (SNK) All Pairwise Multiple Comparisons Procedure was performed to identify specific differences between groups. For comparisons of data groups in which normality and/or equal variance conditions were not met, a Kruskal-Wallis ANOVA on ranks was performed. If the differences in the median values among these groups were found to be significant, then specific differences between groups were tested for by the Dunnas Method of All Pairwise Multiple Comparisons. Mean ranks were calculated from the results of the ranking procedures associated with the nonparametric tests and are presented to indicate trends in the various parameters. Probability and significance levels were set to 0.05 in the SigmaStat package unless otherwise specified. Simple and multiple linear regression procedures were also performed with the SigmaStat package. Zar [1984] and Glanz and Slinker [1990] give details of the statistical tests performed.

10.2.5 Data Verification by Data Center

Data were examined for general consistency and clarity.

11. Notes

11.1 Limitations of the Data

There are no known limitations. However, the user should be aware that there are few other data sets available on soil trace gas fluxes in sites that have been recently burned. Therefore, there is no way at this point to judge the representativeness of this data set.

11.2 Known Problems with the Data

None.

11.3 Usage Guidance

None given.

11.4 Other Relevant Information

The procedures and data obtained in this study are monitored by several mechanisms:

- Formal methods of comparisons. Several comparisons have been made under field and laboratory conditions that have substantiated that the instruments used in this study provide reliable measurements of trace gases.
- Informal comparisons among investigators. Comparisons of the data obtained in this study at unburned control sites with flux data obtained using environmental chambers or towers at other BOREAS NSA sites indicate that these fluxes are in the same range as those observed elsewhere in this region. This favorable comparison suggests that these results are representative of this region.
- Review in the scientific literature. These and other BOREAS results were published in a Special Issue of the Journal of Geophysical Research so that they will be available to the international scientific community. In these publications, the methods were justified to peer referees. These justifications are based on other published methods and tests, which are described in previous papers.

12. Application of the Data Set

These data along with other trace gas measurements from chambers, towers, and aircraft can be used to characterize and model the fluxes of trace gases from the various boreal forest ecosystems.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

These results are being used to improve the CENTURY soils model so that it can be used to evaluate carbon storage and trace gas fluxes in boreal forest soils.

14.2 Software Access

The SigmaStat, Lotus, and other commercial software packages are available from their specific commercial developers.

The CENTURY software will be available from Dr. Dennis Ojima and Dr. William Parton, NREL, Colorado State University, Ft. Collins, CO. The data also likely will be used to improve and test other models that simulate the biosphere-atmosphere exchange of trace gases.

15. Data Access

The CO_2, CH_4, and CO chamber flux data over the NSA are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

None.

16.2 Film Products

None.

16.3 Other Products

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

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

None.

17.2 Journal Articles and Study Reports

Burke, R.A., R.G. Zepp, M.A. Tarr, W.L. Miller, and B.J. Stocks. 1997. Effect of fire on soil-atmosphere exchange of methane and carbon dioxide in Canadian boreal forest sites. Journal of Geophysical Research 102(D24): 29,289-29,300.

Crill, P.M. 1991. Seasonal patterns of methane uptake and carbon dioxide release by a temperate woodland soil. Global Biogeochemical Cycles 5: 319-334.

Glanz, S.A. and B.K. Slinker. 1990. Primer of Applied Regression and Analysis of Variance. McGraw-Hill, New York, 777 pp.

Hutchinson, G.L., and G.P. Livingston. 1993. Use of chamber systems to measure trace gas fluxes, in Agricultural Ecosystem Effects on Trace Gases and Global Climate Change. ASA Special Publication No. 55. American Society of Agronomy, Madison, WI, pp. 63-78.

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.

Topp, G.C., J.L. Davis, W.G. Bailey, and W.D. Zebchuk. 1984. The measurement of soil water content using a portable TDR hand probe. Can. J. Soil Sci., 313-321.

Whalen, S.C. and W.S. Reeburgh. 1988. A methane flux time series for tundra environments. Global Biogeochem. Cycles, 2, 399-409.

Zar, J.H. Biostatistical Analysis, 3rd Ed. 1996. Prentice-Hall, Englewood Cliffs, NJ, 718 pp.

Zepp, R.G., W.L. Miller, M.A. Tarr, R.A. Burke, and B.J. Stocks. 1997. Soil-atmosphere fluxes of carbon monoxide during early stages of postfire succession in upland Canadian boreal forests. Journal of Geophysical Research 102(D24): 29,301-29,311.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None given.

19. List of Acronyms

```
AES     - Atmospheric Environment Services
ANOVA   - One Way Analysis of Variance
ASCII   - American Standard Code for Information Interchange
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
CD-ROM  - Compact Disk-Read-Only Memory
CGR     - Certified by Group
CPI     - Checked by PI
CPI-??? - CPI but questionable
DAAC    - Distributed Active Archive Center
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
EPA     - Environmental Protection Agency
FID     - Flame Ionization Detector
GC      - Gas Chromatograph
GMT     - Greenwich Mean Time
GSFC    - Goddard Space Flight Center
HTML    - HyperText Markup Language
IFC     - Intensive Field Campaign
NASA    - National Aeronautics and Space Administration
```

```
NSA     - Northern Study Area
PANP    - Prince Albert National Park
PI      - Principal Investigator
PRE     - Preliminary
ORNL    - Oak Ridge National Laboratory
SNK     - Student-Newman-Keuls
SOM     - Soil Organic Matter
SSA     - Southern Study Area
TCD     - Thermal conductivity Detector
TDR     - Time Domain Reflectometer
TGB     - Trace Gas Biogeochemistry
URL     - Uniform Resource Locator
UV      - Ultraviolet
```

20. Document Information

20.1 Document Revision Date

Written: 04-Jun-1997
Last Updated: 27-May-1999

20.2 Document Review Date(s)

BORIS Review: 06-Oct-1997
Science Review:

20.3 Document ID

20.4 Citation

When using these data, please contact one of the people listed in Section 2.3 as well as citing relevant papers in Section 17.2:

If using data from the BOREAS CD-ROM series, also reference the data as:
Zepp R.G. and R.A. Burke, "Trace Gas Exchange in the Boreal Forest Biome: Effects of Fire and Beaver Activity." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, 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. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:
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. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM. NASA, 2000.

20.5 Document Curator

20.6 Document URL

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
November 2000

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)
BOREAS TGB-5 CO_2, CH_4, and CO Chamber Flux Data over the NSA

5. FUNDING NUMBERS
923
RTOP: 923-462-33-01

6. AUTHOR(S)
Roger Burke and Richard Zepp
Forrest G. Hall and Sara K. Conrad, Editors

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)
Goddard Space Flight Center
Greenbelt, Maryland 20771

8. PEFORMING ORGANIZATION REPORT NUMBER
2000-03136-0

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS (ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
TM—2000–209891
Vol. 229

11. SUPPLEMENTARY NOTES
R. Burke and R. Zepp: U.S. Environmental Protection Agency, Athens, Georgia;
Sara K. Conrad: Raytheon ITSS

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified–Unlimited
Subject Category: 43
Report available from the NASA Center for AeroSpace Information,
7121 Standard Drive, Hanover, MD 21076-1320. (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The BOREAS TGB-5 team collected a variety of trace gas concentration and flux measurements at several NSA sites. This data set contains carbon dioxide (CO_2), methane (CH_4), and carbon monoxide (CO) chamber flux measurements conducted in 1994 at upland forest sites that experienced stand-replacement fires. These measurements were acquired to understand the impact of fires on soil bio-geochemistry and related changes in trace gas exchange in boreal forest soils. Relevant ancillary data, including data concerning the soil temperature, solar irradiance, and information from nearby un-burned control sites, are included to provide a basis for modeling the regional impacts of fire and climate changes on trace gas biogeochemistry. The data are provided in tabular ASCII files.

14. SUBJECT TERMS
BOREAS, trace gas biogeochemistry.

15. NUMBER OF PAGES
17

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT
UL