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

Forrest G. Hall and Sara K. Conrad, Editors

Volume 230

BOREAS TGB-5 Biogenic Soil Emissions of NO and N_2O

J.S. Levine and E.L. Winstead, NASA Langley Research Center, Hampton, Virginia
D.A.B. Parsons and M.C. Scholes, University of Witwatersrand
R.J. Scholes, Forestek, CSIR
W.R. Cofer and D.R. Cahoon, NASA Langley Research Center, Hampton, Virginia
D.I. Sebacher, SAIC

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

November 2000

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BOREAS TGB-5 Biogenic Soil Emissions of NO and Nitrous Oxide

J.S. Levine, E.L. Winstead, D.A.B. Parsons, M.C. Scholes, R.J. Scholes, W.R. Cofer,
D.R. Cahoon, D.I. Sebacher

Summary

The BOREAS TGB-5 team made several measurements of trace gas concentrations and fluxes at various NSA sites. This data set contains biogenic soil emissions of nitric oxide and nitrous oxide that were measured over a wide range of spatial and temporal site parameters. Since very little is known about biogenic soil emissions of nitric oxide and nitrous oxide from the boreal forest, the goal of the measurements was to characterize the biogenic soil fluxes of nitric oxide and nitrous oxide from black spruce and jack pine areas in the boreal forest. The diurnal variation and monthly variation of the emissions was examined as well as the impact of wetting through natural or artificial means. Temporally, the data cover mid-August 1993, June to August 1994, and mid-July 1995. The data are provided in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TGB-05 Biogenic Soil Emissions of NO and Nitrous Oxide

1.2 Data Set Introduction

The biogenic soil emissions of nitric oxide and nitrous oxide was characterized over a wide range of spatial and temporal parameters. Measurements were made in different terrain/subecosystems in and around the BOReal Ecosystem-Atmosphere Study (BOREAS) Northern Study Area (NSA), including burned and unburned upland black spruce and jack pine sites. Burned sites had been burned at time periods ranging from the years 1987 to 1994. The diurnal variation and monthly variation of these emissions was examined as well as the impact of wetting through natural rainfall or artificial wetting.

1.3 Objective/Purpose

Since very little is known about biogenic soil emissions of nitric oxide and nitrous oxide from the boreal forest, the goal of the project was to characterize the biogenic soil fluxes of nitric oxide and nitrous oxide from upland black spruce and jack pine subecosystems in the boreal forest located near the BOREAS NSA and Thompson, Manitoba, and to examine the postfire effect of fires on the soil fluxes of these gases and how long this effect persists.

1.4 Summary of Parameters

Nitric oxide flux, nitrous oxide flux, and soil temperature.

1.5 Discussion

The biogenic soil emissions of nitric oxide and nitrous oxide were characterized over a wide range of spatial and temporal parameters. Measurements were made in different terrain or subecosystems in and around the BOREAS NSA, including burned and unburned upland black spruce and jack pine sites. Measurements were made during field campaigns during August 1993; June, July, and August 1994; and July 1995. More than 500 flux measurements of NO and more than 500 flux measurements of N_2O were made during these field campaigns. Usually, flux measurements were made at eight plots at each of the sites. Typically, a total of 16 to 20 flux measurements, including wet and dry, were made at one site each day during each Intensive Field Campaign (IFC). At each site, the flux chamber was place down on each plot for 20 minutes before being moved to the next plot. After making the flux measurement at ambient soil moisture conditions, approximately 1 L of distilled water was added to the plot and the measurement was repeated 1 hour after wetting. No water was added to sites that were already wet due to rain. During the time periods that the measurements were made, little or no difference was seen between NO emissions before and after wetting, either artificially or by rain.

Since black spruce was much more dominant than jack pine in this region, most of the NO flux data were collected in black spruce. There were eight black spruce sites -- two unburned and six sites that had been burned over a time period of 8 years. Flux measurements were obtained from sites burned in 1987, 1989, 1992, 1993, 1994, and 1995 as well as from the unburned control sites. There were three jack pine sites -- two unburned and one burned in 1987. Not only did the sites span a period of time since burned, but there was also variation in the depth of burn, which is related to fire intensity. The depth of burn varied from unburned, which had a sphagnum and feather moss ground cover of up to 30 to 40 cm, to a high depth of burn at the 1992 burn site, where the fire had burned down to mineral soil.

Measurements indicated that the amount of NO flux and the duration of increased NO flux correlated with the intensity of the burn and how quickly vegetation returned rather than the time since burning.

1.6 Related Data Sets

BOREAS TE-09 PAR and Leaf Nitrogen Data for NSA Species
BOREAS TE-09 NSA Photosynthetic Capacity and Foliage Nitrogen Data
BOREAS TGB-01 NSA CH4 and CO2 Chamber Flux Data
BOREAS TGB-01 SF6 Chamber Flux Data over NSA Jack Pine Sites
BOREAS TGB-03 CO2 and CH4 Chamber Flux data over the NSA
BOREAS TGB-05 CO2, CH4, and CO Chamber Flux Data over the NSA

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Joel S. Levine
NASA Langley Research Center

Edward L. Winstead
NASA Langley Research Center

2.2 Title of Investigation

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

2.3 Contact Information

Contact 1:
Dr. Joel S. Levine
NASA Langley Research Center
Mail Stop 401B
Hampton, VA 23681
(757) 864-5692
j.s.levine@larc.nasa.gov

Contact 2:
Edward L. Winstead
NASA Langley Research Center
Mail Stop 483
Hampton, VA 23681
(757) 864-4209
e.l.winstead@larc.nasa.gov

Contact 3:
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 NO, NO_2, and NO_X (NO + NO_2) fluxes at the surface of the soil are important components 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. In order to understand and quantify gas exchange in these systems, it is necessary to measure the biogenic soil emissions of nitric oxide and nitrous oxide over a wide range of spatial and temporal parameters, including burned and unburned upland black spruce and jack pine sites.

4. Equipment

4.1 Sensor/Instrument Description

The measurements of NO, NO_2, and NO_X (NO + NO_2) were made with a modified LMA-3 Luminox NO_2 monitor. The Luminox monitor is a lightweight, portable instrument for continuous measurement of NO_2 in air. It operates by detecting the chemiluminescence produced when NO_2 interacts with a surface wetted with a specially formulated luminol solution. The luminol solution is oxidized, producing chemiluminescence in the 425 nm region, which is measured by a photomultiplier tube. The signal from the photomultiplier tube is directly proportional to the mixing ratio of NO_2. Since the NO_2-luminol reaction is temperature sensitive, the NO_2 monitor is equipped for temperature compensation. The signal for a given NO_2 mixing ratio is constant over the temperature range of 5 to 40 °C. For the measurement of NO and NO_X, a chromium trioxide converter system was developed for the conversion of NO to NO_2 prior to introduction into the Luminox detector. The NO to NO_2 converter consists of a Teflon-lined stainless steel tube (6.0 cm x 1.2 cm) packed with a chromosorb support material coated with chromium trioxide. The converter material is prepared by soaking Chromosorb P, 30-60 mesh (manufactured by Johns Manville Corporation) in a 17% chromium trioxide aqueous solution. The excess solution is decanted and the material is dried in an oven at 40 °C. Finally, the material is exposed to ambient air conditions for 24 hours as described by Levaggi et al., 1974. The conversion of NO to NO_2 is nearly 100% efficient provided that the relative humidity of the sample air stream is less than 25%. This is accomplished by pumping the sample air stream at approximately 1.0 L min-1 through a Teflon filter and then through a 1-m-long Nafion tube (Type 815, Dupont perfluorinated polymer, 1.0 mm ID x 0. 875 mm OD, Perma Pure, Incorporated) packed in silica gel. The Nafion dryer lowers the water content of the air to an acceptable level without the loss of NO or NO_2. The dried air is directed either through the chromium trioxide converter where NO is converted to NO_2 for the measurement of NO_X or through an unpacked column for the measurement of NO_2 by the Luminox monitor. NO is calculated as the difference between the converted and unconverted signals. The minimum detectable flux with this instrument is 0.02 ng N/m^2/s of NO over a 10-minute interval at 293 K.

The N_2O measurements were made using a Schimadzu model GC-MINI-2 gas chromatograph equipped with a 63Ni electron capture detector, a 1-mL sample loop and stainless steel Porapak Q column (4-m, 1-mm-ID HayeSep Q micropacked column). The detector temperature was 340 °C, and the oven temperature was 60 °C. The carrier gas, 5% methane in argon, was supplied at a flow rate of 22 mL/min. The minimum detectable flux of N_2O that could be detected with this instrument is 1 ng N/m^2/s of N_2O over a 20-minute period at 293 K.

4.1.1 Collection Environment

Samples were collected under all environmental conditions.

4.1.2 Source/Platform

Ground.

4.1.3 Source/Platform Mission Objectives

The mission objective was to measure soil nitric oxide and nitrous oxide fluxes and relevant ancillary data in fire scars and nearby controls.

4.1.4 Key Variables

Nitric oxide, nitrous oxide, soil temperature, and soil moisture content.

4.1.5 Principles of Operation

The measurements of NO, NO_2, and NO_X (NO + NO_2) were made with a modified LMA-3 Luminox NO_2 monitor. It operates by detecting the chemiluminescence produced when NO_2 interacts with a surface wetted with a specially formulated luminol solution. The signal from the photomultiplier tube is directly proportional to the mixing ratio of NO_2. For the measurement of NO and NO_X, a chromium trioxide converter system was developed for the conversion of NO to NO_2 prior to introduction into the Luminox detector. Dried sample air is directed either through the chromium trioxide converter where NO is converted to NO_2 for the measurement of NO_X or through an unpacked column for the measurement of NO_2 by the Luminox monitor. NO is calculated as the difference between the converted and unconverted signals.

The N_2O measurements were made using a Schimadzu model GC-MINI-2 gas chromatograph equipped with a 63Ni electron capture detector (ECD). Gas samples collected by syringe are injected into the chromatograph via an injection valve equipped with a 1-mL loop. After separation of N_2O from other gas components in a Porapak Q packed column, the concentration of N_2O is measured by the ECD detector and quantified by integration.

4.1.6 Sensor/Instrument Measurement Geometry

Not applicable.

4.1.7 Manufacturer of Sensor/Instrument

Manufacturer of LMA-3 Luminox NO_2 monitor:
Scintrex/Unisearch
222 Snidercroft Road
Concord, Ontario, Canada L4K 1B5
(416) 669-2280
(416) 669-5132 (fax)

The NO to NO_2 converter was built in-house.

The manufacturer of the Shimadzu gas chromatograph is:
Shimadzu Scientific Instruments
7102 Riverwood Drive
Columbia, MD 21046
(301) 381-1227
(301) 381-1222 (fax)

4.2 Calibration

4.2.1 Specifications

4.2.1.1 Tolerance

The Luminox instrument was calibrated for NO using a field calibration master gravimetric standard certified by Scott Specialty Gases (Plumsteadville, PA) at the +1% level. A calibration curve was obtained by dynamic mass flow dilution of the standard with ultra zero ambient monitoring air. The field calibration source was checked against a National Institute of Standards and Technology (NIST) standard reference material (SRM).

4.2.2 Frequency of Calibration

The NO instrumentation was calibrated daily. The N_2O gas chromatograph was calibrated every six injections.

4.2.3 Other Calibration Information

None given.

5. Data Acquisition Methods

NO and N_2O fluxes were determined using a closed chamber flux technique. At sites selected for study, only a flux chamber was placed onto the soil plots with the edges of the chamber extending into the soil to prevent movement of air into or out of the chamber. Rectangular aluminum collars were inserted into the soil to a depth of at least 3 cm for some plots. The top edges of the collar formed a V-shaped groove into which the flux chamber could be set. Flux measurements of plots with and without collars revealed no difference in flux between the measurements. The collar and flux chamber covered an area measuring about 0.4 m^2. The inner surfaces of both the collar and the flux chamber were coated with Teflon. The outer surfaces of the chamber was insulated with reflective aluminum-covered isocyanurate foam. The volume of the flux chamber varied from about 148 L to 175 L, depending upon if a collar was used and the depth to which the collar was inserted into the soil. A muffin fan inside the box stirred the air at the rate of 3 m^3 min-1 at zero static back pressure to ensure that the chamber air was homogeneous. A 0.635-cm vent at the top of the box prevented development of a pressure differential when air was pumped out of the chamber for analysis of NO. Teflon tubing extending 20 cm into the chamber was used for sampling air for NO and NO_X analysis. Bulkhead fittings with silicone rubber septa were used for removal of chamber air by syringe for N_2O analysis. Another fitting allowed insertion of probes used to measure the temperatures of both soil and air within the chamber.

Both O_3 and NO_2 have been shown to decrease to near zero during the first 4 min. after setting the flux chamber down. NO_2 is absorbed onto soils and both absorbed and metabolized by plants. Therefore, NO_2 was ignored and all calculations of NO fluxes were based upon the increase of mixing ratio versus time of NO beginning 4 min after starting the flux measurement. Correction was made for the dilution caused by pumping air into the Luminox LMA-3 monitor at 1 L/min.

6. Observations

6.1 Data Notes

None given.

6.2 Field Notes

Date	Location	Activity
14-Aug-93	93NR	NO, N2O fluxes, Site only accessible by float plane.
15-Aug-93	89JP	NO, N2O fluxes.
16-Aug-93	CJP	NO, N2O fluxes.
17-Aug-93	89FR	NO, N2O fluxes, Site received rain over-night, soil was wet.
18-Aug-93	CGR	NO, N2O fluxes, Feather covering site was wet.
19-Aug-93	92GR	NO, N2O fluxes, Heavy burn to mineral soil in 1992, some moss and shrub regrowth. Feather covering site was wet.
04-Jun-94	CGR	NO, N2O fluxes.
06-Jun-94	CJP	NO, N2O fluxes.
08-Jun-94	89JP	NO, N2O fluxes, Sandy soil, burned to mineral soil.
09-Jun-94	89FR	NO, N2O fluxes.
10-Jun-94	CFR	NO, N2O fluxes.
12-Jun-94	94GR	Sites received heavy rain.
13-Jun-94	94GR	NO, N2O fluxes, Some large logs at site still smoldering from fire which occurred approximately 6/11/94, but not moss.
16-Jun-94	92GR	NO, N2O fluxes.
17-Jun-94	89FR	NO, N2O fluxes.
18-Jun-94	94GR	NO, N2O fluxes, Light burn in 1994, soil surface covered with burned and dead moss.
19-Jun-94	87GR	NO, N2O fluxes, Soil very damp under regrowth of moss.
21-Jul-94	94GR	NO, N2O fluxes, Black ash on top of burned moss.
22-Jul-94	92GR	NO, N2O fluxes, Light rain at the site during the morning.
24-Jul-94	92GR	NO, N2O fluxes, Light rain on the way to site. Ground was wet.
25-Jul-94	CGR	NO, N2O fluxes.
26-Jul-94	89JP	NO, N2O fluxes.
27-Jul-94	89FR	NO, N2O fluxes.
28-Jul-94	CJP	NO, N2O fluxes, Sandy soil covered with reindeer lichen and small shrubs.
29-Jul-94	94GR	NO, N2O fluxes.
31-Jul-94	92GR	NO, N2O fluxes, Diurnal study conducted at site. Late in the afternoon, smoke haze from distant fires visible.
01-Aug-94	92GR	NO, N2O fluxes.
02-Aug-94	92GR	NO, N2O fluxes.

03-Aug-94	89JP	NO, N2O fluxes, During first flux measurement, signal output became noisy.Bad cable was detected and replaced. The first flux measurement was repeated.
04-Aug-94	89FR	NO, N2O fluxes.
05-Aug-94	CJP	NO, N2O fluxes.
06-Aug-94	CFR	NO, N2O fluxes, Site received rain the night before.
17-Jul-95	92GR	NO, N2O fluxes, Light rain that night.
18-Jul-95	92GR	NO, N2O fluxes.
20-Jul-95	94GR	NO, N2O fluxes, Heavy rain during night at site.
21-Jul-95	95GR	NO, N2O fluxes, Black spruce stand burned in July 1995. Mixed burn, burned to mineral soil in some areas, other areas covered with burned and dead moss.
22-Jul-95	87GR	NO, N2O fluxes, Light rain.
24-Jul-95	89FR	NO, N2O fluxes.
25-Jul-95	89JP	NO, N2O fluxes.
26-Jul-95	92GR	NO, N2O fluxes, Light rain.
27-Jul-95	CFR	NO, N2O fluxes.
26-Jul-95		Rain all day.
29-Jul-95	95GR	NO, N2O fluxes.

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 are 55° 91' N, 98° 42' W). Eight black spruce sites were selected about 100 km northeast of Thompson, Manitoba. All eight black spruce sites were exposed to very similar climatic conditions. The sites were located :

- **CGR:** Black spruce control (not burned for >60 yrs) on Gillam Rd (100 km from Thompson); Clay, sand and silt soil; Live sphagnum and feather moss ground cover. (55.154N, 96.718W)
- **CFR:** Control black spruce near Footprint River on Hwy 391 (82 km from Thompson); Clay, sand and silt soil; Live sphagnum and feather moss ground cover. (Coordinates unavailable)
- **87GR:** Black spruce stand burned in 1987 on Gillam Rd. (99 km from Thompson); Clay, sand and silt soil; Heavy burn, strong moss, grass and shrub regrowth. (55.158N, 96.727W)
- **89FR**: Black spruce stand burned in 1989, near Footprint River on Hwy 391 (82 km from Thompson); Clay, sand and silt soil; Heavy burn, burned to mineral soil in spots, some moss and shrub regrowth. (Coordinates unavailable.)
- **92GR:** Black spruce stand burned in 1992 on Gillam Rd. (100 km from Thompson); Clay, sand and silt soil; Heavy burn to mineral soil, some moss and shrub regrowth. (55.149N, 96.712W)
- **93NR:** Black spruce stand burned in 1993 (70 km SE of Thompson, Nelson River); Clay, sand and silt soil; Light burn, top10-15 cm of moss burned. (Coordinates unavailable)
- **94GR:** Black spruce stand burned in 1994 on Gillam Rd. (98 km from Thompson); Clay, sand and silt soil; Clay, sand and silt soil; Light burn, soil surface covered with burned and dead moss. (55.158N, 96.735W)
- **95GR:** Black spruce stand burned in July 1995 (94 km East of Thompson, Gillam Road); Clay, sand and silt soil; Mixed burn, burned to mineral soil in some areas, other areas covered with burned and dead moss. (56.1741N, 96.51963W)

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 north west of Thompson, Manitoba. A jack pine stand, unburned for at least 80 years, located 133 km west north west of Thompson, served as the control for the jack pine burn site. (Coordinates unavailable)

Flux measurements were made in the following jack pine sites in and around the BOREAS NSA:

- **CJP:** Control jack pine (not burned for > 60 yrs) on Hwy 391(132 km from Thompson) and (57 km from Nelson House); Sandy soil covered with reindeer lichen and small shrubs. (55.96257N, 99.83004W)
- **89JP:** Jack pine stand burned in 1989 on Hwy 391(138 km from Thompson); Sandy soil, burned to mineral soil. (56.02696N, 99.87474W)

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

Not available.

7.1.3 Spatial Resolution

Each flux measurement covered an area of 0.40 m^2. Usually flux measurements were made at 8 plots at each of 10 sites.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

Measurements were made during field campaigns during August 1993; June, July, and August 1994; and July 1995.

7.2.2 Temporal Coverage Map

```
   Date      Location
---------    --------
14-Aug-93    93NR
15-Aug-93    89JP
16-Aug-93    CJP
17-Aug-93    89FR
18-Aug-93    CGR
19-Aug-93    92GR
04-Jun-94    CGR
06-Jun-94    CJP
08-Jun-94    89JP
09-Jun-94    89FR
10-Jun-94    CFR
13-Jun-94    94GR
16-Jun-94    92GR
17-Jun-94    89FR
18-Jun-94    94GR
19-Jun-94    87GR
```

```
21-Jul-94   94GR
22-Jul-94   92GR
24-Jul-94   92GR
25-Jul-94   CGR
26-Jul-94   89JP
27-Jul-94   89FR
28-Jul-94   CJP
29-Jul-94   94GR
31-Jul-94   92GR
01-Aug-94   92GR
02-Aug-94   92GR
03-Aug-94   89JP
04-Aug-94   89FR
05-Aug-94   CJP
06-Aug-94   CFR
17-Jul-95   92GR
18-Jul-95   92GR
20-Jul-95   94GR
21-Jul-95   95GR
22-Jul-95   87GR
24-Jul-95   89FR
25-Jul-95   89JP
26-Jul-95   92GR
27-Jul-95   CFR
29-Jul-95   95GR
```

7.2.3 Temporal Resolution

Typically, a total of 16 to 20 flux measurements, including wet and dry, were made at one site each day during each IFC. A diurnal study was also conducted.

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
PLOT_ID
NO_FLUX
N2O_FLUX
SURFACE_TEMP
SOIL_INFO
SOIL_TEMP_2CM
SOIL_TEMP_4CM
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, T RN, 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.
PLOT_ID	This is the plot from which the measurement came.
NO_FLUX	NO FLUX
N2O_FLUX	N2O flux
SURFACE_TEMP	Surface temperature.
SOIL_INFO	The local soil information at the site.
SOIL_TEMP_2CM	Soil temperature at 2cm depth.
SOIL_TEMP_4CM	Soil temperature at 4cm depth.
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

7.3.3 Unit of Measurement

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

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
PLOT_ID	[none]
NO_FLUX	[nanograms N][meter^-2][second^-1]
N2O_FLUX	[nanograms N][meter^-2][second^-1]
SURFACE_TEMP	[degrees Celsius]
SOIL_INFO	[none]
SOIL_TEMP_2CM	[degrees Celsius]
SOIL_TEMP_4CM	[degrees Celsius]
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	Not applicable
SUB_SITE	Not applicable
DATE_OBS	Investigator
TIME_OBS	Investigator
PLOT_ID	Investigator
NO_FLUX	Schimadzu model GC-MINI-2 gas chromatograph
N2O_FLUX	Schimadzu model GC-MINI-2 gas chromatograph
SURFACE_TEMP	Cole-Palmer, model 8402-20
SOIL_INFO	Investigator
SOIL_TEMP_2CM	[Unknown]
SOIL_TEMP_4CM	[Unknown]
CRTFCN_CODE	[BORIS Designation]
REVISION_DATE	[BORIS Designation]

7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	NSA-9BS-T05GR	NSA-9JP-T5391	None	None	None	None
SUB_SITE	TGB05-N87GR	TGB05-NFCJP	None	None	None	None
DATE_OBS	14-AUG-93	29-JUL-95	None	None	None	None
TIME_OBS	1	2357	None	None	None	None
PLOT_ID	1	9	None	None	None	None
NO_FLUX	.02	64.9	-999	None	-777	None
N2O_FLUX			None	None	-777	None
SURFACE_TEMP	8.9	34.2	-999	None	None	None
SOIL_INFO	N/A	N/A	None	None	None	None
SOIL_TEMP_2CM	15.4	28.9	-999	None	None	None
SOIL_TEMP_4CM	1.7	21.2	-999	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	25-SEP-96	26-SEP-96	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 records from a sample data file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,PLOT_ID,NO_FLUX,N2O_FLUX,SURFACE_TEMP,
SOIL_INFO,SOIL_TEMP_2CM,SOIL_TEMP_4CM,CRTFCN_CODE,REVISION_DATE
'NSA-9BS-T5391','TGB05-N89FR',04-AUG-94,1518,1,.06,-777,15.7,'Amb',-999,-999,
'CPI',25-SEP-96
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by the BOREAS Information System (BORIS) was the data 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 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

NO fluxes were calculated from the slope of the NO mixing ratio (ppbv) versus time (minutes) from 4 to 15 minutes after the flux chamber was placed on the soil. During this time the slope was linear. N_2O fluxes were calculated from the slope of the N_2O mixing ratio versus time from time zero.

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

None given.

10.2 Quality Assessment

10.2.1 Data Validation by Source

A comparison of the NO flux methods, instrumentation, and calibration was held during Biosphere-Atmosphere Trace Gas Exchange (BATGE) experiments in 1994 and during Natural emissions of Oxidant precursors: Validation techniques and Assessment project (NOVA) field experiments in 1994 and 1995.

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

None.

11.3 Usage Guidance

None given.

11.4 Other Relevant Information

None given.

12. Application of the Data Set

These data along with other nitrogen values from other data sets can be used to characterize the soils at various boreal forest sites.

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 biogenic soil emissions 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.

17.2 Journal Articles and Study Reports
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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.

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

```
ASCII   - American Standard Code for Information Interchange
BATGE   - Biosphere-Atmosphere Trace Gas Exchange
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
CD-ROM  - Compact Disk-Read-Only Memory
DAAC    - Distributed Active Archive Center
ECD     - Electron Capture Detector
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
IFC     - Intensive Field Campaign
NASA    - National Aeronautics and Space Administration
NIST    - National Institute of Standards and Technology
NOVA    - Natural emissions of Oxidant precursors: Validation techniques and
          Assessment project
NSA     - Northern Study Area
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
SRM     - Standard Reference Material
SSA     - Southern Study Area
TE      - Terrestrial Ecology
TGB     - Trace Gas Biogeochemistry
URL     - Uniform Resource Locator
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13. ABSTRACT *(Maximum 200 words)*
The BOREAS TGB-5 team made several measurements of trace gas concentrations and fluxes at various NSA sites. This data set contains biogenic soil emissions of nitric oxide and nitrous oxide that were measured over a wide range of spatial and temporal site parameters. Since very little is known about biogenic soil emissions of nitric oxide and nitrous oxide from the boreal forest, the goal of the measurements was to characterize the biogenic soil fluxes of nitric oxide and nitrous oxide from black spruce and jack pine areas in the boreal forest. The diurnal variation and monthly variation of the emissions was examined as well as the impact of wetting through natural or artificial means. Temporally, the data cover mid-August 1993, June to August 1994, and mid-July 1995. The data are provided in tabular ASCII files.

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