NASA/TM—2000–209891, Vol. 209

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

Forrest G. Hall and Karl Huemmrich, Editors

Volume 209

BOREAS TF-11 SSA-Fen Tower Flux and Meteorological Data

Shashi B. Verma and Timothy Arkebauer, University of Nebraska-Lincoln
David Valentine, University of Alaska, Fairbanks

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. 209

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

Forrest G. Hall and Karl Huemmrich, Editors

Volume 209

BOREAS TF-11 SSA-Fen Tower Flux and Meteorological Data

Shashi B. Verma and Timothy Arkebauer, University of Nebraska-Lincoln
David Valentine, University of Alaska, Fairbanks

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 TF-11 SSA-Fen Tower Flux and Meteorological Data

Shashi B. Verma, Timothy J. Arkebauer, David Valentine

Summary

The BOREAS TF-11 team collected energy, carbon dioxide, and methane flux data at the BOREAS SSA-Fen site during the growing seasons of 1994 and 1995. The data are available in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TF-11 SSA-Fen Tower Flux and Meteorological Data

1.2 Data Set Introduction

This data set includes heat, carbon dioxide, and methane fluxes measured by eddy correlation and meteorological data all measured at the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA)-Fen site.

1.3 Objective/Purpose

This overall project has the following research components:

- Quantification of surface exchange rates of methane and carbon dioxide (using the micrometeorological eddy correlation technique) at a boreal wetland site.
- Evaluation of soil surface carbon dioxide flux and characterization of its response to controlling variables (such as temperature, water content, and water table depth).
- Experimental quantification of the responses of leaf photosynthesis, plant respiration, and stomatal conductance of dominant plant species to relevant controlling variables.
- Process studies, which include field experimental manipulations to quantify the degree of substrate of pH limitations of methane production and oxidation.

1.4 Summary of Parameters

The variables measured include latent heat flux, sensible heat flux, carbon dioxide flux, methane flux, net radiation, incident Photosynthetic Photon Flux Density (PPFD), incident and reflected solar radiation, wind speed and direction, soil temperatures, precipitation amount, air temperature, absolute humidity, vapor pressure deficit, air pressure, and water table height.

1.5 Discussion

In BOREAS, each surface flux site was located in a unique boreal forest ecosystem component in northern and southern study areas, in an attempt to characterize the boreal forest at both the northern and southern extremes of its extent. In this study, the surface flux station was deployed in a wetland environment of the SSA to make measurements of the fluxes of carbon dioxide, methane, and the energy budget components. These fluxes were considered important in characterizing wetlands of the boreal forest. The surface fluxes were measured using the eddy correlation technique. Supporting meteorological measurements were also made at this site.

A pilot study was conducted during August-September of 1993. A more extensive study was conducted from May to October in 1994 and in 1995.

1.6 Related Data Sets

BOREAS TF-11 Biomass Data over the SSA-Fen
BOREAS TF-11 CO2 and CH4 Concentration Data from the SSA-Fen
BOREAS TF-11 CO2 and CH4 Flux Data from the SSA-Fen
BOREAS TF-11 Decomposition Data over the SSA-Fen
BOREAS TF-10 NSA-Fen Tower Flux and Meteorological Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Shashi B. Verma
School of Natural Resource Sciences
University of Nebraska

Dr. Timothy Arkebauer
Department of Agronomy
University of Nebraska

Dr. David Valentine
Dept. of Forest Sciences
University of Alaska

2.2 Title of Investigation

Field Micrometeorological Measurements, Process-Level Studies, and Modeling Of Methane and Carbon Dioxide Fluxes in a Boreal Wetland Ecosystem

2.3 Contact Information

Contact 1:

Micrometeorological Data
Dr. Shashi B. Verma
School of Natural Resource Sciences
University of Nebraska
Lincoln, NE 68583-0728
(402) 472-6702
agme009@unlvm.unl.edu

Contact 2:
Andy Suyker
School of Natural Resource Sciences
University of Nebraska
Lincoln, NE 68583-0728
(402) 472-2168
agme018@unlvm.unl.edu

Contact 3:
K. Fred Huemmrich
University of Maryland
NASA GSFC
Code 923
Greenbelt, MD 20771
(301) 286-4862
(301) 286-0239 (fax)
Karl.Huemmrich@gsfc.nasa.gov

3. Theory of Measurements

Micrometeorological Flux Measurements

Flux measurements were made using the eddy correlation technique. This technique is well established and has been used in many previous field studies (e.g., Kanemasu et al., 1979; Businger, 1986; Baldocchi et al., 1988; Verma et al., 1992). The eddy correlation method allows for direct measurement of vertical turbulent fluxes at a point above the surface. The measurement at this point, however, represents the integrated effects of a large surface area upwind of the measurement point. In the eddy correlation method, the flux of a quantity is calculated from the covariance of the fluctuations of the vertical wind velocity (w) with the fluctuations of the concentration of interest. For example:

Sensible Heat Flux	$H = rho\ Cp\ \overline{w'T'}$
Latent Heat Flux	$LE = L\ \overline{w'rhov'}$
Carbon Dioxide Flux	$Fc = \overline{w'rhoc'}$
Methane Flux	$Fm = \overline{w'rhom'}$
Momentum Flux	$tau = rho\ \overline{w'u'}$

where T is air temperature, rhov is the absolute humidity of water vapor, rhoc is the atmospheric density of carbon dioxide, rhom is the atmospheric density of methane, u is the horizontal wind velocity, rho is the density of air, Cp is the specific heat of air at constant pressure, and L is the latent heat of vaporization. The (') indicates deviation from the mean, and the overbar indicates a time average.

It is desirable for eddy correlation sensors to be small, aerodynamically smooth, and symmetric about the horizontal plane of measurement, and to have a fast response time (< 0.1 s). It is also desirable to have sensors located close together and to have the sensors mounted on an aerodynamically smooth, rigid platform. The specifications for some of these requirements will depend on the measurement height. Further theoretical details of the eddy correlation method can be found in the following references: Kanemasu et al., 1979; Businger, 1986; Baldocchi et al., 1988.

Corrections for inadequate sensor frequency response (Moore, 1986) and air density effects (Webb et al., 1980) are applied to the eddy correlation measurements.

Filling in Missing Eddy Fluxes of CO_2 and Sensible and Latent Heat

During periods of unacceptable wind direction, low wind speed (at night), or eddy correlation sensor malfunction, fluxes of CO_2 and sensible and latent heat were filled in. For missing periods during daytime, the CO_2 flux was filled in using relationships between CO_2 flux and incident photosynthetically active radiation (PAR) established for different temperature/humidity conditions throughout the season. Nighttime CO_2 flux was filled in using relationships between CO_2 flux (measured on nearby nights during acceptable wind conditions) and soil temperature. Daytime sensible and latent heat fluxes were estimated using linear relationships between these fluxes (measured on nearby days under acceptable conditions) with net radiation. Nighttime sensible and latent heat fluxes were estimated using the data on temperature and humidity gradients, net radiation, and soil heat flux in the Bowen ratio-energy balance approach. During the nighttime periods where the Bowen ratio was unacceptable, fluxes were interpolated.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment

Measurements were collected from mid-May through early-October of 1994 and 1995. Over that time period, temperature conditions ranged from below freezing to over 30 °C.

4.1.2 Source/Platform

Eddy Correlation Sensors:

A bracket holding eddy correlation instrumentation was deployed from the side of 3.5-m-high scaffolding. The scaffolding was mounted on a metal framework base and was guyed. The instruments were at a height of approximately 4.2 m.

Description of Eddy Correlation Instrumentation:

Longitudinal, lateral, and vertical wind velocity components (u, v, and w) were measured with a 3-D sonic anemometer (15-cm path lengths). Vertical wind velocity fluctuations were also measured with single-axis sonic anemometers (10- and 20-cm path length). Temperature fluctuations were measured with fine wire thermocouples (0.0005 in., chromel-constantan). Absolute humidity fluctuations were measured using an open path Krypton hygrometer. Carbon dioxide density fluctuations were measured using a closed path, differential infrared spectrometer. Methane concentration fluctuations were measured using a closed path tunable diode laser spectrometer (TDLS).

Supporting Meteorological Sensors:

Most supporting instrumentation was attached to metal pipes sunk into the peat.

Description of Supporting Meteorological Instrumentation:

Mean air temperatures were measured with platinum resistance temperature devices (RTD) and thermistors. Mean relative humidities were measured with capacitive polymer H chip humidity sensors. Mean horizontal wind velocity was measured using a cup anemometer. Soil heat flux/storage was measured with heat flux transducers and temperature sensors. Soil temperatures were measured with thermistors. Solar radiation was measured with a pyranometer. Reflected solar radiation was measured with an inverted pyranometer. PAR was measured with a quantum sensor. Reflected PAR was measured with an inverted point quantum sensor. Net radiation was measured with a rigid dome net radiation sensor. Precipitation was measured with electronic recording tipping bucket rain gauges. Atmospheric pressure was measured with an aneroid barometer. Wind direction was measured with a wind vane with its null point set to north. The water table was measured using a float/pulley system where the pulley turned a potentiometer.

4.1.3 Source/Platform Mission Objectives

The objective of the towers and supporting rods was to support the instruments.

4.1.4 Key Variables

Data collected included incoming solar radiation, reflected solar radiation, incoming PAR, net radiation, latent heat flux, sensible heat flux, carbon dioxide flux, methane flux, horizontal wind speed at 4 m, soil temperature at 20 cm depth, soil temperature at 10 cm depth, air temperature at 4 m, absolute humidity at 4 m, vapor pressure deficit at 4 m, atmospheric pressure, wind direction, precipitation, and water table height above a reference hollow surface.

4.1.5 Principles of Operation

Both the 1-D and 3-D sonic anemometers determine the wind speed from the difference in travel times of ultrasonic sound pulses transmitted from opposing ends of the measurement path.

The Krypton hygrometer measures atmospheric humidity by relating it to the amount of radiation absorbed by the volume of air in the measurement path. The amount of radiation absorbed is related to the humidity through calibration.

The TDLS CH_4 sensor and the closed path H_2O/CO_2 measure the concentrations of methane and water vapor/carbon dioxide as functions of the amount of radiation absorbed in the measurement path. The amount of radiation absorbed by the constituent in question is determined from the difference in radiation absorbed from two radiation wave bands, one that is absorbed by the constituent and a second that is absorbed by reference gas with a known constituent concentration. Calibration with known concentration gases provides a relationship of sensor output to constituent density.

A fine-wire thermocouple measures temperature fluctuations from the electromotive force (emf) produced at a chromel-constantan thermocouple junction. The thermocouple is referenced to a junction whose mean temperature varies with the ambient.

The wind vane is a potentiometer whose output is related to the wind direction.

The thermistors and platinum RTDs used to measure air and peat temperatures relate changes in resistance to temperature.

Transducers all derive their output from differential thermopiles. The net radiometer relates the temperature difference of upward and downward facing blackbody surfaces to net radiation. The pyranometer relates incoming solar radiation to the temperature difference of blackbody and reflective, upward facing surfaces whose impinging radiation is restricted to shortwave radiation.

Soil heat flux transducers relate soil heat flux to the temperature difference between the top and bottom sides of a plate that is inserted in the soil and has a thermal conductivity similar to that of the surrounding soil.

The PAR sensors relate the cosine-corrected voltage output of a silicon photodiode to the radiation received in the 400- to 700-nm waveband.

The capacitive polymer H chip's voltage output is linearly related to atmospheric relative humidity. The output is derived from changes caused by water vapor upon a thin film capacitor. A thin, water vapor permeable membrane filter covers the capacitor for protective purposes.

Both the cup anemometer and tipping bucket rain gauge operate by producing electrical pulses that are counted and related to the value of the quantity being observed. Both sensors need to be maintained in a level position.

The barometer translates the expansion of a closed cell due to changes in static atmospheric pressure to a voltage signal.

4.1.6 Sensor/Instrument Measurement Geometry

Eddy Correlation Sensors:

The eddy correlation sensors were mounted on a horizontal bar that was mounted on a horizontal, rotatable plate. The bar was mounted tangentially to the plate and approximately 30 cm from the closest edge of the plate. The plate was rotatable so that the eddy correlation sensors could be rotated into the mean wind direction. The plate was set on a bracket that attached to the side of a scaffolding tower. The bracket allowed the plate to slide closer to the tower for sensor maintenance. With the plate extended, the sensors were approximately 2.5 m from the tower. It was also possible to level the plate (and thus the sensors) in its extended position.

The eddy correlation sensors were mounted at a height of 4.2 m. The sensor array contained the 3-D sonic anemometer/thermometer, a fine wire-thermocouple, and intakes for the closed path CH_4 and H_2O/CO_2 sensors.

Supporting Meteorological Sensors:

The atmospheric pressure sensor was mounted at a height of 4.2 m. Mean wind speed, temperature, and relative humidity sensors were mounted on 1 1/4" steel pipes sunk about 2.5 m into the peat. The wind vane was mounted atop the cup anemometer mast. The radiation sensors (solar radiation, reflected solar radiation, net radiation, PAR, reflected PAR) were mounted on a cross bar, at 1.9 m above the peat surface. The rain gauges were attached to wooden stakes sunk into the peat. They were mounted at a height of approximately 1 m. The soil heat flux transducers were installed 0.05 m beneath the surface. The soil temperature sensors were installed at 0.10 and 0.20 m beneath the surface.

The access to eddy correlation sensors was via a raised walkway, while the access to most other sensors was via planks laid on the peat surface.

4.1.7 Manufacturer of Sensor/Instrument

Micrometeorological Sensors
3-D sonic anemometer/thermometer
Advanced Technologies, Inc.
6395 Gunpark Dr. Unit E
Boulder, CO 80301
(303) 530-4977

Single axis sonic anemometer/thermometer
Kaijo Denki Co., Ltd.
No 19.1 Chrome Kanda-Nishikicho
Chiyoda-Ku
Tokyo 101
Japan

Fine-wire thermocouples
Campbell Scientific
P.O. Box 551
Logan, UT 84321
(801) 753-2342
(801) 752-3268 (fax)

Lyman alpha hygrometer
Atmospheric Instrumentation Research, Inc.
1880 South Flatiron Court
Boulder, CO 80301
(303) 499-1701
(303) 499-1767 (fax)

Closed path H_2O/CO_2 sensor
LI-COR, Inc.
4421 Superior Street
P.O. Box 4425
Lincoln, NE 68504
(402) 467-3576
(402) 467-2819 (fax)

Closed path tunable diode laser spectrometer (TDLS) CH_4 sensor
Unisearch Associates, Inc.
222 Snidercroft Rd.
Concord, Ontario
CANADA
L4K 1B5
(416) 669-2280
(416) 669-5132 (fax)

Platinum RTDs for air temperature
Omega Engineering, Inc.
One Omega Dr.
Box 4047
Stamford, CT 06907-0047
(203) 359-1660
(203) 359-7900 (fax)

Vaisala chemical relative humidity/RTD air temperature sensors
Campbell Scientific
P.O. Box 551
Logan, UT 84321
(801) 753-2342
(801) 752-3268 (fax)

Cup anemometers
Cayuga Development
15 Hickory Circle
Ithaca, NY
(607) 272-8599

Soil heat flux transducers
Radiation & Energy Balance Systems, Inc.
P.O. Box 15512
Seattle, WA 98115-0512
(206) 488-9404

Bead thermistors for soil temperature
Omega Engineering, Inc.
One Omega Dr.
Box 4047
Stamford, CT 06907-0047
(203) 359-1660
(203) 359-7900

15-cm platinum RTD bars for soil temperature
Omega Engineering, Inc.
One Omega Dr.
Box 4047
Stamford, CT 06907-0047
(203) 359-1660
(203) 359-7900 (fax)

Pyranometer
The Eppley Laboratory, Inc.
12 Shefield Ave.
P.O. Box 419
Newport, RI 02840
(401) 847-1020
(401) 847-1031 (fax)

Point quantum PAR sensors
LI-COR, Inc.
4421 Superior Street
P.O. Box 4425
Lincoln, NE 68504
(402) 467-3576
(402) 467-2819 (fax)

Net radiation sensor
Radiation & Energy Balance Systems, Inc.
P.O. Box 15512
Seattle, WA 98115-0512
(206) 488-9404

Tipping bucket rain gauges
Campbell Scientific
P.O. Box 551
Logan, UT 84321
(801) 753-2342
(801) 752-3268 (fax)

Wind vane
Campbell Scientific
P.O. Box 551
Logan, UT 84321
(801) 753-2342
(801) 752-3268 (fax)

Static pressure sensor
Alan Bedard
NOAA
Boulder, CO
(303) 497-6508

4.2 Calibration

4.2.1 Specifications

Eddy Correlation Instrumentation:

1-D sonic anemometer:	Supplied by manufacturer
3-D sonic anemometer:	Supplied by manufacturer
Thermocouples:	Supplied by manufacturer
Lyman alpha hygrometer:	Calibrated with dew point generator, RTD
Closed cell H_2O:	Calibrated with dew point generator, RTD
Closed cell CO_2:	Field calibration using known standard gases
Closed cell CH_4:	Field calibration using known standard gases

Supporting Meteorological Instrumentation:

Mean air temperature nickel-iron (NIFe) RTDs:	Calibrated in water bath
Mean air temperature thermistors:	Supplied by manufacturer
Mean relative humidity:	Supplied by manufacturer
Cup anemometers:	Calibrated in wind tunnel
Soil heat flux plates:	Supplied by manufacturer
Soil temperature bead thermistors:	Calibrated in water bath
Pyranometer:	Supplied by manufacturer
PAR quantum sensors:	Supplied by manufacturer
Net radiation sensors:	Supplied by manufacturer
Tipping bucket rain gauges:	Supplied by manufacturer
Wind vane:	Supplied by manufacturer
Atmospheric pressure sensors:	Supplied by manufacturer
Water table sensor:	Supplied by manufacturer

4.2.1.1 Tolerance

Eddy correlation instrumentation

1-D sonic anemometer:

Path length	: 20 cm
Sampling frequency	: 20 Hz
Data frequency	: 10 Hz
Accuracy	: 1 %
Resolution	: 0.005 m/s

3-D sonic anemometer:

Path length	: 15 cm
Sampling frequency	: Hz
Data frequency	: 10 Hz
Accuracy	: 0.05 m/s
Resolution	: 0.01 m/s

Fine wire thermocouples:

Dimension	: 0.0005 in
Time response	: 0.008 s

Lyman alpha hygrometer:

Radiation source	:	UH2
Path length	:	0.5 cm
Time response	:	2 ms
Accuracy	:	4 %
Resolution	:	2 %

Closed cell H_2O/CO_2 sensor:

Path length	:	15 cm
Sample cell volume	:	11.9 cm^3
Sample cell pressure	:	850 mb
Time response	:	0.06 s
Sampling frequency	:	500 Hz
Accuracy	:	3 ppm
Resolution	:	2 ppm

Closed cell CH_4 sensor:

Path length	:	53 m
Sample cell volume	:	0.4 L
Sample cell pressure	:	40 Torr
Sampling frequency	:	0.15 µsec
Data output frequency	:	10 Hz
Accuracy	:	2 %
Resolution	:	15 ppb

Supporting Instrumentation:

Air temperature thermistors:

Linearization error	:	0.1 C

Relative humidity sensors:

Accuracy	:	2 %
Response time	:	15 s
Temperature-induced error	:	0.04 % RH/C

PAR quantum sensors:

Accuracy	:	5 %
Sensitivity	:	0.005 A/mole/s/m^2
Linearity	:	1 %

Tipping bucket rain gauges:

Accuracy	:	1 %
Resolution	:	0.1 mm

Sensor specifications are currently unavailable for these sensors:
Air temperature NIFe RTDs
Soil temperature bead thermistors
Pyranometer
Net radiation sensors
Cup anemometers
Soil heat flux plates
Wind vane
Atmospheric pressure sensor
Water table sensor

4.2.2 Frequency of Calibration

Eddy Correlation Instrumentation:

Lyman alpha hygrometer:	Calibrated monthly
Krypton hygrometer:	Calibrated monthly
Closed cell H2O sensor:	Calibrated at beginning and end of season
Closed cell CO2 sensor:	Calibrated twice daily
Closed cell CH4 sensor:	Calibrated twice daily

Supporting Meteorological Instrumentation:

Mean air temperature NIFe RTDs:	Calibrated prior to season
Mean air temperature thermistors:	Calibrated prior to season
Mean relative humidity:	Calibrated by manufacturer
Cup anemometers:	Calibrated prior to season
Soil heat flux transducers:	Calibrated by manufacturer
Soil temp. bead thermistors:	Calibrated prior to season
Soil temp. platinum RTD:	Calibrated prior to season
Pyranometer:	Calibrated prior to season
PAR quantum sensors:	Calibrated prior to season
Net radiation sensors:	Calibrated prior to season
Atmospheric pressure :	Calibrated prior to season
Water table:	Calibrated by manufacturer

4.2.3 Other Calibration Information

The humidity source used to calibrate the eddy correlation water vapor sensors is a LI-COR LI-620 dew point generator, available from LI-COR, Inc., P.O. Box 4425, Lincoln, NE 68504 (phone 402-467-3576, fax 402-467-2819).

Calibration gases for the eddy correlation CO_2 sensors were obtained from Acklands, 1402 Quebec Ave., Saskatoon, Sask. CANADA, S7K 1V5 (Primary supplier: Linde gas, Alberta, CANADA). These gases were calibrated against gases of known concentration traceable to the National Oceanic and Atmospheric Administration (NOAA), Boulder, CO.

Calibration gases for the TDLS CH_4 sensor were compressed air obtained from Acklands, 1402 Quebec Ave., Saskatoon, Sask. CANADA, S7K 1V5. The compressed air gases were calibrated against gases of known concentration obtained from Matheson Gas Products, P.O. Box 96, Joliet, IL 60434.

Cup anemometers were calibrated in the University of Iowa wind tunnel. A pitot tube anemometer was used as a standard.

5. Data Acquisition Methods

Eddy Correlation

Eddy correlation signals were low-pass filtered with 8-pole Butterworth active filters (12.5-Hz cutoff frequency) and sampled at 25 Hz. These signals were recorded to optical disks. Means, variances, and covariances were calculated on a half-hourly basis.

Supporting Meteorological Measurements

Signals from the supporting instrumentation were recorded using a Campbell CR21X. Half-hourly averages of these signals were calculated. The averaged values were retrieved from the CR21X data loggers using a PC microcomputer.

6. Observations

6.1 Data Notes

None.

6.2 Field Notes

The forest to the east of the fen has been harvested within the past 5 years. However, a band of forest 50 to several hundred meters wide separates the fen from the harvested area.

The instrumentation platforms are located approximately 50 m west of the eastern edge of the fen. On the western edge there is a more gradual change from open fen to tamarack to black spruce forest. The transition from fen to forested land is more abrupt on the eastern edge of this fen.

Within the directions of acceptable fetch, the best fetch is in the west to north directions. In the south to west directions there are some small stands (strings) of tamarack/black spruce.

Data collection was interrupted from 01- to 20-Jun-1995 because of a nearby forest fire.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

All measurements were collected at the SSA-Fen site. North American Datum of 1983 (NAD83) coordinates for the site are latitude 53.80206° N, longitude 104.61798° W, and elevation of 524.7 m above sea level.

7.1.2 Spatial Coverage Map

Not applicable.

7.1.3 Spatial Resolution

Eddy correlation measurements were made at a height of 4.2 m. For this instrument height, the measurements apply to a surface "footprint" (Schuepp et al., 1990; Leclerc and Thurtell, 1990) extending up to about 420 m upwind of the tower, depending upon the meteorological conditions. Adequate upwind fetch was available only in the south through west to north-northeast directions; other directions were inhabited by forest.

7.1.4 Projection

None.

7.1.5 Grid Description

None.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

Data were collected during the periods:

- 23-Aug to 11-Sep-1993
- 18-May to 07-Oct-1994
- 18-May to 09-Oct-1995

Note: Data collection was interrupted from 01- to 20-Jun-1995 because of a nearby forest fire.

7.2.2 Temporal Coverage Map

None.

7.2.3 Temporal Resolution

The values are half-hour averages except for rainfall, which is a half-hour total.

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
SENSIBLE_HEAT_FLUX_ABV_CNPY
CALC_SENSIBLE_HEAT_FLUX
LATENT_HEAT_FLUX_ABV_CNPY
CALC_LATENT_HEAT_FLUX
NET_RAD_ABV_CNPY
CO2_FLUX_ABV_CNPY
CALC_CO2_FLUX
DOWN_PPFD_ABV_CNPY
WIND_DIR_ABV_CNPY
WIND_SPEED_ABV_CNPY
AIR_TEMP_ABV_CNPY
SOIL_TEMP_10CM
SOIL_TEMP_20CM
RAINFALL
DOWN_SOLAR_RAD_ABV_CNPY
UP_SOLAR_RAD_ABV_CNPY
ABS_HUM_ABV_CNPY
VAPOR_PRESS_DEFICIT_ABV_CNPY
SURF_PRESS
WATER_TABLE_HGT
CH4_FLUX_ABV_CNPY
CRTFCN_CODE
REVISION_DATE
```

7.3.2 Variable Description/Definition

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

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the

	identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) of the start of the data collection.
SENSIBLE_HEAT_FLUX_ABV_CNPY	The sensible heat flux measured above the canopy.
CALC_SENSIBLE_HEAT_FLUX	The sensible heat flux measured above the canopy. Data on calm nights have been adjusted. Gaps in the eddy flux measurements have been filled in using regression equations of eddy flux against meteorological variables.
LATENT_HEAT_FLUX_ABV_CNPY	The latent heat flux measured above the canopy.
CALC_LATENT_HEAT_FLUX	The latent heat flux measured above the canopy. Data on calm nights has been adjusted. Gaps in the eddy flux measurements have been filled in using regression equations of eddy flux against meteorological variables.
NET_RAD_ABV_CNPY	The net radiation measured above the canopy.
CO2_FLUX_ABV_CNPY	The carbon dioxide flux measured above the canopy.
CALC_CO2_FLUX	The carbon dioxide flux measured above the canopy. Data on calm nights have been adjusted. Gaps in the eddy flux measurements have been filled in using regression equations of eddy flux against meteorological variables.
DOWN_PPFD_ABV_CNPY	The downward (incoming) photosynthetic photon flux density measured above the canopy.
WIND_DIR_ABV_CNPY	The direction from which the wind is blowing (increasing in a clockwise direction from the North) and measured above the canopy.
WIND_SPEED_ABV_CNPY	The wind speed measured above the canopy.
AIR_TEMP_ABV_CNPY	The air temperature measured above the canopy.
SOIL_TEMP_10CM	Soil temperature at 10 cm depth.
SOIL_TEMP_20CM	Soil temperature at 20 cm depth.
RAINFALL	The amount of rainfall measured above the canopy in the 30 minute period following the time of observation.
DOWN_SOLAR_RAD_ABV_CNPY	The downward (incoming) solar radiation measured above the canopy.
UP_SOLAR_RAD_ABV_CNPY	The reflected (outgoing) solar radiation measured above the canopy.
ABS_HUM_ABV_CNPY	The absolute humidity measured above the canopy.
VAPOR_PRESS_DEFICIT_ABV_CNPY	The vapor pressure deficit measured above the canopy.
SURF_PRESS	The atmospheric pressure measured at the station.
WATER_TABLE_HGT	Water table height above a reference surface.
CH4_FLUX_ABV_CNPY	The methane flux measured above the canopy.
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]
SENSIBLE_HEAT_FLUX_ABV_CNPY	[Watts][meter^-2]
CALC_SENSIBLE_HEAT_FLUX	[Watts][meter^-2]
LATENT_HEAT_FLUX_ABV_CNPY	[Watts][meter^-2]
CALC_LATENT_HEAT_FLUX	[Watts][meter^-2]
NET_RAD_ABV_CNPY	[Watts][meter^-2]
CO2_FLUX_ABV_CNPY	[micromoles][meter^-2][second^-1]
CALC_CO2_FLUX	[micromoles][meter^-2][second^-1]
DOWN_PPFD_ABV_CNPY	[micromoles][meter^-2][second^-1]
WIND_DIR_ABV_CNPY	[degrees]
WIND_SPEED_ABV_CNPY	[meters][second^-1]
AIR_TEMP_ABV_CNPY	[degrees Celsius]
SOIL_TEMP_10CM	[degrees Celsius]
SOIL_TEMP_20CM	[degrees Celsius]
RAINFALL	[millimeters]
DOWN_SOLAR_RAD_ABV_CNPY	[Watts][meter^-2]
UP_SOLAR_RAD_ABV_CNPY	[Watts][meter^-2]
ABS_HUM_ABV_CNPY	[grams][meter^-3]
VAPOR_PRESS_DEFICIT_ABV_CNPY	[kiloPascals]
SURF_PRESS	[kiloPascals]
WATER_TABLE_HGT	[millimeters]
CH4_FLUX_ABV_CNPY	[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	[Supplied by Investigator.]
TIME_OBS	[Supplied by Investigator.]
SENSIBLE_HEAT_FLUX_ABV_CNPY	[fine wire thermocouple]
CALC_SENSIBLE_HEAT_FLUX	[Supplied by Investigator.]
LATENT_HEAT_FLUX_ABV_CNPY	[Krypton hygrometer]
CALC_LATENT_HEAT_FLUX	[Supplied by Investigator.]
NET_RAD_ABV_CNPY	[rigid dome net radiation sensor]
CO2_FLUX_ABV_CNPY	[differential infrared spectrometer]
CALC_CO2_FLUX	[Supplied by Investigator.]
DOWN_PPFD_ABV_CNPY	[quantum sensor]
WIND_DIR_ABV_CNPY	[wind vane]
WIND_SPEED_ABV_CNPY	[cup anemometer]
AIR_TEMP_ABV_CNPY	[platinum resistance temperature device]

```
SOIL_TEMP_10CM                [thermistor]
SOIL_TEMP_20CM                [thermistor]
RAINFALL                      [tipping bucket rain gauge]
DOWN_SOLAR_RAD_ABV_CNPY       [pyranometer]
UP_SOLAR_RAD_ABV_CNPY         [pyranometer]
ABS_HUM_ABV_CNPY              [humidity sensor]
VAPOR_PRESS_DEFICIT_ABV_CNPY  [humidity sensor]
SURF_PRESS                    [aneroid barometer]
WATER_TABLE_HGT               [float/pulley system]
CH4_FLUX_ABV_CNPY             [closed path tunable diode laser spectrometer]
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	SSA-FEN-FLXTR	SSA-FEN-FLXTR	None	None	None	None
SUB_SITE	9TF11-FLX01	9TF11-FLX01	None	None	None	None
DATE_OBS	19-MAY-94	09-OCT-95	None	None	None	None
TIME_OBS	0	2330	None	None	None	None
SENSIBLE_HEAT_FLUX_ABV_CNPY	-93	281	-999	None	None	None
CALC_SENSIBLE_HEAT_FLUX	-93	281	-999	None	None	None
LATENT_HEAT_FLUX_ABV_CNPY	-32	442	-999	None	None	None
CALC_LATENT_HEAT_FLUX	-61	442	-999	None	None	None
NET_RAD_ABV_CNPY	-84	696	-999	None	None	None
CO2_FLUX_ABV_CNPY	-15.9	7.7	-999	None	None	None
CALC_CO2_FLUX	-19.1	7.7	-999	None	None	None
DOWN_PPFD_ABV_CNPY	-3	1953	-999	None	None	None
WIND_DIR_ABV_CNPY	0	360	-999	None	None	None
WIND_SPEED_ABV_CNPY	0	7.22	-999	None	None	None
AIR_TEMP_ABV_CNPY	-5.6	32.6	-999	None	None	None
SOIL_TEMP_10CM	3.3	24.26	-999	None	None	None
SOIL_TEMP_20CM	-1.55	20.03	-999	None	None	None
RAINFALL	0	9.91	-999	None	None	None
DOWN_SOLAR_RAD_ABV_CNPY	-10	895	-999	None	None	None
UP_SOLAR_RAD_ABV_CNPY	-4	179	-999	None	None	None
ABS_HUM_ABV_CNPY	2.14	22.31	-999	None	None	None
VAPOR_PRESS_DEFICIT_ABV_CNPY	0	42.4	-999	None	None	None
SURF_PRESS	92.63	97.84	-999	None	None	None
WATER_TABLE_HGT	50	303	-999	None	None	None
CH4_FLUX_ABV_CNPY	-.02465	.53177	-999	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	09-OCT-98	09-OCT-98	None	None	None	None

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

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

7.4 Sample Data Record

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

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,SENSIBLE_HEAT_FLUX_ABV_CNPY,
CALC_SENSIBLE_HEAT_FLUX,LATENT_HEAT_FLUX_ABV_CNPY,CALC_LATENT_HEAT_FLUX,
NET_RAD_ABV_CNPY,CO2_FLUX_ABV_CNPY,CALC_CO2_FLUX,DOWN_PPFD_ABV_CNPY,
WIND_DIR_ABV_CNPY,WIND_SPEED_ABV_CNPY,AIR_TEMP_ABV_CNPY,SOIL_TEMP_10CM,
SOIL_TEMP_20CM,RAINFALL,DOWN_SOLAR_RAD_ABV_CNPY,UP_SOLAR_RAD_ABV_CNPY,
ABS_HUM_ABV_CNPY,VAPOR_PRESS_DEFICIT_ABV_CNPY,SURF_PRESS,WATER_TABLE_HGT,
CH4_FLUX_ABV_CNPY,CRTFCN_CODE,REVISION_DATE
'SSA-FEN-FLXTR','9TF11-FLX01',01-AUG-94,0,-999.0,11.0,-999.0,120.0,157.0,-999.0,
-2.7,510.0,168.0,1.39,26.99,21.91,19.37,0.0,234.0,33.0,17.42,1.49,95.7,213,
-999.0,'CPI',09-OCT-98
'SSA-FEN-FLXTR','9TF11-FLX01',01-AUG-94,30,-999.0,0.0,-999.0,99.0,89.0,-999.0,
-2.0,353.0,159.0,1.3,27.13,21.96,19.41,0.0,164.0,26.0,17.68,1.54,95.7,213,
-999.0,'CPI',09-OCT-98
```

8. Data Organization

8.1 Data Granularity

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

8.2 Data Format

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

Voltage to Signal Conversion Formulae

All sensors except Krypton hygrometer: $X = a + b*V$

Krypton hygrometer: $X = a + b*\ln(V)$

9.1.1 Derivation Techniques and Algorithms

None.

9.2 Data Processing Sequence

Eddy Correlation Data

- Convert voltages to variables (e.g., temperature, velocity) using calibration equations.
- High pass filter the signals to remove low-frequency noise.
- Calculate means, standard deviations, and covariances.
- Calculate cospectral values.
- Make adjustments to values as appropriate (see Section 9.3).

Supporting Meteorological Data

- Convert voltages to variables (e.g., temperature, velocity) using calibration equations.
- Calculate means.
- Make adjustments to values as appropriate (see Section 9.3).

9.2.1 Processing Steps

None given.

9.2.2 Processing Changes

None.

9.3 Calculations

Eddy Correlation Flux Calculation

Sums of squares and sums of products of signals are calculated during a half-hour run. From these values, variances and covariances can be calculated. In the eddy correlation method, the flux of a quantity is calculated from the covariance of the fluctuations of the vertical wind velocity (w) with the fluctuations of the concentration of interest. For example:

Sensible Heat Flux	$H = rho\ Cp\ \overline{w'T'}$
Latent Heat Flux	$LE = L\ \overline{w'rhov'}$
Carbon Dioxide Flux	$Fc = \overline{w'rhoc'}$
Methane Flux	$Fm = \overline{w'rhom'}$
Momentum Flux	$tau = rho\ \overline{w'u'}$

where T is air temperature, rhov is the absolute density of water vapor, rhoc is the absolute density of carbon dioxide, rhom is the absolute density of methane, u is the horizontal wind velocity, rho is the density of air, Cp is the specific heat of air at constant pressure, and L is the latent heat of vaporization. The (') indicates deviation from the mean, and the overbar indicates a time average.

Adjustments to Results

Frequency Response Correction: A correction is needed to adjust for inadequate frequency response. This correction was applied in a manner similar to that given in Moore (1986).

Correction for Nonspecific Sensor Absorption: The closed path CO_2 sensor has a slight response to water vapor. This adjustment is made based on information supplied by the manufacturer.

Correction for Air Density Effects: Generally, corrections are made to the fluxes of gases, such as CO_2 and CH_4, for the effect of water vapor and temperature on the density of the air being sampled. The use of insulated, metal intake tubing for closed path sensors helped remove most of the temperature fluctuations. For the signals from the closed path CO_2 and CH_4 sensors, adjustments were made for density fluctuations caused by fluctuating water vapor concentrations. Signals from the open path water vapor sensor were adjusted for density fluctuations caused by fluctuating temperature. These corrections are made following a procedure given in Webb et al. (1980).

9.3.1 Special Corrections/Adjustments

None.

9.3.2 Calculated Variables

None.

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

Electronic Noise

Although all sensors were subject to small amounts of high frequency electronic noise, most of this was removed from eddy correlation sensor signals by the low-pass filters prior to recording the raw data. Sensors with noise in lower frequency regions (e.g., occasional spiking) were repaired/adjusted and their data were generally removed from the data set. It is possible that such noise may occasionally be present in some of the data.

Calibration Drift

The CO_2, CH_4, and H_2O sensors may have been subject to some calibration drift. These sensors were calibrated and linear interpolations were used in data processing.

Dew/Wetness

Dew or rain caused aberrant signals in some sensors (net radiometers, PAR quantum sensors, Lyman-alpha hygrometer, sonic anemometers, and fine wire thermocouples). Generally, heavy dew or rain would cause complete deterioration of these signals. Periods during which dew or rain occurred were noted and used in the quality control of data.

10.2 Quality Assessment

10.2.1 Data Validation by Source

A field log book was kept, in which occurrences that may have affected results were recorded. These notes were later scrutinized and converted to a numerical format that could be incorporated into the data set and used in quality control of the data. Comparison of results from alternate sensors (or alternate methods) was also employed in determining the quality of results.

10.2.2 Confidence Level/Accuracy Judgment

The data set is of generally good quality.

10.2.3 Measurement Error for Parameters

SOLAR_RAD_IN	± 1 %
PAR_IN	± 7 %
R_NET	± 4 to 7 %
LE_FLUX_MEASURED	± 15 %
H_FLUX_MEASURED	± 15 %
CO2_FLUX_MEASURED	± 0.01 $\mu mol/m^2/s$
CH4_FLUX	± 0.4 $mg/m^2/h$
HORIZ_WIND_SPEED_4M	± 0.2 m/s
SOIL_TEMP_-20CM	± 0.1 °C
SOIL_TEMP_-10CM	± 0.1 °C
AIR_TEMP_4M	± 0.1 °C
VAP_PRESS_DEF_4M	± 0.1 kPa
WATER_TABLE	± 0.005 m

10.2.4 Additional Quality Assessments

None.

10.2.5 Data Verification by Data Center

Data were examined to check for spikes, values that are four standard deviations from the mean, long periods of constant values, and missing data.

11. Notes

11.1 Limitations of the Data
There are no known limitations in these data.

11.2 Known Problems with the Data
See Section 10.1.

11.3 Usage Guidance
Errors in the micrometeorological data set are indicated by the value -999.00.

11.4 Other Relevant Information
None.

12. Application of the Data Set

These data are useful for the study of water, energy, and carbon exchange in boreal wetlands.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description
None given.

14.2 Software Access
None given.

15. Data Access

The SSA-Fen tower flux and meteorological 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 Report

Baldocchi, D.D., B.B. Hicks, and T.P. Meyers. 1988. Measuring biosphere-atmosphere exchanges of biologically related gases with micrometeorological methods. Ecology, 69:1331-1340.

Businger, J.A. 1986. Evaluation of the accuracy with which dry deposition can be measured with current micrometeorological techniques. J. Clim. and Appl. Meteorol. 25:1100-1124.

Kanemasu, E.T., M.L. Wesely, B.B. Hicks, and J.L. Heilman. 1979. Techniques for calculating energy and mass fluxes. In: Modification of the Environment of Crops. B.L. Barfield and J.F. Gerber, (eds.), Amer. Soc. of Agri. Eng. St. Joseph,. MO. p. 156-182.

Leclerc, M.Y. and G.W. Thurtell. 1990. Footprint prediction of scalar fluxes using a Markovian analysis. Boundary-Layer Meteorology. 52:247-258.

Moore, C.J. 1986. Frequency Response Corrections for Eddy Correlation Systems. Boundary-Layer Meteorology. 37:17-35.

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.

Schuepp, P.H., M.Y. Leclerc, J.I. MacPherson, and R.L. Desjardins. 1990. Footprint prediction of scalar fluxes from analytical solutions of the diffusion equation. Boundary Layer Meteorology 50:355-373.

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.

Suyker, A.E., S.B. Verma, and T.J. Arkebauer. 1997. Season-long measurement of carbon dioxide exchange in a boreal fen. Journal of Geophysical Research 102(D24):29,021-29,028.

Verma, S.B., F.G. Ullman, D. Billesback, R.J. Clement, J. Kim, and E.S. Verry. 1992. Eddy correlation measurements of methane flux in a northern peatland ecosystem. Boundary Layer Meteorology 58:289-304.

Webb, E.K., G.I. Pearman, and R. Leuning. 1980. Correction of flux measurements for density effects due to heat and water vapour transfer. Quart. J. Roy. Meteorol. Soc. 106:85-100.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

```
AES     - Atmospheric Environment Services
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
Cp      - Specific heat of air at constant pressure
CPI     - Certified by PI
CPI-??? - Certified but questionable
DAAC    - Distributed Active Archive Center
e       - Air vapor pressure
emf     - electromotive force
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
NASA    - National Aeronautics and Space Administration
NOAA    - National Oceanic and Atmospheric Administration
NSA     - Northern Study Area
ORNL    - Oak Ridge National Laboratory
p       - Atmospheric pressure
PANP    - Prince Albert National Park
PAR     - Photosynthetically Active Radiation
PPB     - Parts per billion
PPFD    - Photosynthetic Photon Flux Density
PRE     - Preliminary
rho     - Air density
Rhom    - Absolute Atmospheric density of methane
RTD     - Resistance Temperature Device
SSA     - Southern Study Area
T       - Air temperature
TDLS    - Tunable Diode Laser Spectrometer
TF      - Tower Flux
URL     - Uniform Resource Locator
z       - Height or depth
```

20. Document Information

20.1 Document Revision Date

Written: 01-Oct-1997
Last Updated: 24-Aug-1999

20.2 Document Review Date(s)

BORIS Review: 03-Dec-1998
Science Review:

20.3 Document ID

20.4 Citation

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

Micrometeorological data were collected by Dr. Shashi B. Verma and his colleagues of the University of Nebraska-Lincoln.

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

Verma, S.B., T. Arkebauer, and D. Valentine, "Field Micrometeorological Measurements, Process-Level Studies, and Modeling Of Methane and Carbon Dioxide Fluxes in a Boreal Wetland Ecosystem." 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

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	November 2000	Technical Memorandum

4. TITLE AND SUBTITLE
Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)
BOREAS TF-11 SSA-Fen Tower Flux and Meteorological Data

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

6. AUTHOR(S)
Shashi B. Verma, Timothy Arkebauer, and David Valentine
Forrest G. Hall and Karl Huemmrich, 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. 209

11. SUPPLEMENTARY NOTES
S.B. Verma and T. Arkebauer: Univ. of Nebraska-Lincoln; D. Valentine: Univ. of Alaska, Fairbanks; K. Huemmrich: Univ. of Maryland, NASA Goddard Space Flight Center, Greenbelt, Maryland

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 TF-11 team collected energy, carbon dioxide, and methane flux data at the BOREAS SSA-Fen site during the growing seasons of 1994 and 1995. The data are available in tabular ASCII files.

14. SUBJECT TERMS
BOREAS, tower flux.

15. NUMBER OF PAGES
25

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL