NASA/TM—2000–209891, Vol. 206

Te[redacted]Report S[redacted]on the B[redacted]osystem-A[redacted]sphere Study (BOREAS)

[redacted]*ll and Karl Huemmrich, Editors*

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[redacted]AS TF-9 SSA-OBS Tower Flux, [redacted]Soil Temperature

[redacted]*eder, J.B. Moncrieff, M.B. Rayment, and P.G. Jarvis*

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NASA/TM—2000–209891, Vol. 206

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

Forrest G. Hall and Karl Huemmrich, Editors

Volume 206

BOREAS TF-9 SSA-OBS Tower Flux, Meteorological, and Soil Temperature Data

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November 2000

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BOREAS TF-9 SSA-OBS Tower Flux, Meteorological, and Soil Temperature Data

Jonathan M. Massheder, John B. Moncrieff, Mark B. Rayment, Paul G. Jarvis

Summary

The BOREAS TF-9 team collected energy, carbon dioxide, and water vapor flux data at the BOREAS SSA-OBS site during the growing season of 1994 and most of the year for 1996. From the winter of 1995 to 1996, soil temperature data were also collected and provided. The data are available in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS TF-09 SSA-OBS Tower Flux, Meteorological, and Soil Temperature Data

1.2 Data Set Introduction

This data set includes heat, carbon dioxide, and water vapor fluxes measured by eddy covariance (EC) and meteorological data all measured from the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA)-Old Black Spruce (OBS) tower. Soil heat flux and soil temperature profiles are also included. Through the winter of 1995 to 1996, soil temperature data were collected; these data are stored in separate files.

1.3 Objective/Purpose

The objectives of this study were to measure and model the CO_2 exchanges of boreal black spruce forest to determine whether the soils and vegetation are significant global sinks for atmospheric CO_2. Stand CO_2 fluxes were measured using EC, and the CO_2 concentration profile was also measured to allow estimation of the atmospheric storage of CO_2 within the canopy. These measurements will be used to verify scaling up procedures from leaf level measurements and may be scaled up to regional scales.

1.4 Summary of Parameters and Variables

Latent heat flux, sensible heat flux, carbon dioxide flux, soil heat flux, momentum flux, CO_2 profile, water vapor profile, air temperature profile, net radiation, incident and reflected Photosynthetic Photon Flux Density (PPFD), incident and reflected solar radiation, wind speed and direction, friction velocity, soil temperatures, precipitation amount, vapor pressures.

1.5 Discussion

The tower at the SSA-OBS site (53.99° N, 105.312° W) was equipped with a CO_2, water vapor, and sensible heat flux measuring EC system and a weather station to measure flux driving environmental variables. CO_2 concentration profiles and soil temperatures at various depths were also measured, as was soil heat flux.

The EC system at the top of the tower consisted of a Solent 3-D sonic anemometer and LI-COR LI-6262 closed-path infrared gas analyzer (IRGA). The anemometer was placed 2.6 m above the top platform (25.8 m) on a vertical pole on the southwest corner of the tower. The air was ducted by tube from close to the anemometer to the LI-6262. The data were collected and processed in 'real time' to provide near-continuous measurements.

Profiles of CO_2 and H_2O vapor concentrations were continuously monitored. In 1994, five heights were measured; in 1996, measurements were made at eight heights through the canopy. These measurements were made using an IRGA (LI-COR 6262) fitted with time-switched solenoid valves. The sample heights for 1994 were at 1.5, 3, 6, 12, and 26 meters, corresponding to one-eighth, one-fourth, one-half, one, and two times the canopy height. In 1996, the samples were collected at eight heights above the ground at approximately 0.5, 1.5, 3.5, 6.5, 9.5, 12.5, 18, and 26 meters. Air was drawn continuously through the sample pipes at each of the heights, and each line was sampled in turn. In 1994 each line was sampled for 3 minutes of every 15 minutes; in 1996, each line was sampled for 1 minute every 10 minutes. Data from the beginning of each period were discarded to allow for flushing of the short tube between the solenoids and the analyzer. In 1994, the first minute of data was discarded; in 1996, the first 20 seconds were discarded.

At the top of the tower, a simple weather station was set up to measure the following environmental variables: net radiation, PPFD, shortwave solar radiation, temperature, relative humidity, vapor pressure, wind speed and direction, and rainfall. In 1996, a second weather station, comprising a ventilated psychrometer and net radiometer, was set up at 2 m height above the ground. Soil temperatures were measured at four locations at 0.05, 0.1, 0.2, and 0.5 meters depth, using differential thermocouples referenced to thermistors at 1 meter. Soil heat flux was measured using seven soil heat flux plates, buried about 7 cm below the surface.

1.6 Related Data Sets

BOREAS TF-05 SSA-OJP Tower Flux and Meteorological Data
BOREAS TF-03 NSA-OBS Tower Flux, Meteorological, and Soil Temperature Data
BOREAS TF-04 SSA-YJP Tower Flux, Meteorological, and Soil Temperature Data
BOREAS TF-11 SSA Fen Tower Flux and Meteorological Data
BOREAS TF-09 SSA-OBS Branch Level Flux Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Prof. Paul G. Jarvis and Dr. John B. Moncrieff
Institute of Ecology and Resource Management
University of Edinburgh UK

2.2 Title of Investigation

The CO_2 Exchanges of Boreal Black Spruce Forest

2.3 Contact Information

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3. Theory of Measurements

The net carbon uptake of a forest depends on the assimilation of carbon dioxide by photosynthesis and on carbon dioxide emissions resulting from respiratory processes. Carbon dioxide assimilation depends on the species, age, and physiological activity of the trees. Emission depends on the respiratory cost of maintenance and growth, production of litter, and turnover of organic matter in the soil. Influencing both these processes are soil, climate, and weather. During the day, carbon dioxide will generally be taken up by the stand by photosynthesis, while at night carbon dioxide is lost from the stand. A conservation of mass equation gives:

$$Fc = Fa + Fs + Fr + Fg + DS$$

where Fc is the net flux of carbon dioxide into (or out of) the stand from the air above, Fa is the canopy assimilation (or at-night respiration), Fs is stem respiration, Fr is root respiration, Fg is soil respiration, and DS is storage of carbon dioxide in the air of the stand. With EC, the carbon dioxide flux is measured through a plane above the stand (Fc), and with the carbon dioxide concentration profile, the change in storage (DS) can be estimated.

The flux measurements were calculated using EC, and corrections were applied to the covariances to correct for density effects (Webb et al., 1980). Coordinate rotation of the wind vector components ensured that the flux calculated was perpendicular with respect to local streamlines, and transfer functions (Moore, 1986; Philip, 1963) were used to correct for inadequate frequency response.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment

Measurements were collected from late May through mid-September 1994 and early April through late November of 1996. Over that time period, temperature conditions from below freezing to over 30 °C were experienced.

4.1.2 Source/Platform

Above-canopy measurements were made from a 23-meter double scaffold walk-up tower. The anemometer used in the EC measurements was a Solent 3-D research ultrasonic anemometer. The Solent outputs three orthogonal wind velocity components and the speed of sound from which air temperature may be derived at 21 Hz. To measure CO_2 and water vapor concentrations, a LI-COR LI-6262 closed-path IRGA was used. Air 5 cm from the center of the sonic anemometer's path was ducted down a 32-m Dekabon tube (aluminum tube with PVC coating and polyethylene lining) of 6-mm internal diameter (i.d.). The airflow down the tube was controlled by a Tylan FC2900B mass flow controller at 6 dm^3/min, which resulted in pressure in the LI-6262's sample cell typically 7 kPa less than atmospheric. The analog-to-digital (A/D) converter in the Solent was used to sample the analog output from the LI-6262 at 11 Hz. The linear outputs of the LI-6262 were used, which allowed utilization of the LI-6262's processor to correct for sample cell pressure and for CO_2 band broadening and dilution caused by water vapor. The fully processed CO_2 output of the LI-6262 is at 5 Hz and for H_2O at 3 Hz. The combined wind velocity and IRGA outputs were then transmitted from the Solent serially and received by a notebook PC, where the fluxes were calculated by the EddySol software.

All CO_2 concentration data were logged on a Campbell Scientific CR10 logger, which also controlled the sample line switching three-way solenoid valves through a customized control circuit. Sample pipes were of 5-mm-i.d. nylon tubing; CO_2 adsorption/desorption was not considered a problem since all pipes were continuously purged to exhaust while not being sampled to the IRGA. Sample points consisted of a gauze mosquito cover, an inverted funnel water trap and a fine particulate filter. Sampling to the LI-COR 6252 IRGA was carried out via a Charles Austin dymax pump, downstream of which was a needle valve and flow meter, restricting flow to 0.5 dm^3/min. The downstream end of the IRGA was left open to the atmosphere, ensuring operation at atmospheric pressure. The entire apparatus was housed off the ground, within an enclosed, but ventilated, metal box.

Weather station:

Campbell 21x data loggers with AM416 multiplexors were used to log output from the sensors listed below.

Variable	Sensor
Net radiation	2 x Radiation Energy Balance System (REBS) Q6 net radiometers
Low-level net radiation	REBS Q6 net radiometers
Total solar radiation	Kipp solarimeter, LI-COR pyranometer
PPFD	LI-COR quantum sensor
Relative humidity	Campbell Skye humidity probe
Wind direction	Vector Instruments windvane
Wind speed	Vector Instruments cup anemometer
Air temperature	DeltaT ventilated psychrometer
Wet bulb temperature	DeltaT ventilated psychrometer
Soil temperatures	Probe developed at Edinburgh University
Soil heat flux	7 x REBS heat flux plates
Precipitation	DeltaT tipping bucket rain gauge, resolution 0.2 mm

4.1.3 Source/Platform Mission Objectives

The objective was to measure CO_2, water vapor, and sensible heat fluxes and related environmental variables over a black spruce stand at the southern edge of the boreal forest.

4.1.4 Key Variables

EC: CO_2 and water vapor fluxes, sensible heat, latent heat fluxes, air temperature, and wind speed in nominal x, y, and z planes.

Supporting meteorological variables: net radiation, PPFD, air temperature, wet bulb temperature, total solar radiation, wind direction, wind speed, soil temperatures, CO_2, and water vapor concentration profiles.

4.1.5 Principles of Operation

The Solent anemometer uses pulses of ultrasound to measure windspeed. The forward and reverse transit times for a pulse of ultrasound, between two transducers, gives the speed of sound and the wind speed (sound travels faster with a following wind). The 3-D sonic has three pairs of transducers arranged in nonparallel axes, allowing the 3-D components of the wind velocity to be derived.

The LI-COR LI-6262 IRGAs are closed-path instruments with reference and sample cells with an infrared source at one end and a detector at the other. Different gases absorb infrared of different frequencies, and filters are used to select a narrow band that corresponds to an absorption band of the gas of interest. The LI-6252 measures only CO_2, while the LI-6262 measures CO_2 and H_2O concentration. A gas of known concentration is passed through a reference cell, and the gas whose concentration is to be measured is passed through the sample cell. The amount of infrared reaching the detector in each cell is a function of the gas concentration in the cell. The difference in voltage produced by the detectors of the reference and sample cells is then a function of the difference in concentration of the gas in the cells.

Other sensors were common meteorological sensors used in a standard fashion. For principles of operations of these sensors, please see a relevant textbook, e.g., Pearcy et al. (1991).

4.1.6 Sensor/Instrument Measurement Geometry

The closed-path EC system was placed on an upright pole at the southwest corner of the top of the flux tower. The southwest corner was chosen because a tramway system was set up at the northern end of the tower, and the main fetch at the site is from the west. Because the equipment was 3 m above the top of the tower on a pole, the tower would cause very little disturbance to the wind, whatever its direction. Therefore, EC measurements would not be especially invalidated by any wind direction with respect to the tower; however, the access trail to the site is to the east, and any production of CO_2 by people or vehicles on the trail may affect the CO_2 fluxes measured if the wind is from the east. Also, in the making of the access trail, extensive damage was caused to the muskeg, with many trees being felled; hence, photosynthesis over this area will be uncharacteristically lower and respiration similarly high.

Sample points for the CO_2 concentration measurements for 1994 were at 1.5, 3, 6, 12, and 26 meters, corresponding to one-eighth, one-fourth, one-half, one, and approximately two times the canopy height. In 1996 the samples were collected at eight heights above the ground at 0.52, 1.66, 3.36, 6.44, 9.6, 12.66, 17.74, and 27.42 meters.

The weather station was set up on the eastern side at the top of the tower at 24 m about 2.6 m horizontally from the EC system. The rain gauge was located on top of the tower which was the place that offered the least obstruction. Two net radiometers were mounted on the south side of the tower at a height of 16 m extending 3 m from the tower. This position offered more symmetry of the effect of the tower on upward and downward fluxes than if the radiometers were placed at the top of the tower. Two solarimeters (CM3, Kipp & Zonen) were also mounted on these booms, measuring incoming and reflected solar radiation. The low-level EC system and weather station were set up approximately 30 m to the west of the main tower. A net radiometer was positioned below the canopy, at a height of 2 m above the ground.

In 1994, the soil temperature probe was located about 10 m from the southwest corner of the tower. In 1996, four soil temperature probes were installed, two to the northeast and two to the southeast of the tower. Two soil heat flux plates were placed within 5 m of each probe.

4.1.7 Manufacturer of Sensor/Instrument

Solent sonic anemometer:
Gill Instruments Limited
Solent House
Cannon Street
Lymington, Hampshire
SO41 9BR
UK

Campbell CA27s sonic anemometer:
Skye Humidity probe:
Campbell Scientific
P.O. Box 551
Logan, UT 84321
USA

LI-COR LI-6262 and LI-6252 IRGAs
Pyranometer, quantum sensor:
LI-COR P.O. Box 4425/4421
Superior Street
Lincoln, NE 68504
USA

Advanced Systems E009a IRGA:
Advanced Systems Inc.
Okayama City, Japan

Delta-T psychrometers and rain gauge:
Delta-T Devices ltd.
128 Low Rd., Burwell,
Cambs CB5 0EJ
UK

Soil heat flux plate
Net radiometer:
REBS
P.O. Box 15512
Seattle, WA 98115-0512
Elmer NJ 08318
USA

Wind vane, cup anemometer:
Vector Instruments
115 Marsh Road
Rhyl
Clwyd LL18 2AB
UK

Rain gauge:
Cassella
Regent House
Britannia Walk
London N1 7ND
UK

21x, CR10 Data logging system:
Campbell Scientific
P.O. Box 551,
Logan, UT 84321
USA

A/D card:
Strawberry Tree Inc.
160 S. Wolfe Rd.
Sunnyvale, CA 94086
USA

Dekabon tubing:
J.P. Deane & Co. Ltd.,
91, Ormonde Crescent
Glasgow. G44 3SW
UK

Mass flow controller:
Tylan General
Swindon UK

4.2 Calibration

4.2.1 Specifications

Instrument	Description
LI-6262, closed-path EC system	The output linearization of this instrument is calibrated by the manufacturer and was last performed in July 1993. The field calibration fixes the lower and upper ends of the linearization function and is carried out by passing CO_2 and water vapor free air through the reference cell (the instrument is used in the absolute mode) and setting the CO_2 and water vapor channels to zero. The upper point is set by passing dry air of known CO_2 or of known water vapor concentration through the sample cell and adjusting the appropriate channel to read the correct value. CO_2 standard gases were cross-referenced to the BOREAS primary standards, and a LI-COR LI-610 dewpoint generator was used to produce air of known water vapor density.
Solent anemometers	These instruments have stable calibrations, and factory values were used. The calibrations have been tested in Edinburgh University's wind tunnel and were found satisfactory.
LI-6262 CO_2 concentration profile system	The IRGA was calibrated at the outset. The air from the uppermost height was the same air that had been through the EC LI-6262 IRGA, and the analyzer was calibrated whenever the difference between the two IRGAs was more then a couple of ppm. No corrections were applied to compensate water vapor cross-sensitivity.
Radiometers	One of the radiometers was purchased new from the manufacturers: the calibration factor supplied with it was assumed to be accurate, and it was used as a standard against which the second one was calibrated in July 1993.
Quantum sensor	This was calibrated against another quantum sensor that is kept as a standard and is not used the field. This calibration was performed in 1993.
Cup anemometer	The cup anemometer was calibrated in the wind tunnel at Edinburgh University.
Humidity probe	The Skye temperature and humidity probe was calibrated in July 1993 by enclosing it in flasks containing salt solutions of known equilibrium water vapor pressures as supplied by Campbell.
Psychrometer	1994: The psychrometer was calibrated in July 1993. 1996: The psychrometer were purchased new, and the manufacturer's calibration factors for the temperature sensors were assumed to be accurate.
Wind vane	This was purchased new, and the manufacturer's calibration factors were used.
Pyranometer	This was purchased new, and the manufacturer's calibration factors were used.

4.2.1.1 Tolerance
None given.

4.2.2 Frequency of Calibrations
The LI-6262 was usually calibrated, every 4 to 7 days. Typical CO_2 drift was 1-ppm drift in span and offset. Typical drift for the water vapor was 0.1 kPa in span and offset.

4.2.3 Other Calibration Information
None given.

5. Data Acquisition Methods

Closed-path EC system: Analog output from the LI-6262 IRGA (CO_2 and water vapor concentrations) was digitized by the Solent anemometer at 11 Hz (which has provision for up to five analog inputs). The three wind velocity components and speed of sound at 21 Hz were added, and 20 of these records were transmitted in a packet together almost every second to a computer (PC) using a serial (RS232) link. The software (EddySol) then computed fluxes in real time, including coordinate rotation but not frequency response corrections. Corrections for the effect of water vapor density on CO_2 density were carried out by the LI-6262's internal software. The Solent digitization is 11 bit with input voltage between 0 and 5 V. The LI-6262 output A/D converters were set for a 0 to 5 V range to correspond with a 300 to 500 ppm CO_2 concentration range and a 0 to 25 kPa vapor pressure range. Primary data and computed fluxes were stored on hard disk. Primary data were periodically offloaded onto removable Syquest hard disk cartridges.

Three Campbell Scientific 21x data loggers were employed to log the data: one for the soil temperature probes and soil heat flux plates, one for the CO_2 and H_2O concentration profiles and one for the rest of the weather station. The raw signal from each sensor was converted into the appropriate units in the data logger program.

6. Observations

6.1 Data Notes
None.

6.2 Field Notes
None.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage
All data were collected at the BOREAS SSA-OBS site. North American Datum of 1983 (NAD83) coordinates for the site are latitude 53.98717° N, longitude 105.11779° W, and elevation of 628.94 m.

7.1.2 Spatial Coverage Map
Not applicable.

7.1.3 Spatial Resolution

The EC, CO_2 concentration profile, and water vapor measurements are all point measurements, but the concentrations of CO_2 and water vapor and the temperature at a point are influenced by a certain area downwind, sometimes referred to as a "footprint." Other related terms are Wind Aligned Blob (WAB) and fetch, and their use is sometimes confused.

The footprint is the roughly pear-shaped (broad end toward the measurement point) area contributing to a particular measurement and its size and shape depends on measurement height, wind speed, sensible heat flux, and surface roughness during the measurement period. The contribution to the measurement by a point upwind is a logarithmic function of distance . The theoretical footprint is infinite, but to make the concept of a footprint more useful, the footprint should be defined as the area contributing to a certain proportion of the measured quantity; e.g., 95%.

The term WAB as used in BOREAS is the area contributing to measurements over the period of the field campaign; i.e., the area occupied by the footprints of many measurements. The shape of such a WAB is circular, though often with a sector discarded because either the wind rarely comes from that direction or contamination is expected from that direction.

The fetch is the distance the wind travels over a certain surface type before it reaches a particular (e.g., the measurement) point. Therefore, if one is trying to make measurements pertaining to a certain vegetation type, the length of the footprint should be less than or equal to the fetch over that vegetation.

As the measurement is influenced by a large area downwind (the footprint) if the wind flow and vegetation over that area are homogenous, the measurements will be representative for that area; hence, the stringent requirements for EC sites.

The CO_2 concentrations are point data, vertically spread below the EC system with footprints similar to that of the top EC system but smaller and complicated by the less homogenous turbulence within the canopy compared to that above.

7.1.4 Projection

None.

7.1.5 Grid Description

None.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

The data were collected from 24-May to 19-September-1995 and from 24-March to 29-November-1996. Soil temperatures and heat fluxes were measured from 15-November-1995 to 29-November-1996.

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. Soil temperatures in 1996 before 11-April-1996 are hourly averages.

7.3 Data Characteristics

7.3.1 Parameter/Variable

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

TF09_TOWER_FLUX_DATA:

```
         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
SOIL_HEAT_FLUX_7CM
CO2_FLUX_ABV_CNPY
CALC_CO2_FLUX
CO2_CONC_ABV_CNPY
CO2_STORAGE
DOWN_PPFD_ABV_CNPY
UP_PPFD_ABV_CNPY
WIND_DIR_ABV_CNPY
WIND_SPEED_ABV_CNPY
FRICTION_VELOC_ABV_CNPY
MOMENTUM_FLUX_ABV_CNPY
SDEV_U_WIND_SPEED
SDEV_V_WIND_SPEED
SDEV_W_WIND_SPEED
H2O_FLUX_ABV_CNPY
CALC_H2O_FLUX
AIR_TEMP_150CM
AIR_TEMP_350CM
AIR_TEMP_650CM
AIR_TEMP_950CM
AIR_TEMP_1250CM
AIR_TEMP_18M
AIR_TEMP_ABV_CNPY
NET_RAD_BELOW_CNPY
SOIL_TEMP_25MM
SOIL_TEMP_5CM
SOIL_TEMP_10CM
SOIL_TEMP_20CM
SOIL_TEMP_50CM
SOIL_TEMP_100CM
VAPOR_PRESS_ABV_CNPY
VAPOR_PRESS_BELOW_CNPY
RAINFALL
DOWN_SOLAR_RAD_ABV_CNPY
UP_SOLAR_RAD_ABV_CNPY
CO2_CONC_50CM
CO2_CONC_150CM
CO2_CONC_300CM
CO2_CONC_350CM
```

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CO2_CONC_600CM
CO2_CONC_650CM
CO2_CONC_950CM
CO2_CONC_1200CM
CO2_CONC_1250CM
CO2_CONC_1800CM
H2O_CONC_50CM
H2O_CONC_150CM
H2O_CONC_350CM
H2O_CONC_650CM
H2O_CONC_950CM
H2O_CONC_1250CM
H2O_CONC_1800CM
H2O_CONC_ABV_CNPY
CRTFCN_CODE
REVISION_DATE
```

TF09_SOIL_TEMP_DATA:

```
         Column Name
------------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
SOIL_HEAT_FLUX_7CM
SOIL_TEMP_5CM
SOIL_TEMP_10CM
SOIL_TEMP_20CM
SOIL_TEMP_50CM
SOIL_TEMP_100CM
CRTFCN_CODE
REVISION_DATE
```

7.3.2 Variable Description/Definition

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

TF09_TOWER_FLUX_DATA:

```
         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.
SOIL_HEAT_FLUX_7CM	The soil heat flux measured at 7 cm depth.
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.
CO2_CONC_ABV_CNPY	The carbon dioxide concentration measured above the canopy.
CO2_STORAGE	The storage term of carbon dioxide under the eddy flux system.
DOWN_PPFD_ABV_CNPY	The incoming photosynthetic photon flux density measured above the canopy.
UP_PPFD_ABV_CNPY	The reflected photosynthetic photon flux density measured above the canopy.
WIND_DIR_ABV_CNPY	The wind direction measured above the canopy.
WIND_SPEED_ABV_CNPY	The wind speed measured above the canopy.
FRICTION_VELOC_ABV_CNPY	The friction velocity above the canopy.
MOMENTUM_FLUX_ABV_CNPY	The momentum flux measured above the canopy.
SDEV_U_WIND_SPEED	Standard deviation of the streamwise wind speed.
SDEV_V_WIND_SPEED	Standard deviation of the lateral wind speed.
SDEV_W_WIND_SPEED	Standard deviation of the vertical wind speed.
H2O_FLUX_ABV_CNPY	The water vapor flux measured above the canopy.
CALC_H2O_FLUX	The water vapor 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.
AIR_TEMP_150CM	The air temperature measured at 1.5 meters above the ground.
AIR_TEMP_350CM	The air temperature measured at 3.5 meters above the ground.
AIR_TEMP_650CM	The air temperature measured at 6.5 meters above the ground.
AIR_TEMP_950CM	The air temperature measured at 9.5 meters above the ground.
AIR_TEMP_1250CM	The air temperature measured at 12.5 meters above the ground.

AIR_TEMP_18M	The air temperature measured at 18 meters above the ground.
AIR_TEMP_ABV_CNPY	The air temperature measured above the canopy.
NET_RAD_BELOW_CNPY	The net radiation measured below the canopy.
SOIL_TEMP_25MM	The soil temperature recorded at 25 mm in depth.
SOIL_TEMP_5CM	Soil temperature measured at a depth of 5 cm.
SOIL_TEMP_10CM	Soil temperature at 10 cm depth.
SOIL_TEMP_20CM	Soil temperature at 20 cm depth.
SOIL_TEMP_50CM	Soil temperature measured at 50 cm depth.
SOIL_TEMP_100CM	The soil temperature recorded at 1 m in depth.
VAPOR_PRESS_ABV_CNPY	The vapor pressure measured above the canopy.
VAPOR_PRESS_BELOW_CNPY	The vapor pressure measured below the canopy.
RAINFALL	The amount of rainfall in this 30 minute period measured above the canopy.
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.
CO2_CONC_50CM	The carbon dioxide concentration measured at 50 cm above the ground.
CO2_CONC_150CM	The carbon dioxide concentration measured at 1.5 m above the ground.
CO2_CONC_300CM	The carbon dioxide concentration measured at 3 m above the ground.
CO2_CONC_350CM	The carbon dioxide concentration measured at 3.5 m above the ground.
CO2_CONC_600CM	The carbon dioxide concentration measured at 6 m above the ground.
CO2_CONC_650CM	The carbon dioxide concentration measured at 6.5 m above the ground.
CO2_CONC_950CM	The carbon dioxide concentration measured at 9.5 m above the ground.
CO2_CONC_1200CM	The carbon dioxide concentration measured at 12 m above the ground.
CO2_CONC_1250CM	The carbon dioxide concentration measured at 12. 5 m above the ground.
CO2_CONC_1800CM	The carbon dioxide concentration measured at 18 m above the ground.
H2O_CONC_50CM	The water vapor concentration measured at 50 cm above the ground.
H2O_CONC_150CM	The water vapor concentration measured at 1.5 m above the ground.
H2O_CONC_350CM	The water vapor concentration measured at 3.5 m above the ground.
H2O_CONC_650CM	The water vapor concentration measured at 6.5 m above the ground.
H2O_CONC_950CM	The water vapor concentration measured at 9.5 m above the ground.
H2O_CONC_1250CM	The water vapor concentration measured at 12.5 m above the ground.
H2O_CONC_1800CM	The water vapor concentration measured at 18 m above the ground.
H2O_CONC_ABV_CNPY	The water vapor concentration 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.

TF09_SOIL_TEMP_DATA:

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.
SOIL_HEAT_FLUX_7CM	The soil heat flux measured at 7 cm depth.
SOIL_TEMP_5CM	Soil temperature measured at a depth of 5 cm.
SOIL_TEMP_10CM	Soil temperature at 10 cm depth.
SOIL_TEMP_20CM	Soil temperature at 20 cm depth.
SOIL_TEMP_50CM	Soil temperature measured at 50 cm depth.
SOIL_TEMP_100CM	The soil temperature recorded at 1 m in 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 flux data files on the CD-ROM are:

TF09_TOWER_FLUX_DATA:

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]

SOIL_HEAT_FLUX_7CM	[Watts][meter^-2]
CO2_FLUX_ABV_CNPY	[micromoles][meter^-2][second^-1]
CALC_CO2_FLUX	[micromoles][meter^-2][second^-1]
CO2_CONC_ABV_CNPY	[parts per million]
CO2_STORAGE	[micromoles][meter^-2][second^-1]
DOWN_PPFD_ABV_CNPY	[micromoles][meter^-2][second^-1]
UP_PPFD_ABV_CNPY	[micromole][meter^-2][second^-1]
WIND_DIR_ABV_CNPY	[degrees from North]
WIND_SPEED_ABV_CNPY	[meters][second^-1]
FRICTION_VELOC_ABV_CNPY	[meters][second^-1]
MOMENTUM_FLUX_ABV_CNPY	[meters^2][second^-2]
SDEV_U_WIND_SPEED	[meters][s^-1]
SDEV_V_WIND_SPEED	[meters][s^-1]
SDEV_W_WIND_SPEED	[meters][s^-1]
H2O_FLUX_ABV_CNPY	[millimole][meter^-2][second^-1]
CALC_H2O_FLUX	[millimoles][meter^-2][second^-1]
AIR_TEMP_150CM	[degrees Celsius]
AIR_TEMP_350CM	[degrees Celsius]
AIR_TEMP_650CM	[degrees Celsius]
AIR_TEMP_950CM	[degrees Celsius]
AIR_TEMP_1250CM	[degrees Celsius]
AIR_TEMP_18M	[degrees Celsius]
AIR_TEMP_ABV_CNPY	[degrees Celsius]
NET_RAD_BELOW_CNPY	[Watts][meter^-2]
SOIL_TEMP_25MM	[degrees Celsius]
SOIL_TEMP_5CM	[degrees Celsius]
SOIL_TEMP_10CM	[degrees Celsius]
SOIL_TEMP_20CM	[degrees Celsius]
SOIL_TEMP_50CM	[degrees Celsius]
SOIL_TEMP_100CM	[degrees Celsius]
VAPOR_PRESS_ABV_CNPY	[kiloPascals]
VAPOR_PRESS_BELOW_CNPY	[kiloPascals]
RAINFALL	[millimeters]
DOWN_SOLAR_RAD_ABV_CNPY	[Watts][meter^-2]
UP_SOLAR_RAD_ABV_CNPY	[Watts][meter^-2]
CO2_CONC_50CM	[parts per million]
CO2_CONC_150CM	[parts per million]
CO2_CONC_300CM	[parts per million]
CO2_CONC_350CM	[parts per million]
CO2_CONC_600CM	[parts per million]
CO2_CONC_650CM	[parts per million]
CO2_CONC_950CM	[parts per million]
CO2_CONC_1200CM	[parts per million]
CO2_CONC_1250CM	[parts per million]
CO2_CONC_1800CM	[parts per million]
H2O_CONC_50CM	[parts per thousand]
H2O_CONC_150CM	[parts per thousand]
H2O_CONC_350CM	[parts per thousand]
H2O_CONC_650CM	[parts per thousand]
H2O_CONC_950CM	[parts per thousand]
H2O_CONC_1250CM	[parts per thousand]
H2O_CONC_1800CM	[parts per thousand]
H2O_CONC_ABV_CNPY	[parts per thousand]
CRTFCN_CODE	[none]

REVISION_DATE	[DD-MON-YY]

TF09_SOIL_TEMP_DATA:

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
SOIL_HEAT_FLUX_7CM	[Watts][meter^-2]
SOIL_TEMP_5CM	[degrees Celsius]
SOIL_TEMP_10CM	[degrees Celsius]
SOIL_TEMP_20CM	[degrees Celsius]
SOIL_TEMP_50CM	[degrees Celsius]
SOIL_TEMP_100CM	[degrees Celsius]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

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

TF09_TOWER_FLUX_DATA:

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	[Solent anemometer]
CALC_SENSIBLE_HEAT_FLUX	[Supplied by Investigator]
LATENT_HEAT_FLUX_ABV_CNPY	[Infrared Gas Analyzer]
CALC_LATENT_HEAT_FLUX	[Supplied by Investigator]
NET_RAD_ABV_CNPY	[Net radiometer]
SOIL_HEAT_FLUX_7CM	[Heat flux plates]
CO2_FLUX_ABV_CNPY	[Infrared Gas Analyzer]
CALC_CO2_FLUX	[Supplied by Investigator]
CO2_CONC_ABV_CNPY	[Infrared Gas Analyzer]
CO2_STORAGE	[Infrared Gas Analyzer]
DOWN_PPFD_ABV_CNPY	[quantum sensor]
UP_PPFD_ABV_CNPY	[quantum sensor]
WIND_DIR_ABV_CNPY	[windvane]
WIND_SPEED_ABV_CNPY	[cup anemometer]
FRICTION_VELOC_ABV_CNPY	[Solent anemometer]
MOMENTUM_FLUX_ABV_CNPY	[Solent anemometer]
SDEV_U_WIND_SPEED	[Solent anemometer]
SDEV_V_WIND_SPEED	[Solent anemometer]
SDEV_W_WIND_SPEED	[Solent anemometer]
H2O_FLUX_ABV_CNPY	[Infrared Gas Analyzer]
CALC_H2O_FLUX	[Supplied by Investigator]
AIR_TEMP_150CM	[ventilated psychrometer]
AIR_TEMP_350CM	[ventilated psychrometer]
AIR_TEMP_650CM	[ventilated psychrometer]
AIR_TEMP_950CM	[ventilated psychrometer]
AIR_TEMP_1250CM	[ventilated psychrometer]

AIR_TEMP_18M	[ventilated psychrometer]
AIR_TEMP_ABV_CNPY	[ventilated psychrometer]
NET_RAD_BELOW_CNPY	[Net radiometer]
SOIL_TEMP_25MM	[Soil temperature probe]
SOIL_TEMP_5CM	[Soil temperature probe]
SOIL_TEMP_10CM	[Soil temperature probe]
SOIL_TEMP_20CM	[Soil temperature probe]
SOIL_TEMP_50CM	[Soil temperature probe]
SOIL_TEMP_100CM	[Soil temperature probe]
VAPOR_PRESS_ABV_CNPY	[ventilated psychrometer]
VAPOR_PRESS_BELOW_CNPY	[ventilated psychrometer]
RAINFALL	[tipping bucket rain gauge]
DOWN_SOLAR_RAD_ABV_CNPY	[solarimeter]
UP_SOLAR_RAD_ABV_CNPY	[solarimeter]
CO2_CONC_50CM	[Infrared Gas Analyzer]
CO2_CONC_150CM	[Infrared Gas Analyzer]
CO2_CONC_300CM	[Infrared Gas Analyzer]
CO2_CONC_350CM	[Infrared Gas Analyzer]
CO2_CONC_600CM	[Infrared Gas Analyzer]
CO2_CONC_650CM	[Infrared Gas Analyzer]
CO2_CONC_950CM	[Infrared Gas Analyzer]
CO2_CONC_1200CM	[Infrared Gas Analyzer]
CO2_CONC_1250CM	[Infrared Gas Analyzer]
CO2_CONC_1800CM	[Infrared Gas Analyzer]
H2O_CONC_50CM	[Infrared Gas Analyzer]
H2O_CONC_150CM	[Infrared Gas Analyzer]
H2O_CONC_350CM	[Infrared Gas Analyzer]
H2O_CONC_650CM	[Infrared Gas Analyzer]
H2O_CONC_950CM	[Infrared Gas Analyzer]
H2O_CONC_1250CM	[Infrared Gas Analyzer]
H2O_CONC_1800CM	[Infrared Gas Analyzer]
H2O_CONC_ABV_CNPY	[Infrared Gas Analyzer]
CRTFCN_CODE	[Assigned by BORIS]
REVISION_DATE	[Assigned by BORIS]

TF09_SOIL_TEMP_DATA:

Column Name	Data Source
SITE_NAME	[Assigned by BORIS]
SUB_SITE	[Assigned by BORIS]
DATE_OBS	[Supplied by Investigator]
TIME_OBS	[Supplied by Investigator]
SOIL_HEAT_FLUX_7CM	[Heat flux plates]
SOIL_TEMP_5CM	[Soil temperature probe]
SOIL_TEMP_10CM	[Soil temperature probe]
SOIL_TEMP_20CM	[Soil temperature probe]
SOIL_TEMP_50CM	[Soil temperature probe]
SOIL_TEMP_100CM	[Soil temperature probe]
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 flux data files on the CD-ROM.

TF09_TOWER_FLUX_DATA:

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-OBS-FLXTR	SSA-OBS-FLXTR	None	None	None	None
SUB_SITE	9TF09-FLX01	9TF09-FLX01	None	None	None	None
DATE_OBS	23-MAY-94	29-NOV-96	None	None	None	None
TIME_OBS	0	2330	None	None	None	None
SENSIBLE_HEAT_FLUX_ABV_CNPY	-202.958	1349.93	None	None	None	Blank
CALC_SENSIBLE_HEAT_FLUX	-202.958	701.344	None	None	None	Blank
LATENT_HEAT_FLUX_ABV_CNPY	-421.47	436.37	None	None	None	Blank
CALC_LATENT_HEAT_FLUX	-57.194	409.343	None	None	None	Blank
NET_RAD_ABV_CNPY	-145.8	759	None	None	None	Blank
SOIL_HEAT_FLUX_7CM	-11.071	54.72	None	None	None	Blank
CO2_FLUX_ABV_CNPY	-75.4	47.97	None	None	None	Blank
CALC_CO2_FLUX	-18.9484	34.0627	None	None	None	Blank
CO2_CONC_ABV_CNPY	334.1333	447.7667	None	None	None	Blank
CO2_STORAGE	-47.18	27.52	None	None	None	Blank
DOWN_PPFD_ABV_CNPY	0	1936	None	None	None	Blank
UP_PPFD_ABV_CNPY	-7.44	151.9	None	None	None	Blank
WIND_DIR_ABV_CNPY	0	360	None	None	None	Blank
WIND_SPEED_ABV_CNPY	0	11.13	None	None	None	Blank
FRICTION_VELOC_ABV_CNPY	0	1.4812	None	None	None	Blank
MOMENTUM_FLUX_ABV_CNPY	-2.194	1.83	None	None	None	Blank
SDEV_U_WIND_SPEED	.05	5.47	None	None	None	Blank
SDEV_V_WIND_SPEED	.04	4.96	None	None	None	Blank
SDEV_W_WIND_SPEED	.01	2.2	None	None	None	Blank
H2O_FLUX_ABV_CNPY	-9.53	9.87	None	None	None	Blank
CALC_H2O_FLUX	-1.2794	9.2129	None	None	None	Blank
AIR_TEMP_150CM	-30.91	32.74	None	None	None	Blank
AIR_TEMP_350CM	-30.99	33.48	None	None	None	Blank
AIR_TEMP_650CM	-31.1	32.72	None	None	None	Blank
AIR_TEMP_950CM	-27.58	32.2	None	None	None	Blank
AIR_TEMP_1250CM	-24.13	32.31	None	None	None	Blank
AIR_TEMP_18M	-24.06	32.48	None	None	None	Blank
AIR_TEMP_ABV_CNPY	-24.39	31.46	None	None	None	Blank
NET_RAD_BELOW_CNPY	-99.6	606	None	None	None	Blank
SOIL_TEMP_25MM	.18	29.42	None	None	None	Blank
SOIL_TEMP_5CM	-12.397	22.56	None	None	None	Blank
SOIL_TEMP_10CM	-7.206	17.118	None	None	None	Blank
SOIL_TEMP_20CM	-1.035	12.414	None	None	None	Blank
SOIL_TEMP_50CM	-.22	9.111	None	None	None	Blank
SOIL_TEMP_100CM	-.03	7.926	None	None	None	Blank

VAPOR_PRESS_ABV_CNPY	.0026	3.15	None	None	None	Blank
VAPOR_PRESS_BELOW_CNPY	-.007	3.585	None	None	None	Blank
RAINFALL	0	11.4	None	None	None	Blank
DOWN_SOLAR_RAD_ABV_CNPY	-7.37	1007	None	None	None	Blank
UP_SOLAR_RAD_ABV_CNPY	.0001	108.6811	None	None	None	Blank
CO2_CONC_50CM	334.333	713.6	None	None	None	Blank
CO2_CONC_150CM	326.3	659.5	None	None	None	Blank
CO2_CONC_300CM	296.22	567.88	None	None	None	Blank
CO2_CONC_350CM	332.933	624.533	None	None	None	Blank
CO2_CONC_600CM	315.78	496.78	None	None	None	Blank
CO2_CONC_650CM	332.633	597.133	None	None	None	Blank
CO2_CONC_950CM	333.833	463.767	None	None	None	Blank
CO2_CONC_1200CM	283.09	433.82	None	None	None	Blank
CO2_CONC_1250CM	333.767	440.667	None	None	None	Blank
CO2_CONC_1800CM	334.133	440.267	None	None	None	Blank
H2O_CONC_50CM	.15	21.25	None	None	None	Blank
H2O_CONC_150CM	.15	21.083	None	None	None	Blank
H2O_CONC_350CM	.143	21.193	None	None	None	Blank
H2O_CONC_650CM	.123	21.183	None	None	None	Blank
H2O_CONC_950CM	.13	21.317	None	None	None	Blank
H2O_CONC_1250CM	.15	21.55	None	None	None	Blank
H2O_CONC_1800CM	.143	21.45	None	None	None	Blank
H2O_CONC_ABV_CNPY	.163	21.193	None	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	02-SEP-98	02-SEP-98	None	None	None	None

TF09_SOIL_TEMP_DATA:

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	SSA-OBS-FLXTR	SSA-OBS-FLXTR	None	None	None	None
SUB_SITE	9TF09-FLX01	9TF09-FLX01	None	None	None	None
DATE_OBS	15-NOV-95	23-MAR-96	None	None	None	None
TIME_OBS	0	2330	None	None	None	None
SOIL_HEAT_FLUX_7CM	-11.009	2.161	None	None	None	None
SOIL_TEMP_5CM	-7.872	1.338	None	None	None	None
SOIL_TEMP_10CM	-4.328	1.298	None	None	None	None
SOIL_TEMP_20CM	-.836	1.271	None	None	None	None
SOIL_TEMP_50CM	.624	2.399	None	None	None	None
SOIL_TEMP_100CM	1.147	3.004	None	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	03-SEP-98	03-SEP-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 flux data file on the CD-ROM.

TF09_TOWER_FLUX_DATA:

```
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,SOIL_HEAT_FLUX_7CM,CO2_FLUX_ABV_CNPY,CALC_CO2_FLUX,
CO2_CONC_ABV_CNPY,CO2_STORAGE,DOWN_PPFD_ABV_CNPY,UP_PPFD_ABV_CNPY,
WIND_DIR_ABV_CNPY,WIND_SPEED_ABV_CNPY,FRICTION_VELOC_ABV_CNPY,
MOMENTUM_FLUX_ABV_CNPY,SDEV_U_WIND_SPEED,SDEV_V_WIND_SPEED,SDEV_W_WIND_SPEED,
H2O_FLUX_ABV_CNPY,CALC_H2O_FLUX,AIR_TEMP_150CM,AIR_TEMP_350CM,AIR_TEMP_650CM,
AIR_TEMP_950CM,AIR_TEMP_1250CM,AIR_TEMP_18M,AIR_TEMP_ABV_CNPY,NET_RAD_BELOW_CNPY,
SOIL_TEMP_25MM,SOIL_TEMP_5CM,SOIL_TEMP_10CM,SOIL_TEMP_20CM,SOIL_TEMP_50CM,
SOIL_TEMP_100CM,VAPOR_PRESS_ABV_CNPY,VAPOR_PRESS_BELOW_CNPY,RAINFALL,
DOWN_SOLAR_RAD_ABV_CNPY,UP_SOLAR_RAD_ABV_CNPY,CO2_CONC_50CM,CO2_CONC_150CM,
CO2_CONC_300CM,CO2_CONC_350CM,CO2_CONC_600CM,CO2_CONC_650CM,CO2_CONC_950CM,
CO2_CONC_1200CM,CO2_CONC_1250CM,CO2_CONC_1800CM,H2O_CONC_50CM,H2O_CONC_150CM,
H2O_CONC_350CM,H2O_CONC_650CM,H2O_CONC_950CM,H2O_CONC_1250CM,H2O_CONC_1800CM,
H2O_CONC_ABV_CNPY,CRTFCN_CODE,REVISION_DATE
'SSA-OBS-FLXTR','9TF09-FLX01',01-APR-96,0,77.067,77.067,4.696,4.696,37.44,-4.841,
.2878,.2878,377.3333,.774,277.6,22.743,294.1,3.191,.595,-.354,1.27,1.15,.71,
.1038,.1038,-7.24,-6.73,-6.31,-5.88,,,-7.07,-15.26,,-2.248,-1.034,.255,1.201,
1.659,.0993,,0.0,220.2501,21.7411,377.4,377.333,,377.367,,377.233,377.067,,
377.033,376.967,1.51,1.52,1.38,1.363,1.35,1.343,1.36,1.343,'CPI',22-SEP-98
'SSA-OBS-FLXTR','9TF09-FLX01',01-APR-96,30,4.047,4.047,2.109,2.109,-17.21,-4.879,
.0354,.0354,377.8333,.253,151.8,12.558,285.1,3.732,.4911,-.2412,1.03,.9,.57,
.0355,.0355,-7.95,-7.87,-7.5,,,,-7.46,-18.61,,-2.26,-1.035,.253,1.199,1.659,
.0987,,0.0,139.8501,15.2011,378.0,378.067,,377.833,,377.7,377.633,,377.567,377.8,
1.503,1.433,1.373,1.35,1.367,1.343,1.377,1.353,'CPI',22-SEP-98
```

TF09_SOIL_TEMP_DATA:

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,SOIL_HEAT_FLUX_7CM,SOIL_TEMP_5CM,
SOIL_TEMP_10CM,SOIL_TEMP_20CM,SOIL_TEMP_50CM,SOIL_TEMP_100CM,CRTFCN_CODE,
REVISION_DATE
'SSA-OBS-FLXTR','9TF09-FLX01',01-JAN-96,30,-2.94,-1.885,-.745,.499,1.365,1.992,
'CPI',03-SEP-98
'SSA-OBS-FLXTR','9TF09-FLX01',01-JAN-96,130,-2.932,-1.876,-.74,.504,1.366,1.992,
'CPI',03-SEP-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

Fluctuations were calculated using an autoregressive moving average (digital filter). These fluctuations were used to calculate the covariances and variances. Coordinate rotation was a geometric transformation. The speed of sound was corrected for wind speed normal to the transducer path (Kaimal and Gaynor, 1991) with geometric transformations to allow for the nonorthogonal arrangement of transducer in the Solent anemometer. Sonic temperature was calculated from the speed of sound, and corrections to sensible heat flux calculated using sonic rather than absolute temperature were made (Schotanus et al., 1983). Corrections for nonideal response were applied (Moore, 1986; Philip, 1963).

9.1.1 Derivation Techniques and Algorithms

None.

9.2 Data Processing Sequence

Moving averages, variances, and covariances were calculated in real time, and coordinate rotation was applied on the half-hourly covariances and variances. Corrections for the use of sonic temperature were applied after data collection.

9.2.1 Processing Steps

BORIS staff processed these data by:

- Reviewing the initial data files and loading them online for BOREAS team access.
- Designing relational data base tables to inventory and store the data.
- Loading the data into the relational data base tables.
- Working with the team to document the data set.
- Extracting the data into logical files.

9.2.2 Processing Changes

None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None.

9.3.2 Calculated Variables

The eddy flux measurements on calm nights underestimate the surface fluxes. Inspection of the CO_2 storage flux also shows that storage flux does not account for the underestimation by the CO_2 eddy flux. To provide estimates of the surface fluxes of CO_2, H_2O, sensible heat, and latent heat fluxes, the variables FILLED_CO2_FLUX_26M, FILLED_SENSIBLE_HEAT_26M, FILLED_LATENT_HEAT_26M, and FILLED_H2O_FLUX_26M have been added to the data set. These variables are equal to the corresponding eddy flux values except on calm nights as defined below. Gaps in the eddy flux measurements have also been "filled in" by use of regression equations of eddy flux against meteorological variables. Below is the SAS (SAS Institute, NC) program that was used to calculate these variables.

```
/**************** SAS PROGRAM ************************/
data boreas96.boris96f;
  merge boreas96.boris96m boreas96.amodel;
    by end_time;
  SVP = 0.611 * exp(17.27*Tskye/(Tskye+237.15));  * saturated vapor pressure
                                                  * Tskye is AIR_TEMP_26M
  VPD = SVP - VP;       * VPD is saturated vapor pressure deficit
                        * VP is vapor pressure
  Rn_G = Rn - SHF;      * Rn is R_NET_16M; SHF is SOIL_HEAT_FLUX_7CM
  if month >= 6 and month <=8 then
    R = exp(0.6038 + 0.0833 *Ts5cm + 0.0096 * Tskye);  * Respiration
  else
    R = exp(0.2688 + 0.0874 *Ts5cm + 0.0413 * Tskye);
  RTa = exp(0.403+0.0875*Tskye);
            * Respiration as function of AIR_TEMP_26M only
  RTs5 = exp(0.117+0.1483*Ts5cm);
            * Respiration as function of SOIL_TEMP_5CM only
  retain Tmin -3 Topt 18 Tmax 32;
  P = (Tmax-Topt)/(Topt-Tmin);
  if Tskye > Tmin and Tskye < Tmax then
    At = ((Tskye - Tmin)*((Tmax-Tskye)**P)) / ((Topt-Tmin)*((Tmax-Topt)**P));
  else At = 0;         * At is assimilation =(CO2 flux - respiration) as
                       * normalized function of AIR_TEMP_26M
  if VPD < 1.3 then Ad = 1;           * Ad is assimilation as a normalized
  else if VPD > 5 then Ad = 0;        * function of VPD
  else Ad = 1 -1/(5- 1.3)*(VPD - 1.3);
  if month =3 then qfe = 0.0002;      * Quantum flux efficiency
  if month =4 then qfe = 0.004;
  if month =5 then qfe = 0.013;
```

```
  if month =6 then qfe = 0.027;
  if month =7 then qfe = 0.035;
  if month =8 then qfe = 0.032;
  if month =9 then qfe = 0.031;
  if month =10 then qfe = 0.011;
  if month =11 then qfe = 0.0006;
  Amax=50; theta = 0.8;
  Aq = ((qfe*parin+Amax) - sqrt( (qfe*parin+Amax)**2-4*theta*qfe*Amax*parin)) /
2*theta;        * Light response curve, NOT normalized (parin is PPFD_26M )
  Amodel=Aq*Ad*At;
              * Assimilation model s function of PPFD, VPD and temperature
  Fcmodel = -Amodel+R;   * CO2_FLUX_26M model

  if parin = 0 then
    do;
      if Fc = . or friction < 0.35 then    * friction is FRICTION_VELOCITY
         if R = . then
            if Rta = . then Fc_fill = RTs5;
            else Fc_fill = RTa;
         else Fc_fill= R;
      else Fc_fill = Fc;
      if E  = . or friction < 0.35 then E_fill = 0; else E_fill = E;
      if LE = . or friction < 0.35 then LE_fill= 0; else LE_fill = LE;
      if H  = . or friction < 0.35 then
         if shf = . then H_fill = Rn;
         else H_fill = Rn_G;
      else H_fill = H;
    end;
  else
/* if parin > 0;  */
    do;
      if Fc = . then
        if Ts5cm = . then
          Fc_fill = -Amodel + RTa;
        else
          Fc_fill = Fcmodel;
      else Fc_fill = Fc;
      if LE = . then
        if month = 3 then
          if shf = . then LE_fill = 0.04 * Rn;
          else LE_fill = 0.04*Rn_G;
        else if shf = . then LE_fill = 0.30 * Rn;
             else LE_fill = 0.30*Rn_G;
      else LE_fill = LE;
      if E  = . then E_fill  = LE_fill/44.4; else E_fill = E;
      if H  = . then
         if shf = . then H_fill = 0.62 *Rn;
         else H_fill  = 0.62 * Rn_G;
      else H_fill = H;
    end;
  drop VPD CUMTEMP AD AT AQ AQlonly AMMAX LNAMMAX weeks2 week qfe amax
       theta fcres Rn_G Amodel Fcmodel R RTa RTs5 A P Tmin Topt Tmax SVP;
run;
/***************************************************************************/
```

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

The EC system was placed on an upright pole 3 m above the top of the tower so that the tower would cause very little disturbance to the wind, whatever its direction. Therefore, EC measurements would not be especially invalidated by any wind direction with respect to the tower; however, the access trail to the site is to the east, and any production of CO_2 by people or vehicles on the trail may affect the CO_2 fluxes measured if the wind is from the east. Also, in the making of the access trail, extensive damage was caused to the muskeg, with many trees being felled; hence, photosynthesis over this area will be uncharacteristically lower and respiration similarly high. The eddy flux measurements on calm nights underestimate the surface fluxes. This problem is address in the filled data columns.

10.2 Quality Assessment

10.2.1 Data Validation by Source

None given.

10.2.2 Confidence Level/Accuracy Judgment

None given.

10.2.3 Measurement Error for Parameters

None given.

10.2.4 Additional Quality Assessments

None given.

10.2.5 Data Verification by Data Center

Data were examined 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

See Section 10.1.

11.2 Known Problems with the Data

For the 1994 data:

Soil temperature at 1 m: before 01-July-1994 this was measured using a thermistor from which the signal was very noisy. On 01-July-1994 at 22:30 Greenwich Mean Time (GMT) this thermistor was replaced by a thermocouple with a much more accurate output. There was no trend in the soil temperature at 1 m before 15-June-1994 at 02:00 with a mean of 0 °C, and the noisy values for this period have been replaced with 0 °C. From 01-June 02:00 GMT until 01-July-1994 20:00 GMT, the signal has been smoothed. Any true diurnal trend has been removed by this substitution, but the values are estimated to be within 0.3 °C.

EC measurements: The data acquisition software missed the flux averaging times shown below. (This failure was caused by a fragmented hard disk making disk access slow.) Data were not lost, although the fluxes were not averaged at the end of the half hour, but at the end of an hour. Therefore, the missing averages (at the times shown below) have been substituted with the value calculated at the next half hour (times given as GMT):

Date	Times (GMT)
26/07/94	03:30, 05:30, 07:30, 09:30, 11:30, 13:30, 15:30, 21:30, 23:30
27/07/94	00:30 01:30 03:30 05:30 06:00 07:30 09:30 11:30 13:30 19:00 21:00 23:00
28/07/94	00:00, 01:00, 03:00, 07:00, 09:00, 12:30, 13:00, 14:30, 15:00, 15:30, 16:30, 18:30, 20:30, 22:30
29/07/94	00:30, 02:30, 04:30, 06:30, 08:30, 10:30, 12:30, 14:30, 15:00, 16:30, 18:30, 20:30, 21:00, 22:30, 23:00
30/07/94	00:30, 02:30, 03:00, 04:30
09/08/94	18:00, 22:00
10/08/94	04:00, 06:00, 08:00, 10:00, 12:00, 14:00, 16:00, 18:00, 20:00, 22:00, 23:30
11/08/94	00:00, 01:30, 02:00, 03:30, 04:00, 06:00, 08:00, 09:30, 10:00, ,11:30, 12:00, 14:00, 16:00, 18:00, 20:00, 21:30, 22:00, 23:30
12/08/94	00:00, 01:30, 02:00, 03:30, 04:00
29/08/94	17:30, 19:30, 21:30, 23:30
30/08/94	01:30, 03:30, 05:30, 07:30, 09:30, 11:30, 13:30, 15:00, 15:30, ,17:00, 17:30, 19:30, 21:30, 23:00, 23:30
31/08/94	01:00, 01:30, 02:00
09/09/94	02:00, 04:00, 12:00, 14:00, 16:00, 18:00, 20:00, 22:00
10/09/94	00:00, 02:00, 04:00, 06:00, 08:00, 10:00, 12:00, 14:00, 16:00, 18:00
17/09/94	06:00, 18:00, 21:30
18/09/94	01:30, 03:30, 05:30, 07:30, 09:30, 11:30, 13:30, 15:30, 17:30, ,19:30, 21:30, 23:30
19/09/94	01:30, 03:30, 05:30, 07:30

11.3 Usage Guidance

None given.

11.4 Other Relevant Information

None given.

12. Application of the Data Set

These data are useful for the study of water, energy, and carbon exchange in a mature black spruce forest.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

Some samples of code used in the analysis are shown in Section 9.3.2.

14.2 Software Access

None given.

15. Data Access

The SSA-OBS tower flux, meteorological, and soil temperature 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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Pearcy, R.W., J. Ehleringer, H.A. Mooney, and P.W. Rundel. 1991. Plant Physiological Ecology: Field methods and instrumentation. Chapman and Hall, London and New York.

Philip, J.R. 1963. The damping of a fluctuating concentration by continuous sampling through a tube. Aust. J. Phys. 16:454-463.

Scheupp, P.H., M.Y. Leclerc, J.I. Macpherson, and R.L. Desjardins. 1990. Bound. Layer Meteorol. 50:355-373.

Schotanus, P., F.T.M. Nieuwstadt, and H.A.R. de Bruin. 1983. Temperature measurement with a sonic anemometer and its application to heat and moisture fluxes. Bound. Layer Meteorol. 26:81-93.

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

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

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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.

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

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

```
A/D     - Analog to Digital
ASCII   - American Standard Code for Information Interchange
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
CD-ROM  - Compact Disk-Read-Only Memory
DAAC    - Distributed Active Archive Center
EC      - Eddy Covariance
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
i.d.    - internal diameter
IRGA    - Infrared Gas Analyzer
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NSA     - Northern Study Area
OBS     - Old Black Spruce
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
PAR     - Photosynthetically Active Radiation
PC      - Personal Computer
PPFD    - Photosynthetic Photon Flux Density
REBS    - Radiation Energy Balance Systems
SSA     - Southern Study Area
```

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TF     - Tower Flux
URL    - Uniform Resource Locator
WAB    - Wind Aligned Blob
WMO    - World Meteorological Organization
```

20. Document Information

20.1 Document Revision Date
Written: 22-May-1998
Revised: 11-Aug-1999

20.2 Document Review Date(s)
BORIS Review: 06-Oct-1998
Science Review:

20.3 Document ID

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

P.G. Jarvis, J.M. Massheder, J.B. Moncrieff, M.B. Rayment, Sophie Hale, Steve Scott, Institute of Ecology and Resource Management, Edinburgh University.

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

Jarvis, P.G. and J.B. Moncrieff, "The CO_2 Exchanges of Boreal Black Spruce Forest." 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
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 TF-9 SSA-OBS Tower Flux, Meteorological, and Soil Temperature Data

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

6. AUTHOR(S)
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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. 206

11. SUPPLEMENTARY NOTES
J.M. Massheder, J.B. Moncrieff, M.B. Rayment, and P.G. Jarvis: University of Edinburgh, UK;
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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-9 team collected energy, carbon dioxide, and water vapor flux data at the BOREAS SSA-OBS site during the growing season of 1994 and most of the year for 1996. From the winter of 1995 to 1996, soil temperature data were also collected and provided. The data are available in tabular ASCII files.

14. SUBJECT TERMS
BOREAS, tower flux, meteorological data, soil temperature data.

15. NUMBER OF PAGES
30

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