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

Forrest G. Hall and Karl Huemmrich, Editors

Volume 200

BOREAS TF-5 SSA-OJP Tower Flux and Meteorological Data

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National Oceanic and Atmospheric Administration/ATDD
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National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

October 2000

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BOREAS TF-5 SSA-OJP Tower Flux and Meteorological Data

Dennis Baldocchi, Christoph Vogel

Summary

The BOREAS TF-5 team collected tower flux data at the BOREAS SSA-OJP site through the growing season of 1994. The data are available in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS TF-05 SSA-OJP Tower Flux and Meteorological Data

1.2 Data Set Introduction

Eddy correlation flux measurements of sensible heat, latent heat, and CO_2 fluxes were made above and under the canopy of the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) Old Jack Pine (OJP) site.

1.3 Objective/Purpose

The objective was to measure and model air-surface exchange rates of water vapor, sensible heat, and CO_2 over and under a boreal forest and to study the abiotic and biotic factors that control the fluxes of scalars in this landscape. Scalar flux densities were measured with tower-mounted measurement systems. Tower-mounted flux measurement systems were installed above and below an old jack pine forest canopy, which allowed investigation of the relative roles of vegetation and the forest floor on the net canopy exchange of mass and energy. The tower-mounted flux measurement system was also used to study temporal patterns (diurnal and seasonal) of mass and energy exchange at a point in the landscape.

1.4 Summary of Parameters

Key measured flux variables were net radiation, Photosynthetic Photon Flux Density (PPFD), latent heat, sensible heat, soil heat, and CO_2 flux densities above and below the canopy. Key measured meteorological variables included wind speed, wind direction, air temperature, relative humidity, soil temperature, CO_2 concentration, and ozone concentration.

1.5 Discussion

Eddy flux densities of CO_2, water vapor, and sensible heat and turbulence statistics were measured above and below the OJP (Pinus banksiana) site near Nipawin (53.92 °N, 104.69 °W), Saskatchewan, Canada. The site was relatively level and the forest stand was horizontally homogeneous throughout the area deemed as the flux footprint, a region extending over 1 km upwind.

One eddy flux measurement system was mounted at 20 m above the ground. This system was about 5 to 10 m above the canopy and was mounted on the double scaffold tower provided by the BOREAS project. The sensors on a boom extended 3 m upwind of the tower, to minimize flow distortion. The azimuth angle of the boom was altered to place the instrument array into the wind. The subcanopy flux system was mounted 2 m above the ground on a portable telescoping tower, supplied by National Oceanic and Atmospheric Administration/Atmospheric Turbulence and Diffusion Division (NOAA/ATDD). This lower tower was placed 30 to 50 m away from the base of the main tower to avoid interference from local foot traffic. This dual flux measurement method has been successfully developed and used in a deciduous forest (Verma et al., 1986; Baldocchi et al., 1987; Baldocchi and Meyers, 1991). By analogy, the investigators feel that the dual measurement approach can be used with confidence above and below the jack pine stand.

The eddy flux densities were determined by calculating the covariance between vertical velocity and scalar fluctuations (see Baldocchi et al., 1988). Wind velocity and virtual temperature fluctuations were measured with identical 3-D sonic anemometers. Experience has shown that it is prudent to use 3-D sonic anemometers in forest meteorology applications. When deploying an anemometer over a forest, it is nearly impossible to physically align the vertical velocity sensor normal to the mean wind streamlines; sensor orientation problems typically arise because of sloping terrain and the practice of extending a long boom upwind from a tower. The use of a 3-D anemometer allows numerical coordinate rotations to be made to align the vertical velocity measurement normal to the mean wind streamlines. CO_2 and water vapor fluctuations were measured with an open-path, infrared absorption gas analyzer, developed at NOAA/ATDD (Auble and Meyers, 1992).

Fast-response meteorology data were digitized, processed, and stored using a microcomputer-controlled system and in-house software. Digitization of sensor signals was performed with hardware on the sonic anemometer. Sensor data were output at 10 Hz. Spectra and cospectra computations showed that these sampling rates were adequate for measuring fluxes above and below forest canopies (Baldocchi and Meyers, 1991; Amiro, 1990). Scalar fluctuations were computed, real-time, using a running mean removal method (McMillen, 1988). Analytical and numerical tests showed the recursive filter time constant of 400 s yielded fluxes similar to those computed with the conventional Reynolds averaging approach. Mass and energy flux covariances were stored at half-hour intervals on high-capacity Bernoulli removable disk media. Instantaneous data were recorded periodically.

Proper interpretation of experimental results and model evaluation requires detailed ancillary measurements of many environmental variables. Energy balance components that were measured include the net radiation balance, soil heat flux, and canopy heat storage.

1.6 Related Data Sets

BOREAS TF-04 SSA-YJP Tower Flux, Meteorological, and Canopy Condition Data
BOREAS TF-08 NSA-OJP Tower Flux Data
BOREAS TF-09 SSA-OBS Tower Flux, Meteorological, and Soil Temperature Data
BOREAS TF-11 SSA-Fen Tower Flux and Meteorological Data
BOREAS AFM-07 SRC Surface Meteorological and Radiation Data
BOREAS TE-06 Allometry Data
BOREAS TGB-10 Oxidant Concentration Data over the SSA
BOREAS TGB-10 Oxidant Flux Data over the SSA

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Dennis Baldocchi and Dr. Christoph Vogel
NOAA/ATDD

2.2 Title of Investigation

Experimental and Modeling Studies of Water Vapor, Sensible Heat, and CO_2 Exchange Over and Under a Boreal Forest

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3. Theory of Measurements

Micrometeorological Measurement Theory:

Micrometeorological methods allow one to measure short-term flux densities (moles per unit area and time) of scalar compounds to and from forest ecosystems. The equation describing the conservation of mass provides the basic framework for applying micrometeorological methods to measure the vertical flux density of S (F) between the surface and the atmosphere. The conservation equation describes the factors that control the time rate of change of a scalar mixing ratio in a controlled volume. To grasp an understanding of this relationship, the factors controlling the water level in a bath tub must first be considered. The water level will remain the same if the amount of water flowing into the tub equals that removed through the drain. In the atmosphere, for example, the concentration of a sulfur compound will remain unchanged if the mean and turbulent fluxes entering a controlled volume equal those leaving (the flux divergence is zero). On the other hand, concentrations will vary with time if the flux of sulfur entering the system differs from that leaving, as when plume impaction occurs.

How can the conservation equation be applied to measure fluxes? In the field, fluxes are measured at a given height above the surface, but the variable to be determined is the rate CO_2 is taken up by the surface below. The vertical flux density of S will remain unchanged with height if the underlying surface is 1) homogeneous and extends upwind for a considerable distance (this requirement ensures the development of a surface boundary layer); 2) if scalar concentrations are steady with time; and 3) if no chemical reactions are occurring between the surface and the measurement height.

Condition 1 can be met easily through proper site selection. As a rule of thumb, the site should be flat and horizontally homogeneous for a distance between 75 and 100 times the measurement height (Monteith and Unsworth, 1990). Condition 2 is met often for many scalars. Nonsteady conditions are most apt to occur during abrupt transitions between unstable and stable atmospheric thermal stratification, during the passage of a front, or from the impaction of a plume from nearby power plants.

Eddy Correlation Technique:

The eddy correlation method is a direct method for measuring flux densities of scalar compounds. The vertical flux density is proportional to the covariance between vertical wind velocity (w) and scalar concentration fluctuations (c).

A wide range of turbulent eddies contributes to the turbulent transfer of material. Proper implementation requires sampling across this spectrum of eddies. In frequency domain, eddies contributing to turbulent transfer having periods between 0.5 and 2000 seconds typically contribute to mass and energy exchange (Wesely et al., 1989). Hence, wind and chemical instrumentation must be capable of responding to high-frequency fluctuations. Computer-controlled data acquisition systems must sample the instrumentation frequently to avoid aliasing and average the signals over a sufficiently long period to capture all the contributions to the transfer.

On applying the covariance relation, it is assumed implicitly that the mean vertical flux density is perpendicular to the streamlines of the mean horizontal wind flow. Consequently, the mean vertical velocity, perpendicular to the streamlines of the mean wind flow, equals zero. In practice, nonzero vertical velocities occur because of instrument misalignment, sloping terrain, and density fluctuations. These effects must be removed when processing the data; otherwise, mean mass flow can introduced a bias error (see Businger, 1986; Baldocchi et al., 1988).

Evaluating the accuracy of the eddy correlation method is complicated. Factors contributing to instrument errors include time response of the sensor, signal-to-noise ratio, sensor separation distance, height of the measurement, and signal attenuation caused by path averaging and sampling through a tube. Natural variability is caused by nonsteady conditions and surface inhomogeneities. Under ideal conditions, natural variability exceeds about +/-10%, so it is desirable to design a system with an error approaching this metric.

Moore (1986) discusses transfer functions for sensor response time and separation distance. Preliminary calculations of transfer function integrals were performed. Corrections because of sensor time constants and separation are less than a few percent. Hence, it was decided not to make transfer function to the flux measurements; the experimental design minimized the need for such corrections since an open-path infrared gas analyzer (IRGA) and a sonic anemometer were used. Furthermore, these instruments were placed over a tall rough forest, so small distances in physical displacement have little impact on the measurement of scalar flux densities.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment

Measurements were collected continuously through the growing season of 1994. The tower extended above the canopy and was exposed to direct sunlight and weather. The site operated only during the growing season; consequently, the temperatures were mild, and freezing conditions were not encountered.

4.1.2 Source/Platform

Above-canopy measurements were made from a 26-meter double-scaffold walk-up tower. The subcanopy flux system was mounted 2 m above the ground on a portable telescoping tower. This lower tower was placed 30 to 50 m away from the base of the main tower to avoid interference from local foot traffic.

Eddy correlation flux measurements were made using a triple-axis Applied Technology, Inc. (ATI) sonic anemometer and an infrared absorption spectrometer. The sonic anemometer measured vertical (w) and horizontal (u,v) wind velocity and air temperature (T). This anemometer model provides digital output at a rate of 10 Hz. The infrared absorption spectrometer measured water vapor and CO_2 density fluctuations. The sensor responds to frequencies up to 15 Hz and has low noise and high sensitivity (20 mg/m^3/volt). The sensor is rugged and experiences little drift over several weeks of continuous operation.

Soil heat flux density was measured by averaging the output of three soil heat flux plates (Radiation Energy Balance Systems (REBS) model HFT-3, Seattle, WA). They were buried 0.01 m below the surface and were randomly placed within a few meters of the flux system. Soil temperatures were measured with two multilevel thermocouple probes. Sensors were spaced logarithmically at 0.02, 0.04, 0.08, 0.16, and 0.32 m below the surface. Three thermocouples were used to measure bole temperatures. Sensors were placed about 1 cm into the bole and were azimuthally spaced around a tree at breast height. Canopy heat storage was calculated by measuring the time rate of change in bole temperature in the tree trunks.

Photosynthetically active photon flux density and the net radiation balance were measured above the forest with a quantum sensor (LI-COR model LI-190S) and a net radiometer (Swissteco Model S-1 or REBS model 6), respectively. A more detailed experimental design was implemented at the forest floor because the solar radiation field below a forest canopy is highly variable (Baldocchi and Collineau, 1994). To account for this variability, measurements of solar radiation components were made using an instrument package that traversed slowly across a 14.5-m-long track.

Air temperature and relative humidity were measured with appropriate sensors (Campbell model 207 and Vaisala model HMP-35A). Wind speed and direction were measured with a propeller wind speed/direction monitor (RM Young model 05701). Infrared canopy temperature was measured with an Everest radiation thermometer (model 112C). The sensor was pointed south and oriented at 45 degrees. Ancillary data were acquired and logged on a Campbell CR-21x data logger. Half-hour averages were stored on a computer, to coincide with the flux measurements.

CO_2 concentration profiles were measured with a LI-COR 6262 IRGA. Samples were drawn at 22, 17, 12, 6, and 2 m. During the first two Intensive Field Campaigns (IFCs), the 22- and 17-m levels were sampled exclusively between 0600 and 1800 hours, and the full profile at night. During the third IFC, the whole profile was sampled continuously. Solenoid valves were switched every 30 s. Data from the third IFC are most reliable because the system was modified to measure cell pressure and temperature in addition to CO_2 concentration.

The eddy correlation flux systems were digitized on the tower using the analog-to-digital (A/D) converter of the ATI sonic anemometer. The A/D board was a 12- bit system. Digital signals for the three orthogonal wind velocity components, temperature, humidity, CO_2, and ozone were transmitted to a 386 computer in the field lab. In-house software (FLUX.EXE) displayed the data in real time on screen for scrutiny and computed fluctuations from means and 30-minute flux covariances. Campbell 21-X data loggers were used to sample environmental variables. These data loggers were connected to another 386 computer via digital line and were interrogated every 30 minutes using Campbell Scientific software (TELCOM.EXE).

4.1.3 Source/Platform Mission Objectives

The objective was to measure fluxes of sensible and latent heat and CO_2 using the eddy correlation technique, the radiation balance, and ground heat flux. Sampling, recording, and near-real-time processing of the data were done with computer-based data loggers.

4.1.4 Key Variables

Carbon dioxide, solar, sensible and latent heat flux densities above the forest and ground surface, soil heat flux at the soil surface, and canopy heat storage.

4.1.5 Principles of Operation

Sonic Anemometer:

Three-dimensional orthogonal wind velocities (u, v, and w) and virtual temperature (Tv) were measured with a sonic anemometer (ATI, model SWS-211/3K, Boulder, CO). The path length between transducers was 0.15 m. The sensor software corrected for transducer shadowing effects (see Kaimal et al., 1990). Virtual temperature heat flux was converted to sensible heat flux using algorithms described by Kaimal and Gaynor (1991) and Schotanus et al. (1983).

Infrared Absorption Spectrometer:

Water vapor and CO_2 concentrations were measured with an open-path infrared absorption spectrometer. Details and performance characteristics of the spectrometer are discussed by Auble and Meyers (1992). In brief, the infrared beam was reflected three times between mirrors separated by 0.20 m, making an 0.80-m absorption path. The response time of the sensor was less than 0.1 s, sensor noise was less than 300 $\mu g/m^3$, and its calibration was steady (it varied +/- 3% during the course of the experiment). The sensor was calibrated periodically with three standard CO_2 gases mixed in air, whose accuracy was ± 1%.

Soil Heat Flux Transducer:

An encapsulated thermopile yields a voltage output proportional to the temperature difference across the top and bottom surfaces. The device has been calibrated in terms of heat flux through transducer corresponding to the observed temperature difference.

4.1.6 Sensor/Instrument Measurement Geometry

One eddy flux measurement system was placed at 20 m above the ground, on a double-scaffold tower provided by the BOREAS project. The instruments were mounted on a boom that extended 3 m upwind of the tower to minimize flow distortion. The boom was 7 m above the mean tree height and was positioned in the constant flux layer. The azimuth angle of the boom was altered periodically to place the instrument array into the predominant wind direction. Another eddy flux system was positioned near the floor of the canopy. The instruments were 1.8 m above the ground. This location was in the stem space of the canopy and virtually no foliage was present between the canopy floor and the measurement height.

4.1.7 Manufacturer of Sensor/Instrument

Sonic anemometer:
ATI
6395 Gunpark Dr. Unit E
Boulder, CO 80301

Soil heat transducer:
REBS
P.O. Box 15512
Seattle, WA 98115-0512
Elmer, NJ 08318
Radiation thermometer:
Everest Interscience Inc.
P.O. Box 3640
Fullerton, CA 92634

Net radiometer:
REBS
P.O. Box 15512
Seattle, WA 98115-0512
Elmer, NJ 08318

Data logging system:
Campbell Scientific
P.O. Box 551,
Logan, UT 84321

4.2 Calibration

4.2.1 Specifications

The net radiometer, quantum sensors, and soil heat flux plates were calibrated by the manufacturer. A net radiometer and quantum sensor were new and were used as a transfer standard. The instruments were sent to the manufacturer after BOREAS IFC-3 for recalibration. The net radiometer calibrations did not change over the course of the experiment.

Flux and mean concentration CO_2 analyzers were calibrated against standard calibration gases. The gases were referenced to the Atmospheric Environment Service (AES), World Meteorological Organization (WMO) standards, and the BOREAS standard gases. The flux sensors were calibrated two to three times a week. Three reference gases were used to doublecheck linearity. The concentrations of the standard were about 322, 350, and 400 ppm. The zero and span of the LI-COR IRGAs were measured nearly every day.

The water vapor sensor was calibrated against mixed air samples and referenced to data from a chilled mirror dewpoint hygrometer. Stability of the water vapor calibration was checked in the field by comparing the instrument sensitivity to the output of a Vaisala relative humidity sensor. The relative humidity sensor was new and calibrated by the manufacturer. The output of the Vaisala relative humidity sensor was also compared against that of a redundant dewpoint hygrometer. Both sensors yielded identical humidity measurements.

- Sonic anemometer: supplied by manufacturer. 1.0 m/s/V with sonic path length 0.15 m
- Carbon dioxide: about 30 mg/m^3/volt
- Water vapor density fluctuations: varies with vapor density. 2.0 g/m^3/volt at 6 °C and 3 g/m^3/volt at 14 °C
- Soil heat transducer: about 40 W/m^2/mv
- Net radiation: 12 W m^2/mv
- Quantum flux density: 180 *mol/m^2/s/mv
- Ozone: 28 ppb/volt

4.2.1.1 Tolerance

- Solar and net radiation: 1 W/m^2
- Air temperature fluctuations: 0.1 K
- Vertical wind velocity fluctuations: 0.01 m/s
- Surface radiative temperature: 0.1 K

4.2.2 Frequency of Calibration

The net radiometers were calibrated before and after the 1994 field campaign. The calibration coefficient did not change.

The flux sensors were calibrated two to three times a week. The zero and span of the LI-COR IRGA were measured nearly every day.

4.2.3 Other Calibration Information

None.

5. Data Acquisition Methods

The eddy correlation flux systems were digitized on the tower using the A/D converter of the ATI sonic anemometer. The A/D board was a 12-bit system. Digital signals for the three orthogonal wind velocity components, temperature, humidity, CO_2, and ozone were transmitted to a 386 computer in the field lab. In-house software (FLUX.EXE) displayed the data in real time on screen for scrutiny and computed fluctuations from means and 30-minute flux covariances. Campbell 21-X data loggers were used to sample environmental variables. These data loggers were connected to another 386 computer via a digital line and were interrogated every 30 minutes using Campbell Scientific software (TELCOM.EXE).

6. Observations

6.1 Data Notes

None available.

6.2 Field Notes

None available.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

All data were collected at the BOREAS SSA-OJP site. The North American Datum of 1983 (NAD83) coordinates of the site are latitude 53.91634° N, longitude 104.69203° W, and elevation of 579 m.

7.1.2 Spatial Coverage Map

Not applicable.

7.1.3 Spatial Resolution

The data represent point source measurements taken at the given location. The site was relatively level, and the forest stand was horizontally homogeneous throughout the area deemed as the flux footprint, a region extending over 1 km upwind.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

The data were collected nearly continuously from 23-May to 16-Sep-1994.

7.2.2 Temporal Coverage Map

All data were collected at the SSA-OJP site.

7.2.3 Temporal Resolution

Data are reported at a 30-minute average.

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
LATENT_HEAT_FLUX_ABV_CNPY
NET_RAD_ABV_CNPY
SOIL_HEAT_FLUX_1CM
CO2_FLUX_ABV_CNPY
CO2_CONC_ABV_CNPY
CO2_STORAGE
CO2_FLUX_ABV_PLUS_STORAGE
HEAT_STORAGE
DOWN_PPFD_ABV_CNPY
WIND_DIR_ABV_CNPY
WIND_SPEED_ABV_CNPY
FRICTION_VEL_ABV_CNPY
AIR_TEMP_ABV_CNPY
ABS_HUM_ABV_CNPY
SOIL_TEMP_2CM
SOIL_TEMP_4CM
SOIL_TEMP_8CM
SOIL_TEMP_16CM
SOIL_TEMP_32CM
BOLE_TEMP_1CM
WETNESS_SENSOR
OZONE_CONC
SENSIBLE_HEAT_FLUX_BELOW_CNPY
LATENT_HEAT_FLUX_BELOW_CNPY
NET_RAD_BELOW_CNPY
CO2_FLUX_BELOW_CNPY
CO2_FLUX_BELOW_PLUS_STORAGE
CO2_CONC_BELOW_CNPY
DOWN_PPFD_BELOW_CNPY
UP_PPFD_BELOW_CNPY
WIND_DIR_BELOW_CNPY
WIND_SPEED_BELOW_CNPY
FRICTION_VEL_BELOW_CNPY
AIR_TEMP_BELOW_CNPY
ABS_HUM_BELOW_CNPY
VAPOR_PRESS_DEFICIT_BELOW_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.
LATENT_HEAT_FLUX_ABV_CNPY	The latent heat flux measured above the canopy.
NET_RAD_ABV_CNPY	The net radiation measured above the canopy.
SOIL_HEAT_FLUX_1CM	The surface soil heat flux
CO2_FLUX_ABV_CNPY	The carbon dioxide flux measured above the canopy
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.
CO2_FLUX_ABV_PLUS_STORAGE	The sum of the above canopy carbon dioxide flux and the under flux instrument storage term.
HEAT_STORAGE	The canopy heat storage.
DOWN_PPFD_ABV_CNPY	The incoming 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_VEL_ABV_CNPY	The friction velocity above the canopy.
AIR_TEMP_ABV_CNPY	The air temperature measured above the canopy.
ABS_HUM_ABV_CNPY	The absolute humidity measured above the canopy.
SOIL_TEMP_2CM	Soil temperature at 2 cm depth.
SOIL_TEMP_4CM	Soil temperature at 4 cm depth.
SOIL_TEMP_8CM	The soil temperature recorded at 8 cm in depth.
SOIL_TEMP_16CM	The soil temperature recorded at 16 cm in depth.
SOIL_TEMP_32CM	The soil temperature recorded at 32 cm in depth.
BOLE_TEMP_1CM	The average bole temperature at 1 cm depth into tree bole.
WETNESS_SENSOR	The output of the wetness sensor, indicates if the instruments were wet or dry.
OZONE_CONC	The ozone concentration.
SENSIBLE_HEAT_FLUX_BELOW_CNPY	The sensible heat flux measured below the canopy
LATENT_HEAT_FLUX_BELOW_CNPY	The latent heat flux measured below the canopy.
NET_RAD_BELOW_CNPY	The net radiation measured below the canopy.
CO2_FLUX_BELOW_CNPY	The carbon dioxide flux measured below the canopy

CO2_FLUX_BELOW_PLUS_STORAGE	The sum of the below canopy carbon dioxide flux and the under flux instrument storage term.
CO2_CONC_BELOW_CNPY	The carbon dioxide concentration measured below the canopy.
DOWN_PPFD_BELOW_CNPY	The downward photosynthetic photon flux density measured under the canopy.
UP_PPFD_BELOW_CNPY	The upward (reflected) photosynthetic photon flux density measured under the canopy.
WIND_DIR_BELOW_CNPY	The wind direction measured below the canopy.
WIND_SPEED_BELOW_CNPY	The wind speed measured below the canopy.
FRICTION_VEL_BELOW_CNPY	The friction velocity below the canopy.
AIR_TEMP_BELOW_CNPY	The air temperature measured below the canopy.
ABS_HUM_BELOW_CNPY	The absolute humidity measured below the canopy.
VAPOR_PRESS_DEFICIT_BELOW_CNPY	The vapor pressure deficit measured below 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]
LATENT_HEAT_FLUX_ABV_CNPY	[Watts][meter^-2]
NET_RAD_ABV_CNPY	[Watts][meter^-2]
SOIL_HEAT_FLUX_1CM	[Watts][meter^-2]
CO2_FLUX_ABV_CNPY	[micromoles][meter^-2][second^-1]
CO2_CONC_ABV_CNPY	[parts per million]
CO2_STORAGE	[micromoles][meter^-2][second^-1]
CO2_FLUX_ABV_PLUS_STORAGE	[micromoles][meter^-2][second^-1]
HEAT_STORAGE	[Watts][meter^-2]
DOWN_PPFD_ABV_CNPY	[micromoles][meter^-2][second^-1]
WIND_DIR_ABV_CNPY	[degrees from North]
WIND_SPEED_ABV_CNPY	[meters][second^-1]
FRICTION_VEL_ABV_CNPY	[meters][seconds^-1]
AIR_TEMP_ABV_CNPY	[degrees Celsius]
ABS_HUM_ABV_CNPY	[grams][meter^-3]
SOIL_TEMP_2CM	[degrees Celsius]
SOIL_TEMP_4CM	[degrees Celsius]
SOIL_TEMP_8CM	[degrees Celsius]
SOIL_TEMP_16CM	[degrees Celsius]
SOIL_TEMP_32CM	[degrees Celsius]
BOLE_TEMP_1CM	[degrees Celsius]
WETNESS_SENSOR	[none]
OZONE_CONC	[ppb]

SENSIBLE_HEAT_FLUX_BELOW_CNPY	[Watts][meter^-2]
LATENT_HEAT_FLUX_BELOW_CNPY	[Watts][meter^-2]
NET_RAD_BELOW_CNPY	[Watts][meter^-2]
CO2_FLUX_BELOW_CNPY	[micromoles][meter^-2][seconds^-1]
CO2_FLUX_BELOW_PLUS_STORAGE	[micromoles][meter^-2][seconds^-1]
CO2_CONC_BELOW_CNPY	[parts per million]
DOWN_PPFD_BELOW_CNPY	[micromoles][meter^-2][second^-1]
UP_PPFD_BELOW_CNPY	[micromoles][meter^-2][seconds^-1]
WIND_DIR_BELOW_CNPY	[degrees from North]
WIND_SPEED_BELOW_CNPY	[meters][seconds^-1]
FRICTION_VEL_BELOW_CNPY	[meters][seconds^-1]
AIR_TEMP_BELOW_CNPY	[degrees Celsius]
ABS_HUM_BELOW_CNPY	[grams][meter^-3]
VAPOR_PRESS_DEFICIT_BELOW_CNPY	[kiloPascals]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

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

Column Name	Data Source
SITE_NAME	[Assigned by BORIS]
SUB_SITE	[Assigned by BORIS]
DATE_OBS	[Investigator]
TIME_OBS	[Investigator]
SENSIBLE_HEAT_FLUX_ABV_CNPY	[Sonic anemometer]
LATENT_HEAT_FLUX_ABV_CNPY	[Infrared Gas Analyzer]
NET_RAD_ABV_CNPY	[Net radiometer]
SOIL_HEAT_FLUX_1CM	[Soil heat transducer]
CO2_FLUX_ABV_CNPY	[Infrared Gas Analyzer]
CO2_CONC_ABV_CNPY	[Infrared Gas Analyzer]
CO2_STORAGE	[Infrared Gas Analyzer]
CO2_FLUX_ABV_PLUS_STORAGE	[Infrared Gas Analyzer]
HEAT_STORAGE	[Radiation thermometer]
DOWN_PPFD_ABV_CNPY	[Quantum sensor]
WIND_DIR_ABV_CNPY	[propeller wind speed/direction monitor]
WIND_SPEED_ABV_CNPY	[propeller wind speed/direction monitor]
FRICTION_VEL_ABV_CNPY	[Sonic anemometer]
AIR_TEMP_ABV_CNPY	[thermocouple]
ABS_HUM_ABV_CNPY	[Humidity sensor]
SOIL_TEMP_2CM	[thermocouple]
SOIL_TEMP_4CM	[thermocouple]
SOIL_TEMP_8CM	[thermocouple]
SOIL_TEMP_16CM	[thermocouple]
SOIL_TEMP_32CM	[thermocouple]
BOLE_TEMP_1CM	[thermocouple]
WETNESS_SENSOR	[Wetness sensor]
OZONE_CONC	[Ozone sensor]
SENSIBLE_HEAT_FLUX_BELOW_CNPY	[Sonic anemometer]
LATENT_HEAT_FLUX_BELOW_CNPY	[Infrared Gas Analyzer]
NET_RAD_BELOW_CNPY	[Net radiometer]
CO2_FLUX_BELOW_CNPY	[Infrared Gas Analyzer]
CO2_FLUX_BELOW_PLUS_STORAGE	[Infrared Gas Analyzer]

```
CO2_CONC_BELOW_CNPY            [Infrared Gas Analyzer]
DOWN_PPFD_BELOW_CNPY           [Quantum sensor]
UP_PPFD_BELOW_CNPY             [Quantum sensor]
WIND_DIR_BELOW_CNPY            [propeller wind speed/direction monitor]
WIND_SPEED_BELOW_CNPY          [propeller wind speed/direction monitor]
FRICTION_VEL_BELOW_CNPY        [Sonic anemometer]
AIR_TEMP_BELOW_CNPY            [thermocouple]
ABS_HUM_BELOW_CNPY             [Humidity sensor]
VAPOR_PRESS_DEFICIT_BELOW_CNPY [Humidity sensor]
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-OJP-FLXTR	SSA-OJP-FLXTR	None	None	None	None
SUB_SITE	9TF05-FLX01	9TF05-FLX01	None	None	None	None
DATE_OBS	23-MAY-94	16-SEP-94	None	None	None	None
TIME_OBS	0	2330	None	None	None	None
SENSIBLE_HEAT_FLUX_ABV_CNPY	-176.1	497.5	-999	None	None	Blank
LATENT_HEAT_FLUX_ABV_CNPY	-48.1	567.5	-999	None	None	Blank
NET_RAD_ABV_CNPY	-76.9	728	-999 -6999	None	None	Blank
SOIL_HEAT_FLUX_1CM	-44.1	97.6	None	None	None	Blank
CO2_FLUX_ABV_CNPY	-16.36	12.93	-999	None	None	Blank
CO2_CONC_ABV_CNPY	325	3027.3	None	None	None	Blank
CO2_STORAGE	-11.27	11.34	-999	None	None	Blank
CO2_FLUX_ABV_PLUS_STORAGE	-18.25	17.23	-999	None	None	Blank
HEAT_STORAGE	-323.3	410.1	-999	None	None	Blank
DOWN_PPFD_ABV_CNPY	-1	1947	-999	None	None	Blank
WIND_DIR_ABV_CNPY	0	360	None	None	None	Blank
WIND_SPEED_ABV_CNPY	.09	173.199	None	None	None	Blank
FRICTION_VEL_ABV_CNPY	0	22.627	-999	None	None	Blank
AIR_TEMP_ABV_CNPY	2.19	29.13	-999	None	None	Blank
ABS_HUM_ABV_CNPY	3.86	15.53	None	None	None	Blank
SOIL_TEMP_2CM	3.69	25.18	-999	None	None	Blank
SOIL_TEMP_4CM	4.14	22.75	-999	None	None	Blank
SOIL_TEMP_8CM	4.587	20.39	-999	None	None	Blank
SOIL_TEMP_16CM	3.59	18.19	-999	None	None	Blank
SOIL_TEMP_32CM	-3024	16.63	None	None	None	Blank
BOLE_TEMP_1CM	.36	34.97	None	None	None	Blank
WETNESS_SENSOR	DEW	PPT	None	None	None	Blank
OZONE_CONC	-29.08	35.41	-999	None	None	Blank
SENSIBLE_HEAT_FLUX_BELOW_CNPY	-7896.2	7918.5	None	None	None	Blank
LATENT_HEAT_FLUX_	-24.9	476.4	-999	None	None	Blank

BELOW_CNPY						
NET_RAD_BELOW_CNPY	-265.5	241.1	-999	None	None	Blank
CO2_FLUX_BELOW_CNPY	-15.93	13.61	-999	None	None	Blank
CO2_FLUX_BELOW_PLUS_ STORAGE	-17.86	14.09	-999	None	None	Blank
CO2_CONC_BELOW_CNPY	320	619	-999	None	None	Blank
DOWN_PPFD_BELOW_CNPY	-31	1548	-999	None	None	Blank
UP_PPFD_BELOW_CNPY	-13	346	-999	None	None	Blank
WIND_DIR_BELOW_CNPY	0	360	None	None	None	Blank
WIND_SPEED_BELOW_ CNPY	.009	173.199	None	None	None	Blank
FRICTION_VEL_BELOW_ CNPY	0	3.885	-999	None	None	Blank
AIR_TEMP_BELOW_CNPY	-2.5	31.44	-999	None	None	Blank
ABS_HUM_BELOW_CNPY	.22	15.01	None	None	None	Blank
VAPOR_PRESS_DEFICIT_ BELOW_CNPY	.5	4.59	-999	None	None	Blank
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	14-MAY-98	19-JUN-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,
LATENT_HEAT_FLUX_ABV_CNPY,NET_RAD_ABV_CNPY,SOIL_HEAT_FLUX_1CM,CO2_FLUX_ABV_CNPY,
CO2_CONC_ABV_CNPY,CO2_STORAGE,CO2_FLUX_ABV_PLUS_STORAGE,HEAT_STORAGE,
DOWN_PPFD_ABV_CNPY,WIND_DIR_ABV_CNPY,WIND_SPEED_ABV_CNPY,FRICTION_VEL_ABV_CNPY,
AIR_TEMP_ABV_CNPY,ABS_HUM_ABV_CNPY,SOIL_TEMP_2CM,SOIL_TEMP_4CM,SOIL_TEMP_8CM,
SOIL_TEMP_16CM,SOIL_TEMP_32CM,BOLE_TEMP_1CM,WETNESS_SENSOR,OZONE_CONC,
SENSIBLE_HEAT_FLUX_BELOW_CNPY,LATENT_HEAT_FLUX_BELOW_CNPY,NET_RAD_BELOW_CNPY,
CO2_FLUX_BELOW_CNPY,CO2_FLUX_BELOW_PLUS_STORAGE,CO2_CONC_BELOW_CNPY,
DOWN_PPFD_BELOW_CNPY,UP_PPFD_BELOW_CNPY,WIND_DIR_BELOW_CNPY,
WIND_SPEED_BELOW_CNPY,FRICTION_VEL_BELOW_CNPY,AIR_TEMP_BELOW_CNP
Y,ABS_HUM_BELOW_CNPY,VAPOR_PRESS_DEFICIT_BELOW_CNPY,CRTFCN_CODE,REVISION_DATE
'SSA-OJP-FLXTR','9TF05-FLX01',01-JUL-94,0,7.1,2.6,84.3,-17.3,3.05,360.7,-4.2,
-1.16,30.3,285.0,310.0,.99,.132,8.06,7.91,8.43,,,10.76,11.17,5.23,'DRY',3.92,
,,,,,,,,,,,,,,'CPI',12-JUN-98
'SSA-OJP-FLXTR','9TF05-FLX01',01-JUL-94,30,5.4,22.3,37.8,-12.6,2.3,348.3,-6.11,
-3.82,50.5,226.0,288.0,.72,.119,10.22,8.26,8.84,,,10.72,11.15,6.13,'DRY',4.06,
,,,,,,,,,,,,,,'CPI',12-JUN-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

9.1.1 Derivation Techniques and Algorithms

Sample computer code displaying processing methods:

Sensible Heat Flux

1) Test if flux covariances are significantly different from zero for 18000 samples

```
--Is wT non-zero?
```

```
IF TT > 0 THEN
SIGT = TT ^ .5
RWT = WT / (SIGW * SIGT)
ELSE
RWT = 0
END IF

IF ABS(RWT) < .0146 THEN WT = 0

--correct virtual temperature heat flux from sonic to actual heat flux.
--We apply the formula of Kaimal and Gaynor 1991. Bound. Layer Met.

--The Schotanus et al. 1983 BLM correction is not needed for the
--ATI sonic (-2 T u w'u'/c^2)
SPECIFIC_HUMIDITY = ABSOLUTE_HUMIDITY / (AIR_DENSITY * 1000)

--Heat capacity of air weight by the moist and dry air contributions
CP_AIR = 1010 * AIR_DENSITY + 4182 * ABSOLUTE_HUMIDITY
SIG = ABSOLUTE_HUMIDITY/(1000 * AIR_DENSITY)
SIGTOT = ABSOLUTE_HUMIDITY/1000 / (ABSOLUTE_HUMIDITY/1000 + AIR_DENSITY)
```

2) Correct the sonic derived sensible heat fluxes to the actual sensible heat flux.

```
--Note: WTCORR should be in the WE calculation, hence looping
--is needed between sensible and latent heat flux computations

WTGUESS = WT_SONIC
CCC = 0

NEWWE:
WTCORR = (WT_SONIC - .51 * TK * WQQ)      --K m/s

IF ABS(WTCORR - WTGUESS) > .00001 THEN
CCC = CCC + 1
IF CCC > 10 THEN GOTO OUTWE
WTGUESS = WTCORR
GOTO NEWWE
END IF

OUTWE:
SENSIBLE_HEAT_FLUX = WTCORR * CP_AIR      --W/m2
```

Water Vapor and Latent Heat Flux Densities

1) 'Is wq covariance non-zero?

```
IF WW > 0 THEN
SIGW = WW ^ .5
ELSE
SIGW = 9999
END IF

IF QQ > 0 THEN
SIGQ = QQ ^ .5
```

```
RWQ = WQ / (SIGW * SIGQ)
ELSE
RWQ = 0
END IF

IF ABS(RWQ) < .0146 THEN WQ = 0
WQX = WQ_COVARIANCE * H2OCAL          --g/m2/s
```

2) Compute latent heat flux by considering temperature variations in the latent heat of vaporization.

```
LFUSION = 334000
LATENT_HEAT = 3149000 - 2370 * TAIR_K
IF TK < 273 THEN LATENT_HEAT = LAMBDA + LFUSION
LAMBDA = LATENT_HEAT / 1000
```

3) Apply Webb et al density correction for E. Units are Ecorr ($g/m^2/s$)

```
ECORR = (1 + SIG * 1.6077) * (WQX + ABSOLUTE_HUMIDITY * WTGUESS / TK)
--factor of 1000 is needed to change ECORR from g/m3 to
--kg m-3, so units cancel when divided by rhoa
WQQ = ECORR * (1 - SPECIFIC_HUMIDITY) / (1000 * (AIR_DENSITY +
ABSOLUTE_HUMIDITY/1000))  --m/s
LATENT_HEAT_FLUX= LAMBDA * WQX      --(W/m2)
```

CO_2 Flux Densities

```
WC = WC_COVARIANCE * CO2CAL         --mg/m2/s
```

1) Apply Webb et al. corrections for CO_2 and latent heat fluxes

```
CO2CONC = CO2_DENSITY * 8.314 * TK / (PRESS_KPA * 44.01)
NU = CO2CONC* 44.01 / (28.96 * 1000000)
SIG = ABSOLUTE_HUMIDITY / (AIR_DENSITY * 1000)
SIGTOT = (ABSOLUTE_HUMIDITY / 1000) / (AIR_DENSITY + ABSOLUTE_HUMIDITY / 1000)
TERM1 = 1.6077 * NU * LATENT_HEAT_FLUX / LAMBDA
H=SENSIBLE_HEAT_FLUX
TERM2 = (1 + SIG * 1.6077) * RHOC * H / (TK * AIR_DENSITY * 1005)
FC_CORR = WC + TERM1 + TERM2
```

Canopy Heat Storage

Define canopy biomass and representative specific heat by weighting the water and cellulose contributions.

1) define volume of vegetation as the product of canopy height and its basal area.

```
JACK PINE: height= 13.5 m; basal area=22 m2/ha
```

2) heat transfer coefficient is volume x Cp/time for 30 minutes

```
CP=4.175 MJ/M3/C  for water
CP=2.500 MJ/M3/C  for cellulose
```

3) Computed canopy heat capacity using Gower's (TE-06) biomass data

a) bole contribution

```
PLANT_COEF = 19.9        --W/m2/C/s
CG1 = DELTA_BOLE_TEMPERATURE * PLANT_COEF
TBOLOLD = TBOL
```

b) heat storage in the air layer

```
DELTA_AIR_TEMPERATURE = TAVG - TOLD
```

c) branch and needle heat storage

```
CG1A = 3.9 * DELTAIR
CG2 = DELTAIR * 12.8   '20x1.15x1005/1800s
TOLD = TAVG
```

d) latent heat storage in air layer of canopy

```
DELTA_RHOV = RHOVAVG - RHOVOLD
CG3 = 27.1 * DELRHOV        --20x2442/1800
RHOVOLD = RHOVAVG
CANOPY_HEAT_STORAGE = CG1 + CG1A + CG2 + CG3
```

9.2 Data Processing Sequence

9.2.1 Processing Steps

Flux covariances were computed in the field by the data acquisition program. Back at home, calibrations were double- and triple-checked by comparing old and new calibrations and by comparing the mean response of the scalar flux sensors against independent meteorological instruments. Tests were made for energy balance closure to ensure that the data were of reliable quality. Programs were then run to delete periods when the sensors were offline, off range, being maintained, or unreliable because of rain or instrument malfunction.

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

Eddy fluctuations:

```
CO2_DENSITY = CO2PPM * AIR_DENSITY * 44 / 29     --mg m-3
```

9.3.2 Calculated Variables

None.

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

Factors contributing to instrument errors include time response of the sensor, signal-to-noise ratio, sensor separation distance, height of the measurement, and signal attenuation caused by path averaging and sampling through a tube. Natural variability is caused by nonsteady conditions and surface inhomogeneities. Under ideal conditions, natural variability exceeds about ±10%.

10.2 Quality Assessment

10.2.1 Data Validation by Source

Surface energy balance was tested by comparing measurements of available energy against the sum of latent and sensible heat flux. Tests over the jack pine stand showed that the eddy flux system closes the surface energy balance within 12% and that this degree of closure is comparable with the state-of-the-art demonstrated in the literature.

Several independent checks have been made on components of this data set. The Vaisala humidity sensor was compared against a dewpoint hygrometer, and the comparison was excellent. The output of the net radiometer was compared against measurements made on Tim Crawford's airplane (Airborne Fluxes and Meteorology (AFM)-01). There was no bias between the measurements, suggesting that the impact of the net radiometer seeing the tower structure was small.

10.2.2 Confidence Level/Accuracy Judgment

The following are the best estimates of accuracy for a single flux estimate:

Net radiation	± 4 to 7%
Soil heat flux	± 10%
Latent heat flux	± 15 to 20% or ±30 W m^2, whichever is larger
Sensible heat flux	± 15 to 20% or ±30 W m^2, whichever is larger

None of these estimates addresses the variability of flux estimates from site to site.

- Detection limit of CO_2 flux system: 0.01 mg/m^2/s
- The intermittence of turbulence limits the sampling error of turbulent fluxes to 10 to 20%. In addition, measurement errors must be accounted for. Fortunately, a large amount of statistical averaging reveals stable fluxes and small bias errors (< 12%) on the surface energy fluxes.

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

Flux data were collected during the growing season of 1994; no wintertime data were acquired.

11.2 Known Problems with the Data

Data have been rejected when:

- The voltages of the CO_2 and water vapor sensor were nearly or entirely off scale.
- The log book denoted problems with specific sensors.
- The gas analyzer was calibrated or when the instrument boom was moved.
- Flux runs were less than 15 minutes.
- The mean vertical velocity of the sonic anemometer exceeded 0.3 m/s (an indication of water on the transducer or continued spiking).
- Friction velocity exceeded 1.5 m/s.

Values during these periods have been assigned values of -999 (or -6999).

The third order screening of the data deleted data that were several standard deviations greater than the population means and were true spikes and outliers. The following data were deleted:

- LE fluxes greater than 350 W/m^2 and less than -50 W/m^2.
- CO_2 fluxes greater than 0.50 $mg/m^2/s$ and less than -0.75 $mg/m^2/s$.

Be careful when using data during WET periods, i.e. when the WETNESS_SENSOR has a value of WET. These periods have not been screened and are retained to complete the record. Problems may occur because the domes on the radiometers were wet and water films may be covering optics of the IRGA and the transducer of the sonic anemometer. When using these data to test models, it is recommended that data from wet periods not be included!

Be careful about using data when wind was blowing through the tower; these data have not been deleted from the record. Closure of the surface energy balance was diminished during these periods, and an upwind bias on the vertical wind velocity, caused by aerodynamic distortion from the tower, was noted. Wind directions to be cautious about are in the zone between 350 and 60 degrees. When using these data to test models, it is recommended that data from nonideal wind directions be omitted.

Mean CO_2 concentrations were assigned values of 350 when the sensor was out of range. Also be cautious about using the mean CO_2 concentrations. There were some zero and span drifting problems with the IRGA. Typical midday CO_2 concentration should be on the order of 330 and 350 ppm. Data exceeding 400 ppm would have bypassed data filters and would be spurious.

The mean CO_2 concentration calibrations have been double-checked and an attempt was made to compensate for drift from calibration to calibration. Sometimes the drift was small; other times it was between -10 and +10 ppm over a few days. At this point the relative change in CO_2 from hour to hour is OK. Use the absolute values with much skepticism and caution. These data should not be used to assess the seasonal change in CO_2 over the boreal region.

Periods when calibrating or moving boom, given as day number and ending time of the half-hour observation (Central Standard Time):

```
DOY Time
--- ----
143 1300
145 1130
150 1100
150 1300
151 0930
153 1030
154 0930
154 1630
```

```
155 1100
156 1130
161 0930
163 1030
164 0930
164 1030
164 0930
164 1000
179 1530
188 1300
189 1300
189 1330
from 200 1400 through 200 1500
201 1130
204 1230
210 1000
211 0930
215 1130
242 1500
242 1300
245 1400
from 247 1400 through 248 1000
253 1100
```

Periods when net radiometer and incident Photosynthetically Active Radiation (PAR) sensor were shaded by the tower, given as day number and ending time of the half-hour observation (Central Standard Time):

```
from 145 0800 through 145 0930
from 146 0800 through 146 0930
from 147 0800 through 147 0930
from 148 0800 through 148 0930
from 149 0800 through 149 0930
from 150 0800 through 150 0930
from 151 0800 through 151 0930
```

CO_2 Concentration Data:

The absolute quality of the LI-COR CO_2 data is uncertain. The instrument was new to the investigator and seemed to be unstable. Calibrations were conducted almost every day, but the zero and span seemed to drift. Some first-order corrections are being made to put the values in line with reality, but more work needs to be done. The quality of these data is especially called into question because the investigator is now using a brand new sensor in Oak Ridge and automatically zeroing and spanning the sensor every day, and has not seen the zero or span change for 3 months. Spurious CO_2 values may be real, however, if smoke from forest fires were a problem. Thus, there are some reservations about accepted elevated CO_2 values.

11.3 Usage Guidance

CAUTION should be exercised when using flux data for several hours surrounding dawn and dusk, since these are periods of unsteady conditions. In addition, nighttime data should be scrutinized.

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 jack pine 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 9.1.1.

14.2 Software Access

None given.

15. Data Access

The TF-05 SSA-OJP 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 Reports

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

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A/D     - Analog-to-Digital
AES     - Atmospheric Environment Service
AFM     - Airborne Fluxes and Meteorology
ASCII   - American Standard Code for Information Interchange
ATDD    - Atmospheric Turbulence and Diffusion Division
ATI     - Applied Technology, Inc.
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
CD-ROM  - Compact Disk-Read-Only Memory
DAAC    - Distributed Active Archive Center
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
GIS     - Geographic Information System
GMT     - Greenwich Mean Time
GSFC    - Goddard Space Flight Center
HTML    - HyperText Markup Language
IFC     - Intensive Field Campaign
IRGA    - Infrared Gas Analyzer
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NOAA    - National Oceanic and Atmospheric Administration
NSA     - Northern Study Area
OJP     - Old Jack Pine
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
PAR     - Photosynthetically Active Radiation
PPFD    - Photosynthetic Photon Flux Density
REBS    - Radiation Energy Balance Systems
SSA     - Southern Study Area
TE      - Terrestrial Ecology
TF      - Tower Flux
URL     - Uniform Resource Locator
WMO     - World Meteorological Organization
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The BOREAS TF-5 team collected tower flux data at the BOREAS SSA-OJP site through the growing season of 1994. The data are available in tabular ASCII files.

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