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

*Forrest G. Hall and David E. Knapp, Editors*

## Volume 7

## BOREAS AFM-04 Twin Otter Aircraft Sounding Data

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Greenbelt, Maryland 20771

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# BOREAS AFM-4 Twin Otter Aircraft Sounding Data

J. Ian MacPherson, Raymond L. Desjardins

## Summary

The BOREAS AFM-4 team used the NRC Twin Otter aircraft to make sounding measurements through the boundary layer. These measurements included concentrations of carbon dioxide and ozone, atmospheric pressure, dry bulb temperature, potential temperature, dewpoint temperature, calculated mixing ratio, and wind speed and direction. Aircraft position, heading, and altitude were also recorded. Data were collected at both the NSA and the SSA in 1994 and 1996. These data are stored in tabular ASCII files.

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## 1. Data Set Overview

### 1.1 Data Set Identification

BOREAS AFM-04 Twin Otter Aircraft Sounding Data

### 1.2 Data Set Introduction

The BOReal Ecosystem-Atmosphere Study (BOREAS) Airborne Fluxes and Meteorology (AFM)-04 team used the National Research Council (NRC) Twin Otter aircraft to make sounding measurements through the boundary layer. These measurements included concentrations of carbon dioxide and ozone, atmospheric pressure, dry bulb temperature, potential temperature, dewpoint temperature, calculated mixing ratio, and wind speed and direction. Aircraft position, heading, and altitude were also recorded. Data were collected at both the Northern Study Area (NSA) and Southern Study Area (SSA) in 1994 and 1996. These data are stored in tabular American Standard Code for Information Interchange (ASCII) files.

### 1.3 Objective/Purpose

The Twin Otter was one of four flux aircraft operated in BOREAS. The purpose of its sounding flights was to make measurements through the boundary layer to document the vertical structure of the atmosphere over the test area (MacPherson, 1996; MacPherson and Bastian, 1997). The mixed layer was of particular interest in this research.

### 1.4 Summary of Parameters

Atmospheric pressure, orthogonal components of the wind velocity, wind speed and direction, dry bulb temperature, potential temperature, dewpoint temperature, calculated mixing ratio, carbon dioxide concentration, ozone concentration, aircraft position, heading, altitude (radar and pressure).

### 1.5 Discussion

The Twin Otter operated in all three Intensive Field Campaigns (IFCs) in 1994 and in July and August 1996. The archived data were collected on sounding runs over the BOREAS site from near the surface to between 6,000 and 8,000 ft (2 and 2.5 km). The Twin Otter flew 51 sounding flights in 1994 and 26 flights in 1996.

### 1.6 Related Data Sets

BOREAS AFM-01 NOAA/ATDD Long-EZ 1994 Aircraft Flux Data over the SSA
BOREAS AFM-02 Wyoming King Air 1994 Aircraft Flux and Moving Window Data
BOREAS AFM-02 Wyoming King Air 1994 Aircraft Sounding Data
BOREAS AFM-03 NCAR Electra 1994 Aircraft Flux Data
BOREAS AFM-03 NCAR Electra 1994 Aircraft Moving Window Data
BOREAS AFM-03 NCAR Electra 1994 Aircraft Sounding Data
BOREAS AFM-04 NRC Twin Otter Aircraft Flux Data
BOREAS AFM-05 Level-1 Upper Air Network Data
BOREAS AFM-05 Level-2 Upper Air Network Standard Pressure Level Data
BOREAS AFM-11 Aircraft Flux Analysis and Comparison PDF Documents

## 2. Investigator(s)

### 2.1 Investigator(s) Name and Title

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### 2.2 Title of Investigation

Atmospheric Boundary Layer Analyses from Canadian Twin Otter Aircraft

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## 3. Theory of Measurements

A series of reports addressing the theory and practice of measuring atmospheric variables from a moving, aircraft platform may be found in MacPherson (1988, 1990a, 1990b, 1992, 1996), MacPherson and Morgan (1981), and MacPherson and Bastian (1997).

A basic requirement for measuring gas fluxes from a moving aircraft is to account for the motion of the air relative to the motion of the aircraft. The true air motion is derived from the vector difference between the air velocity relative to the aircraft velocity relative to the ground.

Air motion relative to the aircraft is measured by a nose-mounted gust boom incorporating a Rosemount 858AJ28 5-hole probe. This device and the associated pressure transducers measure static pressure (altitude), dynamic pressure (airspeed), and the angles of attack and sideslip. These instruments in combination with a global positioning system (GPS) and an inertial reference system (IRS) are used to derive the flux measurements.

# 4. Equipment

## 4.1 Sensor/Instrument Description

The Twin Otter atmospheric research aircraft is a highly instrumented platform for research on the atmospheric boundary layer, air pollution, etc. Descriptions of the aircraft and its instrumentation and software are given in detail in MacPherson (1988, 1990a, 1990b, 1996), MacPherson and Morgan (1981), and MacPherson and Bastian (1997).

The instruments used to make these measurements included:

| **Parameter** | **Instrument** |
|---|---|
| Sensible Heat | Rosemount fast response 102DJ1CG |
| Incident Solar Radiation | Kipp and Zonen CM-11 pyranometer (305-2800 nm range) |
| Reflected Solar Radiation | Eppley pyranometer |
| Greenness Index | Skye Industries Vegetation Greenness Indicator |
| Surface Temperature | Barnes PRT-5 infrared radiometer |
| Satellite Simulation | Exotech 100BX Satellite Simulator |
| $CO_2$, $H_2O$ | LI-COR LI-6262 $CO_2$/$H_2O$ analyzer (these $CO_2$ data reported to BORIS) |
| | ESRI (developed by Agriculture Canada) |
| Dew Point | E, G, and G Model 137-S10 Cambridge dew point sensor |
| Ozone | TECO Ozone Analyzer Model 49 (these $O_3$ data reported to BORIS) |
| | GFAS (unit borrowed from German Aerospace Research Establishment) |
| | Scintrex LOZ-3 ozone detector |
| Momentum | Wind Components |
| Inertial Velocity | Litton LTN-90-100 Inertial Reference System |
| Position | Trimble Model TNL-7880SR GPS/VLF/Omega |
| Altitude (AGL) | Sperry AA-200 Radio Altimeter (1994 and 1996) |
| | Riegl LD-90-3 Laser Altimeter (1996 only) |

### 4.1.1 Collection Environment

The data were collected from the aircraft, flying from near the surface to between 6,000 and 8,000 ft (2 and 2.5 km).

#### 4.1.2 Source/Platform

Twin Otter DHC-6-200 twin turboprop utility transport.

The maximum gross takeoff weight is 11,579 lb. The service ceiling is 20,000 ft. The endurance is 3 to 4 hours, depending on instrumentation and weather.

#### 4.1.3 Source/Platform Mission Objectives

The primary objective was to make measurements through the boundary layer to document the vertical structure of the atmosphere over the test area (MacPherson, 1996; MacPherson and Bastian, 1997). The mixed layer was of particular interest in this research.

#### 4.1.4 Key Variables

Atmospheric pressure, orthogonal components of the wind velocity, wind speed and direction, dry bulb temperature, potential temperature, dewpoint temperature, calculated mixing ratio, carbon dioxide concentration, ozone concentration, aircraft position, heading, altitude (radar and pressure).

#### 4.1.5 Principles of Operation

The principles of operation of the aircraft and its instrumentation and software are given in detail in MacPherson (1988, 1990a, 1990b, 1996), MacPherson and Morgan (1981), and MacPherson and Bastian (1997).

#### 4.1.6 Sensor/Instrument Measurement Geometry

See MacPherson (1988, 1990a, 1990b, 1996) and MacPherson and Bastian (1997).

#### 4.1.7 Manufacturer of Sensor/Instrument

See Sections 4.1 and 6, MacPherson (1996), and MacPherson and Bastian (1997).

### 4.2 Calibration

Instruments on the aircraft were calibrated prior to each IFC. Key instruments (such as temperature probes) were calibrated two or three times during each IFC.

#### 4.2.1 Specifications

Not available at this revision.

##### 4.2.1.1 Tolerance

Not available at this revision.

#### 4.2.2 Frequency of Calibration

All instruments were calibrated at least once per IFC.

#### 4.2.3 Other Calibration Information

See MacPherson (1988, 1990a, 1990b, 1996) and MacPherson and Bastian (1997).

## 5. Data Acquisition Methods

The data were collected from the aircraft, flying from near the surface to between 6,000 and 8,000 ft (2 and 2.5 km) in a spiral pattern.

# 6. Observations

## 6.1 Data Notes

The following is a table that describes how the data were recorded.

Note: 128 channels of data are recorded digitally in 16-bit words at 16 samples per second (1994) or 32 samples per second (1996) on a digital archive tape (DAT) drive. Signals are low-pass filtered with a breakpoint of 5 Hz to prevent aliasing.

The following table lists the 128 recorded signals. Not all of these are archived to BORIS (see Section 8), but many contribute to calculated quantities such as true airspeed (TAS), wind velocity, and fluxes.

**Note:*** This is basically the recorder buffer to be used in the BOREAS site visit in May 1993. Additional parameters were recorded in BOREAS (e.g., satellite simulator). A Trimble GPS replaced or augmented the Loran-C in 1994.

| Channel Number | Variable Name | Units | Resultion (per bit) | Instrument | Description |
|---|---|---|---|---|---|
| 1 | FILEHR | hrs | 1 | NAE Clock | combined word, tape file and GMT hours |
| 2 | MINSEC | min/sec | 1 | NAE Clock | combined word, GMT minutes/ seconds |
| 3 | EVENT | - | 1 | Event Marker | multi-level event marker |
| 4 | LTD | deg | 1 | ARNAV Loran-C | latitude degrees |
| 5 | LTM | min | 0.01 | Model 40-AVA-100 | latitude minutes |
| 6 | LGD | deg | 1 | Model 40-AVA-100 | longitude degrees |
| 7 | LGM | min | 0.01 | Model 40-AVA-100 | longitude minutes |
| 8 | LTML | min | 0.01 | Litton Inertial Ref System, LTN-90-100 | latitude minutes |
| 9 | LGML | min | 0.01 | Litton Inertial Ref System, LTN-90-100 | longitude minutes |
| 10 | HDGT | deg | 0.1 | Sperry C-12 Gyro | true heading (magnetic heading corrected to true heading using mag variation output from Loran-C) |
| 11 | HDGTL | dec | 0.1 | Litton 90 IRS | true heading, Litton |
| 12 | WDTI | deg | 0.1 | *Derived* | wind direction from doppler/ inertial system, degrees true (note 1) |

| Channel Number | Variable Name | Units | Resultion (per bit) | Instrument | Description |
|---|---|---|---|---|---|
| 13 | WDTL | deg | 0.1 | *Derived* | from Litton system (see note 2) |
| 14 | WSMI | m/s | 0.01 | *Derived* | wind speed from doppler inertial system (note 1) |
| 15 | WSML | m/s | 0.01 | *Derived* | from Litton system (see note 2) |
| 16 | UGE | m/s | 0.01 | *Derived* | north/south wind component from doppler /inertial system, + from north |
| 17 | VGE | m/s | 0.0 | *Derived* | east/west, + from east |
| 18 | WGE | m/s | 0.0 | *Derived* | vertical wind, + up |
| 19 | LWN | m/s | 0.0 | *Derived* | north/south wind component from Litton system, (note 2), + from north |
| 20 | LWE | m/s | 0.01 | *Derived* | east/west wind component, + from east |
| 21 | WEP | m/s | 0.01 | *Derived* | vertical wind component |
| 22 | TSNBC | deg C | 0.01 | *Derived* | static temperature, derived from TAS & total temp (see ch 48) nose starboard temperature probe |
| 23 | DEWPTC | deg C | 0.01 | Egg Model 137 | dew point |
| 24 | SDCTC | deg C | 0.01 | *Derived* | static temperature in $CO_2$ analyzer duct, derived from duct TAS & duct total temp; Rosemount 102 probe |
| 25 | PRT5C | deg C | 0.01 | Barnes PRT-5 | surface temperature |
| 26 | RADUP | $w/m^2$ | 0.1 | Kipp & Zonen CM-11 | upward facing radiometer, measures incident radiation (see also note 3) |
| 27 | RADOWN | $w/m^2$ | 0.1 | Eppley Pyranometer- 2 | downward facing radiometer, measures reflected radiation |
| 28 | CO2NO2 | $mg/m^3$ | 0.1 | Ag Canada ESRI $CO_2/H_2O$ Analyzer | carbon dioxide conc, 20 Hz response, low pass filtered at 5.5 Hz for anti-aliasing |
| 29 | H2O | $g/m^3$ | 0.01 | Ag Canada ESRI $CO_2/H_2O$ Analyzer | water vapor conc |

| Channel Number | Variable Name | Units | Resultion (per bit) | Instrument | Description |
|---|---|---|---|---|---|
| 30 | RALT | m | 0.1 | Sperry AA-200 Radio Altimeter | height above ground |
| 31 | TASFK | kts | 0.1 | *Derived* | true airspeed, fuselage probes |
| 32 | TASNBK | kts | 0.1 | *Derived* | true airspeed, noseboom probes |
| 33 | TASDCT | kts | 0.1 | *Derived* | true airspeed in $CO_2$/$H_2O$ analyzer duct |
| 34 | PSDUCT | mb | 0.1 | A.I.R. AIR-DB-2C | static pressure in duct |
| 35 | PSNBC | mb | 0.1 | Paroscientific 215L-AW-01 2 | static pressure, noseboom, corrected for position error |
| 36 | TSFC | deg C | 0.01 | *Derived* | static temperature, derived from tas and total temp measured by fuselage port rosemount probe (see channel 47) |
| 37 | GRNRAT | - | 0.001 | Skye Industries SKR-100 | greenness ratio, 730 nm signal/660 nm signal |
| 38 | VDTM | m/s | 0.1 | Decca Doppler Radar-72 | ground speed, total vector from doppler radar |
| 39 | GSL | kts | 0.1 | Litton 90 IRS | ground speed, total vector from Litton |
| 40 | LCCO2 | mv | 1.0 | LI-COR 6262 | $CO_2$ concentration, recorded as millivolts, converted to ppm |
| 41 | LCTSC | deg C | 0.01 | LI-COR 6262 | temperature in licor analyzer test cell |
| 42 | UGEIL | m/s | 0.01 | *Derived* | north/south wind component from doppler/Litton system, + from north |
| 43 | VGEIL | m/s | 0.01 | *Derived* | east/west, + from east |
| 44 | WGEIL | m/s | 0.01 | *Derived* | vertical wind, + up |
| 45 | LCH2O | mv | 1.0 | LI-COR 6262 | $H_2O$ concentration recored as millivolts, converted to ppt |
| 46 | WFIL | m/s | 0.01 | *Derived* | high-pass filtered vertical wind for eddy accumulation system |

| Channel Number | Variable Name | Units | Resultion (per bit) | Instrument | Description |
|---|---|---|---|---|---|
| 47 | TTF | deg K | 0.01 | Rosemount 102DJ1CG | total temperature, fast response, port fuselage probe |
| 48 | TTNB | deg K | 0.01 | Rosemount 102DJ1CG | total temperature, fast response, starboard fuselage probe |
| 49 | PSFC | mb | 0.1 | Rosemount 1201F1B4A1 B | static pressure, fuselage ports, corrected for position error. |
| 50 | METHAN | ppb | 1.0 | Unisearch TDL Methane Analyzer | methane concentration |
| 51 | -- | -- | -- | -- | not used |
| 52 | TECO | ppb | 0.1 | TECO-49 Ozone Analyzer | ozone concentration, slow response for mean concentrations |
| 53 | OZD | ppb | 0.1 | German GFAS OS-G-2 Ozone Analyzer | ozone concentration fast response (>10 Hz) |
| 54 | DOZD | ppb | 0.01 | German GFAS OS-G-2 Ozone Analyzer | hi-sensitivity ozone fluctuations from start of flux run |
| 55 | UCO2N2 | $mg/m^3$ | 0.1 | Ag Canada ESRI $CO_2/H_2O$ Analyzer | raw $CO_2$ unfiltered |
| 56 | UH20N2 | $g/m^3$ | 0.01 | Ag Canada ESRI $CO_2/H_2O$ Analyzer | raw $H_2O$ unfiltered |
| 57 | THETAL | deg | 0.01 | Litton-90 IRS | pitch attitude + nose up |
| 58 | PHIL | deg | 0.01 | Litton-90 IRS | roll attitude + right wing down |
| 59 | VXMLTN | m/s | 1/128 | Decca Doppler Radar-72 | along-heading component of ground speed, positive forward, corrected to position of Litton-90 IRS |
| 60 | VYMLTN | m/s | 1/256 | Decca Doppler Radar-72 | across-heading component of ground speed, positive starboard, corrected to position of Litton-90 IRS |
| 61 | VZMLTN | m/s | 1/512 | Decca Doppler Radar-72 | vertical component of aircraft velocity relative to ground, + down, corrected to position of Litton-90 IRS |

| Channel Number | Variable Name | Units | Resultion (per bit) | Instrument | Description |
|---|---|---|---|---|---|
| 62 | ULN | m/s | 0.01 | Litton-90 IRS | north/south inertial velocity, + to north. |
| 63 | VLE | m/s | 0.0 | Litton-90 IRS | east/west inertial velocity, + to east |
| 64 | WZL | m/s | 0.0 | Litton-90 IRS | vertical inertial velocity, + down |
| 65 | PDF | mb | 0.01 | Rosemount Transducer 1221F-2VL7 A1A | dynamic pressure, fuselage pitot uncorrected for p.e. |
| 66 | PDNB | mb | 0.01 | Rosemount Transducer 1221F-1V7A 1B | dynamic pressure, noseboom pitot uncorrected for p.e. |
| 67 | PSF | mb | 0.10 | Rosemount Transducer 1201F-1B4A 1B | static pressure, fuselage ports, uncorrected for p.e. |
| 68 | PSNBLR | mb | 0.10 | Paroscientific 215L-AW-01 2 | static pressure, noseboom, corrected to lab standard, uncorrected for p.e. |
| 69 | PD | mb | 0.01 | *Derived* | dynamic pressure used (PDNB or PDF) in real time software selected by function switch |
| 70 | PDFNB | mb | 0.01 | *Derived* | dynamic pressure from fuselage port corrected to noseboom position, used as PDNB backup |
| 71 | EACONT | bits | 1.0 | *Derived* | signal that controls eddy accumulation system,1000 when WFIL is up, -1000 when WFIL is down, zero in dead zone |
| 72 | TS | deg C | 0.01 | *Derived* (TSFC or TSNBC) | static temperature used in real time software, selected by function switch |
| 73 | GRN660 | - | 0.01 | Skye Industries SKR-100 | 660 nm signal from SKR-100 greenness device |
| 74 | GRN730 | - | 0.01 | Skye Industries SKR-100 | 730 nm signal from SKR-100 greenness device |
| 75 | TSPARO | deg F | 0.01 | Paroscientific 215L-AW-01 2 | transducer temperature used to correct static pressure signal |

| Channel Number | Variable Name | Units | Resultion (per bit) | Instrument | Description |
|---|---|---|---|---|---|
| 76 | WGAI | m/s | 0.01 | *Derived* | vertical wind, doppler system, a/c axes |
| 77 | LALT | ft | 1.0 | Litton 90/100 IRS | absolute height |
| 78 | PALT | ft | 1.0 | *Derived* | pressure height, uses PSNBC |
| 79 | LTDL | deg | 1.0 | Litton 90/100 IRS | Litton latitude, deg only |
| 80 | LTDL | deg | 1.0 | Litton 90/100 IRS | Litton longitude, deg only |
| 81 | PDFC | mb | 0.01 | Rosemount Transducer 1221F-2VL7 A1A | dynamic pressure, fuselage pitot corrected for p.e. |
| 82 | PDNBC | mb | 0.01 | Rosemount Transducer 1221F-1v7a1 b | dynamic pressure, noseboom pitot corrected for p.e. |
| 83 | VX | knots | 0.10 | Decca Doppler Radar-72 | ground speed, x component a/c axes, + forward |
| 84 | VY | knots | 0.10 | Decca Doppler Radar-72 | ground speed, y component a/c axes, + to starboard |
| 85 | VX | knots | 0.10 | Decca Doppler Radar-72 | ground speed, z component a/c axes, + down |
| 86 | THETA | deg | 0.01 | Kearfott Attitude Gyro, T2109 | attitude pitch, + nose up |
| 87 | PHI | deg | 0.01 | Kearfott Attitude Gyro, T2109 | attitude roll, + right wing down |
| 88 | AZL | $m/s^2$ | 0.01 | Litton 90/100 Irs | vertical acceleration, a/c axes,+ a/c down |
| 89 | EAZL | $m/s^2$ | 0.01 | Litton 90/100 IRS | vertical acceleration earth axes, +a/c down |
| 90 | UAIRN | m/s | 1/128 | *Derived* | north component of true airspeed (TAS) vector |
| 91 | VAIRE | m/s | 1/128 | *Derived* | east component of true airspeed (TAS) vector |

| Channel Number | Variable Name | Units | Resultion (per bit) | Instrument | Description |
|---|---|---|---|---|---|
| 92 | WAIRZ | m/s | 1/128 | *Derived* | vertical component of true airspeed (TAS) vector,+ a/c down |
| 93 | UAIR | m/s | 1/128 | *Derived* | x-axis TAS component |
| 94 | VAIR | m/s | 1/128 | *Derived* | y-axis TAS component |
| 95 | WAIR | m/s | 1/128 | *Derived* | z-axis TAS component |
| 96 | UANAE | m/s | 1/128 | *Derived* | x-axis TAS component, corrected to NAE accelerometer location |
| 97 | VANAE | m/s | 1/128 | *Derived* | y-axis TAS component, corrected to NAE accelerometer location |
| 98 | WANAE | m/s | 1/128 | *Derived* | z-axis TAS component, corrected to NAE accelerometer location |
| 99 | UALTN | m/s | 1/128 | *Derived* | x-axis TAS component, corrected to Litton IRS location |
| 100 | VALTN | m/s | 1/128 | *Derived* | y-axis TAS component, corrected to Litton IRS location |
| 101 | WALTN | m/s | 1/128 | *Derived* | z-axis TAS component, corrected to Litton IRS location |
| 102 | UMIX7 | m/s | 1/128 | *Derived* | x inertial velocity component from NAE/doppler system |
| 103 | VMIX7 | m/s | 1/128 | *Derived* | y inertial velocity component from NAE/doppler system |
| 104 | WMIX7 | m/s | 1/128 | *Derived* | z inertial velocity component from NAE/doppler system |
| 105 | PDDUCT | mb | 0.01 | Rosemount Transducer 12211F-2VL7 A1A | dynamic pressure in $CO_2$ measurement duct |
| 106 | ALPHA | deg | 0.01 | Rosemount 858AJ28 & Transducer 12211F-1VL5 A1 | angle of attack probe measured by 5 hole probe on noseboom |

| Channel Number | Variable Name | Units | Resultion (per bit) | Instrument | Description |
|---|---|---|---|---|---|
| 107 | BETA | deg | 0.01 | Rosemount 858AJ28 & Transducer 12211F-1VL5 A1 | angle of side-probe & slip measured by 5 hole probe on noseboom. |
| 108 | UDOTN | $m/s^2$ | 1/128 | *Derived* | derivative of x inertial velocity from NAE/doppler system |
| 109 | VDOTN | $m/s^2$ | 1/128 | *Derived* | derivative of y inertial velocity from NAE/doppler system |
| 110 | WDOTN | $m/s^2$ | 1/128 | *Derived* | derivative of z inertial velocity from NAE/doppler system |
| 111 | UGAI | m/s | 0.01 | *Derived* | longitudinal wind, doppler system, a/c axes |
| 112 | VGAI | m/s | 0.01 | *Derived* | lateral wind, doppler system, a/c axes |
| 113 | PALFNB | mb | 0.01 | Rosemount Transducer 12211F-1VL5 A1 R-858 | differential pressure angle of attack ports |
| 114 | UGAIL | m/s | 0.01 | *Derived* | longitudinal wind, Litton/doppler system, a/c axes |
| 115 | VGAIL | m/s | 0.01 | *Derived* | lateral wind, Litton/doppler system, a/c axes |
| 116 | WGAIL | m/s | 0.01 | *Derived* | vertical wind, Litton/doppler system, a/c axes |
| 117 | AXL | $m/s^2$ | 0.01 | Litton 90/100 IRS | longitudinal acceleration, a/c axes, + a/c fwd |
| 118 | AYL | $m/s^2$ | 0.01 | Litton 90/100 IRS | lateral acceleration, a/c axes, + a/c starboard |
| 119 | PBETNB | mb | 0.01 | Rosemount Transducer 12211F-1VL5A 1 R-858 | differential pressure angle of sideslip ports |
| 120 | AX | $m/s^2$ | 0.01 | Systron Donner 4211 | longitudinal acceleration, a/c axes, backup system |

| Channel Number | Variable Name | Units | Resultion (per bit) | Instrument | Description |
|---|---|---|---|---|---|
| 121 | AY | $m/s^2$ | 0.01 | Systron Donner 4211 | lateral acceleration, a/c axes |
| 122 | AX | $m/s^2$ | 0.01 | Systron Donner 4211 | vertical acceleration, a/c axes |
| 123 | PRATEL | deg/s | 0.01 | Litton 90/100 IRS | roll rate, + right wing down |
| 124 | QRATEL | deg/s | 0.01 | Litton 90/100 IRS | pitch rate, + nose up |
| 125 | RRATEL | deg/s | 0.01 | Litton 90/100 IRS | yaw rate, + nose right |
| 126 | PRATE | deg/s | 0.01 | Smiths Gyros 402-RGA | roll rate, + right wing down |
| 127 | QRATE | deg/s | 0.01 | Smiths Gyros 402-RGA | pitch rate, + nose up |
| 128 | RRATE | deg/s | 0.01 | Smiths Gyros 402-RGA | yaw rate, + nose right |

**NOTE 1:** This is the backup, or alternative, wind measuring system in case the Litton 90/100 inertial reference system (IRS) should fail. Calculation of wind components is described in reports by MacPherson (1988, 1990a, 1990b, 1996) and MacPherson and Bastian (1997). The air velocity relative to the aircraft is measured by the true air speed (TAS) and noseboom angles of attack and sideslip. The aircraft inertial velocity relative to Earth is measured in aircraft axes by a system incorporating complementary filtering in real time on the aircraft microprocessor. A system of accelerometers and rate gyros provides the high-frequency components to this filter; the Decca 3-axis Doppler radar provides the low-frequency components. The resulting calculated velocity components in a/c axes are subtracted from the TAS components to get the three components of winds in a/c axes. These are then resolved into Earth axes using the pitch and roll attitude and the aircraft heading to get uge, vge, and wge (channels 16-18).

**NOTE 2:** The primary wind system uses a Litton 90/100 IRS to measure the aircraft inertial velocity components in 3 Earth axes. The IRS is similar to an INS (Inertial Navigation System), but measures the velocities, accelerations and rates in aircraft axes as well as Earth axes. This is also used to derive wind given in channels 11, 13, 15, 19, 20, 21, 42, 43, and 44 above. Numerous tests have been done to compare flux data derived with these two different wind measuring systems on the Twin Otter. Some of this appears in MacPherson (1990a, 1996). These studies reveal that fluxes derived with the older Doppler-based system appear to be underestimated by 10-15 percent. The Litton based wind should be used whenever possible (channels 19, 20, 21, 13, and 15).

## 6.2 Field Notes

None.

# 7. Data Description

## 7.1 Spatial Characteristics

### 7.1.1 Spatial Coverage

The sounding flights were made centered over a specific point, flying in a spiral pattern, ascending in altitude. The North American Datum of 1983 (NAD83) coordinates for the start and end points for each sounding flight were as follows:

| | | Start | | End | |
|---|---|---|---|---|---|
| **IFC #** | **Date** | **Latitude** | **Longitude** | **Latitude** | **Longitude** |
| IFC-1: | 25-May-1994 | 53.51883N | 105.48317W | 53.59817N | 105.25850W |
| | | 53.58183N | 106.27834W | 53.49650N | 106.10700W |
| | 26-May-1994 | 53.51467N | 105.48350W | 53.62700N | 105.10416W |
| | | 53.78517N | 104.82267W | 53.67783N | 105.06850W |
| | 29-May-1994 | 53.51900N | 105.48317W | 53.65617N | 105.38084W |
| | 01-Jun-1994 | 53.60417N | 106.29400W | 53.51883N | 106.13850W |
| | 04-Jun-1994 | 53.62283N | 105.20500W | 53.76150N | 104.87217W |
| | | 53.63650N | 106.20467W | 53.52950N | 106.06033W |
| | 07-Jun-1994 | 55.80250N | 98.38917W | 55.84517N | 98.47000W |
| | 08-Jun-1994 | 55.79000N | 98.41100W | 55.88383N | 98.82283W |
| | | 55.94933N | 98.39883W | 55.89467N | 98.14183W |
| | 09-Jun-1994 | 55.84883N | 98.41950W | 55.80550N | 98.03200W |
| | 10-Jun-1994 | 55.79583N | 98.41783W | 55.77517N | 98.56100W |
| | 11-Jun-1994 | 55.79817N | 97.87016W | 55.83650N | 98.09634W |
| | | 55.87500N | 98.37517W | 55.84083N | 98.32350W |
| | 13-Jun-1994 | 55.95250N | 98.39600W | 55.93683N | 98.24050W |
| | | 55.82833N | 98.32750W | 55.83117N | 98.45900W |
| IFC-2: | 20-Jul-1994 | 53.52433N | 105.48083W | 53.59583N | 105.28967W |
| | 21-Jul-1994 | 53.53117N | 105.47667W | 53.62850N | 105.22800W |
| | | 53.52850N | 105.47933W | 53.71933N | 105.32267W |
| | 22-Jul-1994 | 53.63283N | 106.18916W | 53.54867N | 105.91483W |

| | | | | | |
|---|---|---|---|---|---|
| | 24-Jul-1994 | 53.52850N | 105.47816W | 53.62033N | 105.23367W |
| | | 53.52417N | 105.48217W | 53.69150N | 105.42416W |
| | 25-Jul-1994 | 53.52567N | 105.48100W | 53.61467N | 105.17733W |
| | | 53.39400N | 105.99416W | 53.53667N | 106.30717W |
| | 26-Jul-1994 | 53.52800N | 105.48083W | 53.63300N | 105.19083W |
| | 27-Jul-1994 | 53.52400N | 105.48383W | 53.54600N | 105.75816W |
| | 28-Jul-1994 | 55.93433N | 98.43684W | 55.86283N | 98.08283W |
| | 29-Jul-1994 | 55.80000N | 97.86333W | 55.85450N | 98.20634W |
| | 01-Aug-1994 | 55.78867N | 98.41367W | 55.94533N | 98.94550W |
| | 02-Aug-1994 | 55.91933N | 98.67316W | 55.79033N | 98.27766W |
| | 04-Aug-1994 | 55.79433N | 98.39983W | 55.81483N | 98.34267W |
| | 08-Aug-1994 | 55.90267N | 98.31233W | 55.92767N | 98.24866W |
| IFC-3: | 31-Aug-1994 | 55.81317N | 98.37100W | 55.77517N | 98.50450W |
| | 02-Sep-1994 | 55.79716N | 97.87117W | 55.86967N | 98.35633W |
| | 08-Sep-1994 | 55.92333N | 98.66634W | 55.92883N | 98.41517W |
| | | 53.64500N | 106.15800W | 53.64333N | 105.81067W |
| | 11-Sep-1994 | 53.51900N | 105.48233W | 53.70433N | 105.34650W |
| | | 53.49117N | 106.00517W | 53.53767N | 106.28000W |
| | 13-Sep-1994 | 53.51733N | 105.48183W | 53.66017N | 105.24450W |
| | 14-Sep-1994 | 53.52167N | 105.48050W | 53.74967N | 105.38450W |
| | | 53.93367N | 105.35000W | 53.90200N | 105.37634W |
| | 15-Sep-1994 | 53.33067N | 105.81433W | 53.44700N | 105.97350W |
| | | 53.49133N | 105.45050W | 53.71200N | 105.31883W |
| | 16-Sep-1994 | 53.52000N | 105.48067W | 53.65750N | 105.01950W |
| | 17-Sep-1994 | 53.36100N | 105.93784W | 53.59817N | 106.34866W |
| | 18-Sep-1994 | 53.41450N | 106.07133W | 53.56283N | 106.41734W |
| | | 54.95267N | 101.96133W | 55.88883N | 97.99500W |
| | | 55.88883N | 97.99500W | 55.92300N | 97.92367W |

| | | | | | |
|---|---|---|---|---|---|
| | 19-Sep-1994 | 55.79833N | 98.08283W | 55.80353N | 98.32050W |
| | | 55.89717N | 98.27634W | 55.87133N | 98.02666W |
| | | | | | |
| **1996:** | 09-Jul-1996 | 53.68847N | 105.48505W | 53.77241N | 105.10998W |
| | | 53.78666N | 104.81798W | 53.75954N | 105.10448W |
| | | 53.42411N | 105.93343W | 53.62444N | 106.19762W |
| | 10-Jul-1996 | 53.68332N | 105.48402W | 53.94030N | 105.21469W |
| | 11-Jul-1996 | 53.96244N | 104.92509W | 53.83380N | 105.21297W |
| | 12-Jul-1996 | 53.68967N | 105.48196W | 53.83541N | 105.29588W |
| | 14-Jul-1996 | 53.68813N | 105.47733W | 53.77911N | 105.26052W |
| | | 53.78923N | 105.28061W | 53.84983N | 105.32730W |
| | 19-Jul-1996 | 53.45467N | 105.96296W | 53.54633N | 106.19831W |
| | 20-Jul-1996 | 53.93017N | 105.14603W | 53.99265N | 105.14139W |
| | | 53.89687N | 105.28954W | 53.85172N | 105.36043W |
| | | 53.85841N | 105.40403W | 53.77928N | 105.37331W |
| | | 53.64933N | 105.16645W | 53.76005N | 104.90450W |
| | 26-Jul-1996 | 53.58015N | 106.29976W | 53.54736N | 106.18561W |
| | 27-Jul-1996 | 53.91438N | 104.97076W | 53.89841N | 104.92166W |
| | 29-Jul-1996 | 53.52213N | 105.48334W | 53.62976N | 105.22104W |
| | | 53.78666N | 104.82622W | 53.72709N | 104.98947W |
| | | 53.48213N | 105.91318W | 53.65328N | 106.13737W |
| | 30-Jul-1996 | 53.46806N | 106.13874W | 53.56144N | 106.39194W |
| | | 54.95413N | 101.96686W | 54.87190N | 101.89870W |
| | | 55.87458N | 98.37261W | 55.88642N | 98.19408W |
| | 31-Jul-1996 | 55.80608N | 98.11426W | 55.78463N | 98.33227W |
| | | 55.87921N | 98.62667W | 55.87870N | 98.26447W |
| | | 55.77793N | 98.41999W | 55.80059N | 98.19494W |

| | | | | | |
|---|---|---|---|---|---|
| | 02-Aug-1996 | 55.79424N | 97.88835W | 55.80025N | 98.15804W |
| | | 55.90101N | 98.30532W | 55.88951N | 98.23975W |
| | 03-Aug-1996 | 55.87440N | 98.24009W | 55.79716N | 98.45861W |
| | 05-Aug-1996 | 55.79630N | 97.87411W | 55.89071N | 98.19528W |
| | | 55.99354N | 98.50307W | 55.94582N | 98.59818W |
| | | 55.91887N | 98.63697W | 55.85175N | 98.41106W |
| | 07-Aug-1996 | 55.79613N | 97.87239W | 55.81535N | 98.11391W |
| | | 55.82874N | 98.32780W | 55.85604N | 98.20215W |
| | 08-Aug-1996 | 55.87492N | 98.37106W | 55.92693N | 98.20438W |

### 7.1.2 Spatial Coverage Map
None.

### 7.1.3 Spatial Resolution
The spatial resolution of the original data used in the flux computations is a function of the aircraft speed (approximately 55 m/s), the digital recording rate (16 Hz in 1994, 32 Hz in 1996), and the anti-alias filtering applied to the data prior to recording (5.5 Hz). This translates to a basic sampling resolution of approximately 12 m (1994) and 6 m (1996) for the Twin Otter.

### 7.1.4 Projection
These data were collected at point locations.

### 7.1.5 Grid Description
None.

## 7.2 Temporal Characteristics

### 7.2.1 Temporal Coverage
Sounding data were collected from 25-May-1994 to 19-Sep-1994 and 09-Jul-1996 to 08-Aug-1996.

### 7.2.2 Temporal Coverage Map

| | |
|---|---|
| IFC-1: | 25-May-1994 to 26-May-1994 |
| | 29-May-1994 |
| | 01-Jun-1994 |
| | 04-Jun-1994 |
| | 07-Jun-1994 to 11-Jun-1994 |

| | |
|---|---|
| | 13-Jun-1994 |
| IFC-2: | 20-Jul-1994 to 22-Jul-1994 |
| | 24-Jul-1994 to 29-Jul-1994 |
| | 01-Aug-1994 to 02-Aug-1994 |
| | 04-Aug-1994 |
| | 08-Aug-1994 |
| IFC-3: | 31-Aug-1994 |
| | 02-Sep-1994 |
| | 08-Sep-1994 |
| | 11-Sep-1994 to 19-Sep-1994 |
| 1996: | 09-Jul-1996 to 12-Jul-1996 |
| | 14-Jul-1996 |
| | 19-Jul-1996 to 20-Jul-1996 |
| | 26-Jul-1996 to 27-Jul-1996 |
| | 29-Jul-1996 to 31-Jul-1996 |
| | 02-Aug-1996 to 03-Aug-1996 |
| | 05-Aug-1996 |
| | 07-Aug-1996 to 08-Aug-1996 |

### 7.2.3 Temporal Resolution

The aircraft data were recorded at a basic rate of 16 Hz in 1994 and 32 Hz in 1996. Flight durations were typically 3 to 3.5 hours. On several occasions there were two flights per day.

## 7.3 Data Characteristics

### 7.3.1 Parameter/Variable

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

```
         Column Name
------------------------------
SPATIAL_COVERAGE
DATE_OBS
TIME
FLUX_MISSION_DESIGNATOR
LATITUDE
LONGITUDE
```

BOREAS_X
BOREAS_Y
PRESS_ALT
RADAR_ALT
HEADING
WIND_DIR
WIND_SPEED
U_COMPNT_WIND_VELOC
V_COMPNT_WIND_VELOC
ATMOSPHERIC_PRESS
DRY_BULB_TEMP
POTENT_TEMP
DEWPOINT_TEMP
MIXING_RATIO_AFM
CO2_CONC
O3_CONC
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 |
|---|---|
| SPATIAL_COVERAGE | The general term used to denote the spatial area over which the data were collected. |
| DATE_OBS | The date on which the data were collected. |
| TIME | The Greenwich Mean Time (GMT) when the data were collected. |
| FLUX_MISSION_DESIGNATOR | The two-letter mission identifier used to identify the type of mission being flown, where GS or GN=grids and stacks, CS=Candle Lake runs, TS or TN=site-specific runs, RT=transects, LS or LN=mini- or meso-transects, PS or PN=Budget Box pattern, HS or HN=stacks and tees, FS or FN=flights of two for intercomparison, ZS=low-level routes, and XX=not standard. |
| LATITUDE | The NAD83-based latitude coordinate at the site. |
| LONGITUDE | The NAD83-based longitude coordinate at the site. |
| BOREAS_X | The x component of the BOREAS grid coordinate at the site. |
| BOREAS_Y | The y component of the BOREAS grid coordinate at the site. |
| PRESS_ALT | The measured pressure altitude. |
| RADAR_ALT | The measured radar altitude. |
| HEADING | The aircraft heading. |
| WIND_DIR | The direction from which the wind was traveling, increasing in a clockwise direction from north. |
| WIND_SPEED | The wind speed. |
| U_COMPNT_WIND_VELOC | The westerly (from the west) vector component of the wind speed and wind direction. |
| V_COMPNT_WIND_VELOC | The southerly (from the south) vector component of the wind speed and wind direction. |

| | |
|---|---|
| ATMOSPHERIC_PRESS | The atmospheric pressure. |
| DRY_BULB_TEMP | The temperature measured from the dry-bulb thermometer. |
| POTENT_TEMP | The computed potential temperature. |
| DEWPOINT_TEMP | The measured dewpoint temperature. |
| MIXING_RATIO_AFM | The calculated mixing ratio. |
| CO2_CONC | CO2 concentration. |
| O3_CONC | The measured ozone concentration. |
| 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 |
|---|---|
| SPATIAL_COVERAGE | [none] |
| DATE_OBS | [DD-MON-YY] |
| TIME | [HHMMSS GMT] |
| FLUX_MISSION_DESIGNATOR | [none] |
| LATITUDE | [degrees] |
| LONGITUDE | [degrees] |
| BOREAS_X | [kilometers] |
| BOREAS_Y | [kilometers] |
| PRESS_ALT | [meters] |
| RADAR_ALT | [meters] |
| HEADING | [degrees] |
| WIND_DIR | [degrees] |
| WIND_SPEED | [meters][second^-1] |
| U_COMPNT_WIND_VELOC | [meters][second^-1] |
| V_COMPNT_WIND_VELOC | [meters][second^-1] |
| ATMOSPHERIC_PRESS | [kiloPascals] |
| DRY_BULB_TEMP | [degrees Celsius] |
| POTENT_TEMP | [degrees Kelvin] |
| DEWPOINT_TEMP | [degrees Celsius] |
| MIXING_RATIO_AFM | [grams of water vapor][kilogram dry air^-1] |
| CO2_CONC | [parts per million] |
| O3_CONC | [parts per billion] |
| CRTFCN_CODE | [none] |
| REVISION_DATE | [DD-MON-YY] |

### 7.3.4 Data Source

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

| Column Name | Data Source |
|---|---|
| SPATIAL_COVERAGE | [Assigned by BORIS.] |
| DATE_OBS | [Supplied by AFM-04.] |
| TIME | [Supplied by AFM-04.] |
| FLUX_MISSION_DESIGNATOR | [Supplied by AFM-04.] |
| LATITUDE | [Supplied by AFM-04.] |
| LONGITUDE | [Supplied by AFM-04.] |
| BOREAS_X | [Supplied by AFM-04.] |
| BOREAS_Y | [Supplied by AFM-04.] |
| PRESS_ALT | [Supplied by AFM-04.] |
| RADAR_ALT | [Supplied by AFM-04.] |
| HEADING | [Supplied by AFM-04.] |
| WIND_DIR | [Supplied by AFM-04.] |
| WIND_SPEED | [Supplied by AFM-04.] |
| U_COMPNT_WIND_VELOC | [Supplied by AFM-04.] |
| V_COMPNT_WIND_VELOC | [Supplied by AFM-04.] |
| ATMOSPHERIC_PRESS | [Supplied by AFM-04.] |
| DRY_BULB_TEMP | [Supplied by AFM-04.] |
| POTENT_TEMP | [Supplied by AFM-04.] |
| DEWPOINT_TEMP | [Supplied by AFM-04.] |
| MIXING_RATIO_AFM | [Supplied by AFM-04.] |
| CO2_CONC | [Supplied by AFM-04.] |
| O3_CONC | [Supplied by AFM-04.] |
| 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 |
|---|---|---|---|---|---|---|
| SPATIAL_COVERAGE | N/A | N/A | None | None | None | None |
| DATE_OBS | 25-MAY-94 | 08-AUG-96 | None | None | None | None |
| TIME | 104003 | 221750 | None | None | None | None |
| FLUX_MISSION_ DESIGNATOR | SN | SN | None | None | None | None |
| LATITUDE | 53.214 | 56.0225 | None | None | None | None |
| LONGITUDE | -106.4173 | -97.86333 | -999 | None | None | None |
| BOREAS_X | 303.205 | 817.865 | -999 | None | None | None |
| BOREAS_Y | 261.727 | 630.012 | -999 | None | None | None |
| PRESS_ALT | 224.7 | 2733.8 | None | None | None | None |
| RADAR_ALT | 3.9 | 920 | -999 | None | None | None |
| HEADING | .1 | 360 | None | None | None | None |
| WIND_DIR | 0 | 360 | None | None | None | None |
| WIND_SPEED | 0 | 23.5 | None | None | None | None |
| U_COMPNT_WIND_VELOC | -9.46 | 17.18 | None | None | None | None |
| V_COMPNT_WIND_VELOC | -18.05 | 19.82 | None | None | None | None |

| | | | | | | |
|---|---|---|---|---|---|---|
| ATMOSPHERIC_PRESS | 72.68 | 99.41 | None | None | None | None |
| DRY_BULB_TEMP | -4.24 | 27.85 | None | None | None | None |
| POTENT_TEMP | 284.97 | 308.91 | None | None | None | None |
| DEWPOINT_TEMP | -25.7 | 16 | None | None | None | None |
| MIXING_RATIO_AFM | .19 | 13.04 | None | None | None | None |
| CO2_CONC | 342.3 | 427.1 | None | None | None | None |
| O3_CONC | -6.24 | 196.63 | None | None | None | None |
| CRTFCN_CODE | CPI | CPI | None | None | None | None |
| REVISION_DATE | 12-AUG-96 | 02-MAR-99 | 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.

```
SPATIAL_COVERAGE,DATE_OBS,TIME,FLUX_MISSION_DESIGNATOR,LATITUDE,LONGITUDE,
BOREAS_X,BOREAS_Y,PRESS_ALT,RADAR_ALT,HEADING,WIND_DIR,WIND_SPEED,
U_COMPNT_WIND_VELOC,V_COMPNT_WIND_VELOC,ATMOSPHERIC_PRESS,DRY_BULB_TEMP,
POTENT_TEMP,DEWPOINT_TEMP,MIXING_RATIO_AFM,CO2_CONC,O3_CONC,CRTFCN_CODE,
REVISION_DATE
'SSA',25-MAY-94,161831,'SN',53.51883,-105.4832,365.277,294.68,573.4,83.9,6.4,316,
.9,.59,-.63,95.18,15.82,293.09,3.6,5.45,366.3,33.09,'CPI',12-AUG-96
'SSA',25-MAY-94,161832,'SN',53.51983,-105.4832,365.268,294.791,579.1,88.3,8.3,
311,1.3,.95,-.82,95.12,15.8,293.12,3.6,5.45,366.3,33.08,'CPI',12-AUG-96
'SSA',25-MAY-94,161833,'SN',53.52017,-105.4823,365.324,294.833,583.1,93.5,10.6,
295,1.6,1.47,-.69,95.07,15.74,293.1,3.6,5.48,366.3,33.08,'CPI',12-AUG-96
```

# 8. Data Organization

## 8.1 Data Granularity

The smallest orderable data set available is one file of flux runs during a day for a given study area.

## 8.2 Data Format(s)

The Compact Disk-Read-Only Memory (CD-ROM) files contain 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

See MacPherson (1990b).

### 9.1.1 Derivation Techniques and Algorithms

See MacPherson (1990b).

## 9.2 Data Processing Sequence

### 9.2.1 Processing Steps

- AFM-04 processed the data and sent them to BORIS.
- BORIS staff received the data, made necessary conversions to standard units, and loaded the data into the data base.
- BORIS staff documented the data set and compiled basic statistics about the data.

See MacPherson (1988, 1990a, 1990b, 1996) and MacPherson and Bastian (1997) for more detailed information about the processing that AFM-04 did to the data before submitting them to BORIS.

### 9.2.2 Processing Changes

There are quite a number of selectable options in the playback program for the Twin Otter data. These include the option to use the alternative (backup) wind computations if there should be a problem with the Litton 90/100 IRS.

## 9.3 Calculations

### 9.3.1 Special Corrections/Adjustments

Calculation of wind components is described in MacPherson (1990b) and MacPherson and Morgan (1981). The air velocity relative to the aircraft is measured by the true airspeed (TAS) and noseboom angles of attack and sideslip. The TAS vector is then resolved into Earth axes (north, east, and vertical components). From these are subtracted the aircraft inertial velocity components measured by a Litton 90/100 IRS, to get the three components of the wind velocity in Earth-fixed axes.

An alternative, or backup, wind system is employed on the Twin Otter in case the Litton 90 is unserviceable (rare). For this system, known as the NAE/DOP winds, the aircraft inertial velocity relative to the Earth is measured in aircraft axes by a system incorporating complementary filtering in real time on the aircraft microprocessor. A system of accelerometers and rate gyros provides the high-frequency components to this filter; the Decca 3-Axis Doppler radar provides the low-frequency components. The resulting calculated velocity components in A/C axes are subtracted from the TAS

components to get the three components of wind in A/C axes. These are then resolved into Earth axes using the pitch, roll, attitude, and heading.

### 9.3.2 Calculated Variables

None given.

### 9.4 Graphs and Plots

None.

## 10. Errors

### 10.1 Sources of Error

Errors can result from a number of different sources. The flux measurements are subject to possible errors relating to the measurements from the IRS.

A problem was detected with the ESRI $CO_2$ analyzer. Possible reasons for this problem are listed in MacPherson (1996). As a result of this problem with the ESRI, data from the LI-COR were reported for the $CO_2$ and $H_2O$ fluxes.

### 10.2 Quality Assessment

### 10.2.1 Data Validation by Source

Great care has been taken in the collection and analysis of the Twin Otter data. The wind measuring system is continually monitored for accuracy using techniques such as wind boxes, control input cases, and intercomparisons with other aircraft (Dobosy et al., 1997). Cospectral plots have been used to check the flux contributions at all wavelengths to ensure that they were not contaminated by inadequate compensation for aircraft motion.

Aircraft data were compared at various BOREAS workshops. This led to the decision to include all three sets of fluxes (i.e., from raw, detrended, and high-pass filtered time histories) in the data base.

### 10.2.2 Confidence Level/Accuracy Judgment

See Section 10.2.1.

### 10.2.3 Measurement Error for Parameters

Not available at this revision.

### 10.2.4 Additional Quality Assessments

See Dobosy et al. (1997).

### 10.2.5 Data Verification by Data Center

Data were examined for general consistency and clarity.

## 11. Notes

### 11.1 Limitations of the Data

None given.

### 11.2 Known Problems with the Data

None given.

### 11.3 Usage Guidance

None.

### 11.4 Other Relevant Information

None.

## 12. Application of the Data Set

These data can be used to obtain study area and regional scale estimates of the various fluxes.

## 13. Future Modifications and Plans

None given.

## 14. Software

### 14.1 Software Description

None given.

### 14.2 Software Access

None given.

## 15. Data Access

The Twin Otter aircraft sounding data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributd 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/ [Internet Link].

### 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

Not applicable.

## 16.2 Film Products

Not applicable.

## 16.3 Other Products

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

# 17. References

## 17.1 Platform/Sensor/Instrument/Data Processing Documentation

The Twin Otter Atmospheric Research Aircraft and its instrumentation have been described in the following reports available from the NRC:

MacPherson, J.I. 1988. NAE Twin Otter Operations in FIFE. National Research Council Canada Report LTR-FR-104.

MacPherson, J.I. 1989. NAE Twin Otter Operations in the 1988 Eulerian Model Evaluation Field Study. National Research Council Canada Report LTR-FR-107.

MacPherson, J.I. 1990a. NAE Twin Otter Operations in FIFE 1989. National Research Council Report LTR-FR-113.

MacPherson, J.I. 1990b. Wind and Flux Calculations on the NAE Twin Otter. NAE Laboratory Technical Report LTR-FR-109. National Research Council. January 1990.

MacPherson, J.I. 1992. NRC Twin Otter Operations in the 1991 California Ozone Deposition Experiment. National Research Council of Canada Report LTR-FR-118. May 1992.

MacPherson, J.I. 1996. NRC Twin Otter Operations in BOREAS 1994. Laboratory Technical Report LTR-FR-129. National Research Council Canada. April 1996.

MacPherson, J.I. and J.M. Morgan. 1981. The N.A.E. Twin Otter Atmospheric Research Aircraft. National Research Council Report LTR-FR-80.

MacPherson, J.I. and M. Bastian. 1997. NRC Twin Otter Operations in BOREAS 1996. Laboratory Technical Report LTR-FR-134. National Research Council of Canada. November 1997.

MacPherson, J.I. and S.W. Baillie. 1986. The N.A.E. Atmospheric Research Aircraft. National Research Council Report, NAE Misc 62.

MacPherson, J.I., R.J. Grossman, and R.D. Kelly. 1992. Intercomparison Results for FIFE Flux Aircraft. Journal of Geophysical Research 97(D17):18,499-18,514.

## 17.2 Journal Articles and Study Reports

Barr, A.G., A.K. Betts, R.L. Desjardins, and J.I. MacPherson. 1997. Comparison of regional surface fluxes from boundary-layer budgets and aircraft measurements above boreal forest. Journal of Geophysical Research 102(D24): 29,213-29,218.

Desjardins, R.L., J.I. MacPherson, L. Mahrt, P. Schuepp, E. Pattey, H. Neumann, D. Baldocchi, S. Wofsy, D. Fitzjarrald, H. McCaughey, and D.W. Joiner. 1997. Scaling up flux measurements for the boreal forest using aircraft-tower combinations. Journal of Geophysical Research 102(D24): 29,125-29,133.

Dobosy, R.J., T.L. Crawford, J.I. MacPherson, R.L. Desjardins, R.D. Kelly, S.P. Oncley, and D.H. Lenschow. 1997. Intercomparison among four flux aircraft at BOREAS in 1994. Journal of Geophysical Research 102(D24):29,101-29,111.

MacPherson, J.I. and A.K. Betts. 1997. Aircraft encounters with strong coherent vortices over the boreal forest. Journal of Geophysical Research 102(D24): 29,231-29,234.

MacPherson, J.I. and R.L. Desjardins. 1991. Airborne Tests of Flux Measurement by the Relaxed Eddy Accumulation Technique. Proceedings of the Seventh Symposium on Meteorological Observations and Instrumentation. American Meteorological Society. New Orleans. January, 1991.

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Ogunjemiyo, S., P.H. Schuepp, J.I. MacPherson, and R.L. Desjardins. 1997. Analysis of flux maps versus surface characteristics from Twin Otter grid flights in BOREAS 1994. Journal of Geophysical Research 102(D24): 29,135-29,145.

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

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

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

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102(D24): 28,731-28,770.

## 17.3 Archive/DBMS Usage Documentation

None.

## 18. Glossary of Terms

None.

## 19. List of Acronyms

```
AFM     - Airborne Fluxes and Meteorology
AGL     - Above Ground Level
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
DAT     - Digital Archive Tape
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
FIFE    - First ISLSCP Field Experiment
FIS     - FIFE Information System
GIS     - Geographic Information System
GMT     - Greenwich Mean Time
GPS     - Global Positioning System
GSFC    - Goddard Space Flight Center
HP      - high pass
HTML    - HyperText Markup Language
IAR     - Institute for Aerospace Research
IFC     - Intensive Field Campaign
INS     - Inertial Navigation System
IRS     - Inertial Reference System
ISLSCP  - International Satellite Land Surface Climatology Project
MSL     - Mean Sea Level
NAD83   - North American Datum of 1983
NAE     - National Aeronautical Establishment
NASA    - National Aeronautics and Space Administration
NCAR    - National Center for Atmospheric Research
NRC     - National Research Council, Canada
NSA     - Northern Study Area
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
RMS     - Root Mean Square
SSA     - Southern Study Area
TAS     - True Air Speed
URL     - Uniform Resource Locator
```

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

MacPherson, J.I. and R.L. Desjardins, "Atmospheric Boundary Layer Analyses from Canadian Twin Otter Aircraft." 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:

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The BOREAS AFM-4 team used the NRC Twin Otter aircraft to make sounding measurements through the boundary layer. These measurements included concentrations of carbon dioxide and ozone, atmospheric pressure, dry bulb temperature, potential temperature, dewpoint temperature, calculated mixing ratio, and wind speed and direction. Aircraft position, heading, and altitude were also recorded. Data were collected at both the NSA and the SSA in 1994 and 1996. These data are stored in tabular ASCII files.

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