



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

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

**Volume 31**

**BOREAS HYD-6 Ground Gravimetric  
Soil Moisture Data**

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# **BOREAS HYD-6 Ground Gravimetric Soil Moisture Data**

Eugene L. Peck, Thomas Carroll

## **Summary**

The BOREAS HYD-6 team collected several data sets related to the moisture content of soil and overlying humus layers. This data set contains percent soil moisture ground measurements. These data were collected on the ground along the various flight lines flown in the SSA and NSA during 1994 by the gamma ray instrument. The data are available in tabular ASCII files.

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## **1. Data Set Overview**

### **1.1 Data Set Identification**

BOREAS HYD-06 Ground Gravimetric Soil Moisture Data

### **1.2 Data Set Introduction**

This data set contains information on the locations of field in situ measurement sites along BOREal Ecosystem-Atmosphere Study (BOREAS) flight lines with ground measurements of soil moisture, depth of moss/humus layer, and water content of the moss/humus layer and contains information on soil conditions and vegetative cover around the sites.

### **1.3 Objective/Purpose**

The objectives of this research were: 1) to obtain improved estimates of the soil moisture conditions for the BOREAS experimental areas; 2) to develop techniques for measuring the water content of the moss/humus layer; 3) to provide assistance to the Hydrology (HYD)-04 team in measuring the water equivalent of the snow cover; 4) to provide information for validating and calibrating other remote sensing methods; and 5) to provide information on the soil moisture of the mineral soil, the water content of the moss/humus layer, and the water equivalent of the snow cover to

other investigators.

#### **1.4 Summary of Parameters**

This data set contains information (flight line identifiers, sample identifiers, latitudes and longitudes) on the locations of ground sampling sites at which measurements of the soil moisture of the mineral soil were obtained. In addition to the data on the samples collected for computing the soil moisture of the mineral soil, brief information on the vegetation is included for those sites where measurements were made by members of HYD-04. For locations where measurements of the soil moisture of the mineral soil were made by members of HYD-06, detailed information on the terrain, the vegetative cover, and soil conditions is contained in this data set.

#### **1.5 Discussion**

As part of the BOREAS experiment, natural terrestrial gamma radiation data over a network of 48 flight lines were collected. For each of these flight lines, ground in situ soil moisture measurements of the mineral soil and water content of the moss/humus layer were collected and used, along with other available measurements, to establish one-time calibration of the natural terrestrial radioisotope signal over the flight line network.

#### **1.6 Related Data Sets**

BOREAS HYD-06 Aircraft Gamma Ray Soil Moisture Data  
BOREAS HYD-06 Moss/Humus Moisture Data

## **2. Investigator(s)**

### **2.1 Investigator(s) Name and Title**

Dr. Eugene L. Peck  
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Dr. Thomas Carroll  
National Weather Service (NWS)

### **2.2 Title of Investigation**

Remote Sensing of Hydrologic Variables in Boreal Areas

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### **3. Theory of Measurements**

In situ ground samples of the soil moisture of the mineral soil and of the water content of the moss/humus layer are obtained using the gravimetric method (percent by weight of dry soil). The soil and moss/humus layer samples are placed in plastic containers and are later dried out for 24 hours in an drying oven at 105 °C.

### **4. Equipment**

#### **4.1 Sensor/Instrument Description**

A soil sampler with a 2.54 cm<sup>2</sup> orifice is used to collect the sample of the mineral soil to a depth of 20 cm, where possible. An Eastern Snow Conference (ESC)-30 snow tube with an orifice of 30 cm<sup>2</sup> is used to collect samples of the moss/humus layer. Depth of the moss/humus layer is measured by a ruler after digging down to the mineral soil.

##### **4.1.1 Collection Environment**

Samples were collected from the Northern Study Area (NSA) and the Southern Study Area (SSA). The airborne and ground measurements of soil moisture and moss/humus were planned the evening before each day's surveying. The airborne and ground measurements were taken simultaneously as much as possible. Ground measurements for calibration purposes were obtained when the flight line areas were fairly dry and never during rain occurrences.

##### **4.1.2 Source/Platform**

Human.

##### **4.1.3 Source/Platform Mission Objectives**

The objective was to collect cores of soil and moss/humus at various locations.

##### **4.1.4 Key Variables**

Soil and moss/humus moisture content.

#### **4.1.5 Principles of Operation**

Unknown.

#### **4.1.6 Sensor/Instrument Measurement Geometry**

A soil sampler with a 2.54-cm<sup>2</sup> orifice was used to collect the sample of the mineral soil to a depth of 20 cm, where possible. An ESC-30 snow tube with an orifice of 30 cm<sup>2</sup> was used to collect samples of the moss/humus layer.

#### **4.1.7 Manufacturer of Sensor/Instrument**

Unknown.

#### **4.2 Calibration**

Unknown.

##### **4.2.1 Specifications**

Unknown.

##### **4.2.1.1 Tolerance**

Unknown.

##### **4.2.2 Frequency of Calibration**

Unknown.

##### **4.2.3 Other Calibration Information**

Unknown.

### **5. Data Acquisition Methods**

Ground measurements were collected at over 1,100 locations along 42 of the 48 BOREAS airborne gamma radiation flight lines during the field experiments. Maps showing locations of most BOREAS established flight lines are shown on Figures 5.2.1.4a, 5.2.1.4b, and 5.2.1.4c of version 3.0 of the BOREAS Experimental Plan. Revised computerized maps of all of the 48 flight lines prepared by National Operational Hydrologic Remote Sensing Center (NOHRSC) (March 1995) are available in the BOREAS Information System (BORIS) (containing a few additional lines that were established during the field experiments).

The flight lines are numbered BP100 to BP123 and CR954 to CR960 in the SSA and BP201 to BP213 in the NSA. Flight lines BP301 to BP305 are located along the transect between the SSA and NSA. The CR lines in the SSA are part of the operational snow measurement program of the Atmospheric Environment Service (AES) of Canada.

### **6. Observations**

#### **6.1 Data Notes**

None.

#### **6.2 Field Notes**

Field notes for the ground sampling of the soil moisture of the mineral soil and the water content of the moss/humus layer by members of HYD-04 and HYD-06 during nonsnow periods are contained in the actual data. Ground samples of the water equivalent of the snow cover and other measurements obtained during 1993 and the 1994 Intensive Field Campaigns (IFCs) are being placed in BORIS by HYD-04.

Ground measurements were collected during September 1993 for a proposed north-south flight line on the western side of the highway directly east of the Young Jack Pine (YJP) and Fen tower sites in the SSA. Ground and airborne observations clearly indicated that the vegetation over the area to be measured by the airborne gamma surveys was highly variable, so much so that any reasonable number of measurements could not provide acceptable information on average conditions along the flight line. Information collected for this proposed line is listed under flight line BP140 in the file Mastergd.DAT.

## 7. Data Description

### 7.1 Spatial Characteristics

The two BOREAS study areas are located with a large area of interest covering over a million square kilometers in the Canadian Provinces of Saskatchewan (SSA) and Manitoba (NSA). Each of the study areas are approximately 50 by 100 km. The data that provide the locations of the various flight lines are described in the HYD-06 Airborne Estimate of Soil Moisture document.

#### 7.1.1 Spatial Coverage

These soil moisture measurements were made on the ground at various point locations within the NSA and SSA. There is a reference table called HYD06\_TRANSECT\_REF that contains information about the location of the various flight lines.

NSA Spatial Coverage (North American Datum of 1983 (NAD83))

|           | Longitude | Latitude |
|-----------|-----------|----------|
|           | -----     | -----    |
| Northwest | 98.82 W   | 56.247 N |
| Northeast | 97.24 W   | 56.081 N |
| Southeast | 97.49 W   | 55.377 N |
| Southwest | 99.05 W   | 55.54 N  |

SSA Spatial Coverage

|           | Longitude | Latitude |
|-----------|-----------|----------|
|           | -----     | -----    |
| Northwest | 106.23 W  | 54.319 N |
| Northeast | 104.24 W  | 54.223 N |
| Southeast | 104.37 W  | 53.419 N |
| Southwest | 106.32 W  | 53.513 N |

#### 7.1.2 Spatial Coverage Map

Not available.

#### 7.1.3 Spatial Resolution

The ground samples of soil and moss/humus were made at point locations throughout the NSA and SSA.

#### 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 for as many flight lines as possible during the following periods:

08-Sep-1993 to 11-Sep-1993 (over SSA)

07-Feb-1994 to 11-Feb-1994, IFC-W in cooperation with HYD-04 (over SSA and NSA)

24-Jul-1994 to 05-Aug-1994, IFC-2 (over SSA and NSA)

30-Aug-1994 to 10-Sep-1994, IFC-3 (over SSA)

### 7.2.2 Temporal Coverage Map

Not available.

### 7.2.3 Temporal Resolution

Ground samples were collected on a daily basis. For most of the flight lines, the times the ground samples were obtained are included in the file Mastergd.DAT. Times of sampling were not noted for those collected by members of HYD-04.

## 7.3 Data Characteristics

### 7.3.1 Parameter/Variable

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

```

      Column Name
-----
HYD06_SITE_ID
DATE_OBS
TIME_OBS
FLIGHT_LINE
SAMPLE_NUM
SUBSAMPLE_NUM
LONGITUDE
LATITUDE
BOREAS_X
BOREAS_Y
TOTAL_WEIGHT
DRY_WEIGHT
WATER_WEIGHT
SOIL_WEIGHT
SOIL_MOIST_GRAV
SLOPE
ASPECT
SOIL_LAYER_DESCR
VEG_REMARKS
MOSS_DEPTH
WATER_CONTENT_MOSS_HUMUS
MOSS_DEPTH_1
MOSS_DEPTH_2
MOSS_DEPTH_3
MOSS_DEPTH_4
COMMENTS
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   |
|--------------------------|---|
| HYD06_SITE_ID            | The identifier assigned to the site by BOREAS, in the format AAA-FFF-GGGGG-SMAC01 where AAA is the study area, FFF is the flight line number, GGGGG is the science group, and SMAC01 stands for Soil Moisture Aircraft. |
| DATE_OBS                 | The date on which the data were collected.  |
| TIME_OBS                 | The Greenwich Mean Time (GMT) when the data were collected.   |
| FLIGHT_LINE              | The designation for the line/transect over which the aircraft flew.   |
| SAMPLE_NUM               | The number of the sample.   |
| SUBSAMPLE_NUM            | The designation of the in situ sub sample.  |
| LONGITUDE                | The NAD83 based longitude coordinate at the site.   |
| LATITUDE                 | The NAD83 based latitude 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.  |
| TOTAL_WEIGHT             | The total weight of the soil sample and the container with the lid.   |
| DRY_WEIGHT               | The dry weight of the soil sample and the container without the lid.  |
| WATER_WEIGHT             | The calculated weight of the water in the sample.   |
| SOIL_WEIGHT              | The weight of the soil in the sample.   |
| SOIL_MOIST_GRAV          | The percent gravimetric soil moisture of the sample.  |
| SLOPE                    | The percent slope at the given site.  |
| ASPECT                   | The aspect direction of the given site expressed as degrees clockwise from North.   |
| SOIL_LAYER_DESCR         | The soil type and depth at the site.  |
| VEG_REMARKS              | Remarks about the vegetation in the area where the soil sample was collected.   |
| MOSS_DEPTH               | The depth of the moss (if any) at the site.   |
| WATER_CONTENT_MOSS_HUMUS | The water content of the moss/humus layer.  |
| MOSS_DEPTH_1             | The moss depth at a point 5 meters forward from the sample collection site.   |
| MOSS_DEPTH_2             | The moss depth at a point 5 meters right of the sample collection site.   |
| MOSS_DEPTH_3             | The moss depth at a point 5 meters back from the soil collection site.  |
| MOSS_DEPTH_4             | The moss depth at a point 5 meters left of the soil collection site.  |
| COMMENTS                 | Descriptive information to clarify or enhance the understanding of the other entered data.  |
| 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         |
|--------------------------|---------------|
| HYD06_SITE_ID            | [none]        |
| DATE_OBS                 | [DD-MON-YY]   |
| TIME_OBS                 | [HHMM GMT]    |
| FLIGHT_LINE              | [none]        |
| SAMPLE_NUM               | [none]        |
| SUBSAMPLE_NUM            | [none]        |
| LONGITUDE                | [degrees]     |
| LATITUDE                 | [degrees]     |
| BOREAS_X                 | [kilometers]  |
| BOREAS_Y                 | [kilometers]  |
| TOTAL_WEIGHT             | [grams]       |
| DRY_WEIGHT               | [grams]       |
| WATER_WEIGHT             | [grams]       |
| SOIL_WEIGHT              | [grams]       |
| SOIL_MOIST_GRAV          | [percent]     |
| SLOPE                    | [percent]     |
| ASPECT                   | [degrees]     |
| SOIL_LAYER_DESCR         | [none]        |
| VEG_REMARKS              | [none]        |
| MOSS_DEPTH               | [millimeters] |
| WATER_CONTENT_MOSS_HUMUS | [millimeters] |
| MOSS_DEPTH_1             | [millimeters] |
| MOSS_DEPTH_2             | [millimeters] |
| MOSS_DEPTH_3             | [millimeters] |
| MOSS_DEPTH_4             | [millimeters] |
| COMMENTS                 | [none]        |
| 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                |
|---------------|----------------------------|
| HYD06_SITE_ID | [Assigned by BORIS]        |
| DATE_OBS      | [Supplied by Investigator] |
| TIME_OBS      | [Supplied by Investigator] |
| FLIGHT_LINE   | [Supplied by Investigator] |
| SAMPLE_NUM    | [Supplied by Investigator] |
| SUBSAMPLE_NUM | [Supplied by Investigator] |
| LONGITUDE     | [Supplied by Investigator] |
| LATITUDE      | [Supplied by Investigator] |
| BOREAS_X      | [Calculated by BORIS]      |
| BOREAS_Y      | [Calculated by BORIS]      |
| TOTAL_WEIGHT  | [Supplied by Investigator] |
| DRY_WEIGHT    | [Supplied by Investigator] |
| WATER_WEIGHT  | [Supplied by Investigator] |

|                          |                            |
|--------------------------|----------------------------|
| SOIL_WEIGHT              | [Supplied by Investigator] |
| SOIL_MOIST_GRAV          | [Supplied by Investigator] |
| SLOPE                    | [Supplied by Investigator] |
| ASPECT                   | [Supplied by Investigator] |
| SOIL_LAYER_DESCR         | [Supplied by Investigator] |
| VEG_REMARKS              | [Supplied by Investigator] |
| MOSS_DEPTH               | [Supplied by Investigator] |
| WATER_CONTENT_MOSS_HUMUS | [Supplied by Investigator] |
| MOSS_DEPTH_1             | [Supplied by Investigator] |
| MOSS_DEPTH_2             | [Supplied by Investigator] |
| MOSS_DEPTH_3             | [Supplied by Investigator] |
| MOSS_DEPTH_4             | [Supplied by Investigator] |
| COMMENTS                 | [Supplied by Investigator] |
| 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<br>Data<br>Value | Maximum<br>Data<br>Value | Missng<br>Data<br>Value | Unrel<br>Data<br>Value | Below<br>Detect<br>Limit | Data<br>Not<br>Clcltd |
|--------------------------|--------------------------|--------------------------|-------------------------|------------------------|--------------------------|-----------------------|
| HYD06_SITE_ID            | N/A                      | N/A                      | None                    | None                   | None                     | None                  |
| DATE_OBS                 | 08-SEP-93                | 05-SEP-94                | None                    | None                   | None                     | None                  |
| TIME_OBS                 | 0                        | 2358                     | None                    | None                   | None                     | None                  |
| FLIGHT_LINE              | BP102                    | CR960                    | None                    | None                   | None                     | None                  |
| SAMPLE_NUM               | 1                        | 97                       | None                    | None                   | None                     | None                  |
| SUBSAMPLE_NUM            | 1                        | 2                        | None                    | None                   | None                     | Blank                 |
| LONGITUDE                | -106.32553               | -98.23027                | None                    | None                   | None                     | Blank                 |
| LATITUDE                 | 53.37768                 | 56.9962                  | None                    | None                   | None                     | Blank                 |
| BOREAS_X                 | 309.192                  | 802.6                    | None                    | None                   | None                     | Blank                 |
| BOREAS_Y                 | 284.789                  | 682.842                  | None                    | None                   | None                     | Blank                 |
| TOTAL_WEIGHT             | 0                        | 252.9                    | -999                    | None                   | None                     | Blank                 |
| DRY_WEIGHT               | 0                        | 198.5                    | -99.9                   | None                   | None                     | Blank                 |
| WATER_WEIGHT             | 0                        | 87.76                    | None                    | None                   | None                     | Blank                 |
| SOIL_WEIGHT              | -13.2                    | 185.3                    | None                    | None                   | None                     | Blank                 |
| SOIL_MOIST_GRAV          | -100                     | 354.3                    | None                    | None                   | None                     | Blank                 |
| SLOPE                    | 0                        | 15                       | None                    | None                   | None                     | Blank                 |
| ASPECT                   | 0                        | 338                      | None                    | None                   | None                     | None                  |
| SOIL_LAYER_DESCR         | N/A                      | N/A                      | None                    | None                   | None                     | Blank                 |
| VEG_REMARKS              | N/A                      | N/A                      | None                    | None                   | None                     | Blank                 |
| MOSS_DEPTH               | 0                        | 1000                     | None                    | None                   | None                     | Blank                 |
| WATER_CONTENT_MOSS_HUMUS | 0                        | 284                      | None                    | None                   | None                     | Blank                 |
| MOSS_DEPTH_1             | 30                       | 1000                     | None                    | None                   | None                     | Blank                 |
| MOSS_DEPTH_2             | 40                       | 1000                     | None                    | None                   | None                     | Blank                 |
| MOSS_DEPTH_3             | 50                       | 1000                     | None                    | None                   | None                     | Blank                 |
| MOSS_DEPTH_4             | 30                       | 1000                     | None                    | None                   | None                     | Blank                 |
| COMMENTS                 | N/A                      | N/A                      | None                    | None                   | None                     | Blank                 |
| CRTFCN_CODE              | CPI                      | CPI                      | None                    | None                   | None                     | None                  |
| REVISION_DATE            | 11-JUL-95                | 11-JUL-95                | None                    | None                   | None                     | None                  |

Minimum Data Value -- The minimum value found in the column.  
 Maximum Data Value -- The maximum value found in the column.  
 Missing Data Value -- The value that indicates missing data. This is used to indicate that an attempt was made to determine the parameter value, but the attempt was unsuccessful.  
 Unrel Data Value -- The value that indicates unreliable data. This is used to indicate an attempt was made to determine the parameter value, but the value was deemed to be unreliable by the analysis personnel.  
 Below Detect Limit -- The value that indicates parameter values below the instruments detection limits. This is used to indicate that an attempt was made to determine the parameter value, but the analysis personnel determined that the parameter value was below the detection limit of the instrumentation.  
 Data Not Cllctd -- This value indicates that no attempt was made to determine the parameter value. This usually indicates that BORIS combined several similar but not identical data sets into the same data base table but this particular science team did not measure that parameter.  
 Blank -- Indicates that blank spaces are used to denote that type of value.  
 N/A -- Indicates that the value is not applicable to the respective column.  
 None -- Indicates that no values of that sort were found in the column.

-----\*

## 7.4 Sample Data Record

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

```

DATE_OBS, HYD06_SITE_ID, TIME_OBS, FLIGHT_LINE, SAMPLE_NUM, SUBSAMPLE_NUM, LONGITUDE,
LATITUDE, BOREAS_X, BOREAS_Y, TOTAL_WEIGHT, DRY_WEIGHT, WATER_WEIGHT, SOIL_WEIGHT,
SOIL_MOIST_GRAV, SLOPE, ASPECT, SOIL_LAYER_DESCR, VEG_REMARKS, MOSS_DEPTH,
WATER_CONTENT_MOSS_HUMUS, MOSS_DEPTH_1, MOSS_DEPTH_2, MOSS_DEPTH_3, MOSS_DEPTH_4,
COMMENTS, CRTFCN_CODE, REVISION_DATE
08-SEP-93, 'SSA-111-HYD06-SMAC01', 0, 'BP111', 2, '', -105.50048, 53.53005, 364.036,
295.835, 145.38, 126.18, 19.2, 112.98, 17.0, , 0, 'clay', 'soybean', , , , , , , 'CPI',
11-JUL-95

```

### Abbreviations used in the comment and remark fields

| Abbreviation | Meaning  |
|--------------|--|
| cm           | centimeters  |
| drk          | dark   |
| dk           | dark   |
| est          | estimated  |
| Fl line      | flight line  |
| Hvy          | heavy  |
| Hwy          | highway  |
| Lat          | latitude   |
| Lgt          | light  |
| Long         | longitude  |
| m            | meter  |
| M/H          | moss/humus   |
| Med          | medium   |
| Mod          | moderate   |
| n/a          | not appropriate  |
| SM           | soil moisture (of mineral soil in percent by dry weight) |
| u/c          | undercover   |
| u/s          | under storage  |
| u/b          | underbrush   |
| Veg          | vegetation   |
| Vry          | very   |
| WC           | water equivalent of the moss/humus layer                 |
| Wht          | white  |
| wgt          | weight   |

### Abbreviations for Vegetation

| Abbreviation | Meaning                    |
|--------------|----------------------------|
| A            | Aspen                      |
| B            | Birch                      |
| BB           | Bear Berry plant           |
| BS           | Black Spruce               |
| BP           | Black Pine                 |
| JP           | Jack Pine                  |
| P            | Pine                       |
| Lab Tea      | Labrador Tea plant         |
| MBS          | Moderate aged Black Spruce |
| OA           | Old Aspen                  |
| OBS          | Old Black Spruce           |
| OJP          | Old Jack Pine              |
| OTA          | Old Trembling Aspen        |
| OWB          | Old White Birch            |
| YA           | Young Aspen                |
| YBS          | Young Black Spruce         |
| YTA          | Young Trembling Aspen      |
| YWS          | Young White Spruce         |
| WS           | White Spruce               |

## 8. Data Organization

### 8.1 Data Granularity

The smallest amount of data that can be ordered from this data set is a day's worth of data.

### 8.2 Data Format(s)

The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

## **9. Data Manipulations**

### **9.1 Formulae**

None.

### **9.1.1 Derivation Techniques and Algorithms**

None.

### **9.2 Data Processing Sequence**

The soil samples in the sealed plastic containers obtained in the field are weighed (total weight), the lids are removed, and the samples are dried in ovens and weighed again (dry weight). The weight of the water is determined by subtracting the dry weight and the weight of an average plastic lid for that day from the total weight. The weights of the plastic lids and the plastic containers vary from shipment to shipment, and the average weights of those being used each day are recorded on the laboratory form with the total and dry weights. The weight of the soil for the sample is computed by subtracting the average weight of the plastic container from the dry weight of the sample. The soil moisture of the mineral soil is the weight of the water divided by the weight of the soil (percent of dry soil by weight).

Samples processed by members of HYD-04 are sealed and taken to AES offices in Downsview, Ontario, for processing.

### **9.2.1 Processing Steps**

BORIS staff processed the 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.
- Performing the conversions on measurements into System International (SI) units.
- Working with the HYD-06 team to document the data set.
- Extracting the standardized data into logical files.

### **9.2.2 Processing Changes**

None.

## **9.3 Calculations**

### **9.3.1 Special Corrections/Adjustments**

None.

### **9.3.2 Calculated Variables**

None.

## **9.4 Graphs and Plots**

Maps of the BOREAS flight lines, digitized by NOHRSC, are in BORIS. Maps are also in the BOREAS Experiment Plan (version 3.0) (Figures 5.2.1.4a, 5.2.1.4b, and 5.2.1.4c).

## **10. Errors**

### **10.1 Sources of Error**

Errors in determining the soil moisture of the mineral soil (and the water content of the moss/humus layer) are introduced by nonrepresentative samples of the mineral soil (or of the moss/humus layer). These may be caused by incorrect introduction of the sampler into the soil, rocks in the soil that prevent insertion of the sampling tube to the desired depth, and failure to clean off the soil between samples. The ability to remove a sample from the soil without disturbing the sample

within the tube is related to the experience of the observer.

## **10.2 Quality Assessment**

### **10.2.1 Data Validation by Source**

Confidence in the soil moisture in situ measurement depends on many factors regarding the accuracy of locating the sampling points along flight line as well as the experience and training of the field personnel.

### **10.2.2 Confidence Level/Accuracy Judgment**

The confidence level of the soil moisture measurements varies with the experience of the person selecting the flight line or locating the sampling sites on a map. In very flat areas, the exact location of a ground measurement is more difficult to identify than for a site near a stream or in areas of variable terrain.

### **10.2.3 Measurement Error for Parameters**

A precise estimate of the error of a soil moisture measurement of the mineral soil cannot be determined. The selection of sites for in situ measurements of the soil moisture and the water content of the moss/humus layer along a flight line is very critical. During the development of the airborne system in the United States, it was clear that using a grid method to collect soil moisture samples over farmland in Minnesota was not viable. One or more measurements taken in shallow, low ravines subject to high soil moisture following periods of runoff-producing precipitation would result in unrepresentative average soil moisture values for sections of farmland. Averages of these values would not correlate with the airborne estimates. In Minnesota, soil moisture observations of average land slope, generally one to two percent, of corn fields and other crops were found to be best correlated with airborne measurements.

Experience with the airborne gamma radiation system during the recent field experiments for the First International Satellite Land Surface Climatology Project (ISLSCP) Field Experiment (FIFE) in Kansas (Carroll et al., 1988) illustrates the need to obtain ground measurements representative of the average of the area from which ground-based gamma are received by the airborne detectors. During FIFE, a few lines were established in areas where permission to traverse all of the line on foot was not possible. Airborne estimates for days without ground truth measurements showed that the estimated values tend to be reasonable when the average soil moisture of the future flight was approximately equal to that computed during calibration. However, during periods when the average soil moisture departs significantly, either high or low, from the calibration average, the estimates of the total soil moisture for one or more bins along the line often appear to be exceptionally high or low.

During the BOREAS field experiments, careful attention has been given to obtaining as representative measurements of in situ soil moisture along the flight lines as possible. Most of the originally established flight lines were located over areas having as consistent vegetative cover as possible (i.e., all old aspen). However, in some areas, due to heterogeneous conditions, it was not possible to judge what measurements would provide representative averages. When the flight and bin estimates are consistently in line with other measurements, for all ranges of conditions, it is clear that the calibration of the line was representative. The calibration of most, but not all, of the flight lines in the SSA appear to be reliable, and the soil moisture estimates are considered to be very representative. The experience of the person selecting the in situ sites and the consistency of the vegetative cover are the two most important factors for obtaining representative calibration of the flight lines.

### **10.2.4 Additional Quality Assessments**

All of the airborne estimates have been, or are in the process of being, checked by comparison with available soil moisture and water content measurements along the same and nearby flight lines. As additional soil moisture and water content values become available, a second level of quality control will be accomplished by comparing the revised ground records with airborne measurements.

### **10.2.5 Data Verification by Data Center**

BORIS personnel reviewed the data and documentation for clarity and agreement.

## **11. Notes**

### **11.1 Limitations of the Data**

None given.

### **11.2 Known Problems with the Data**

Experience with the airborne gamma radiation system during the recent field experiments FIFE in Kansas (Carroll et al., 1988) illustrates the need to obtain ground measurements representative of the average of the area from which ground-based gamma are received by the airborne detectors. During FIFE, a few lines were established in areas where permission to traverse all of the line on foot was not possible. Airborne estimates for days without ground truth measurements showed that the estimated values tend to be reasonable when the average soil moisture of the future flight was approximately equal to that computed during calibration. However, during periods when the average soil moisture departs significantly, either high or low, from the calibration average, the estimates of the total soil moisture for one or more bins along the line often appear to be exceptionally high or low.

### **11.3 Usage Guidance**

The airborne gamma radiation soil moisture estimates of the total soil moisture are only representative of average conditions along the flight line. Considerable change in soil conditions may be found, even for lines having nearly consistent vegetative cover. Careful review of the soil and vegetative conditions are necessary to transfer the soil moisture estimates to nearby areas. However, the use of the airborne estimates for similar conditions for flux analyses and other studies can add considerable information on the spatial and temporal variation in the soil moisture of the mineral soil and of the water content of the moss/humus layer.

### **11.4 Other Relevant Information**

Ground measurements in file Mastermh.DAT (and in Mastergd.DAT) collected by members of HYD-06 were collected under slightly different methods than those collected by members of HYD-04. Those observed by members of HYD-04 do not show times of observations.

Members of HYD-04 followed sampling procedures established for the operational airborne gamma radiation snow surveys that have been collected in the BOREAS area for many years. Sampling points are selected on a set distance from the beginning of the flight line (either at 1-km or 2-km intervals depending on the length of the flight line). This approach has proven useful for the operational snow measuring program. Using this approach, the measurement sites are selected at nearly the same location along the flight line during snow and nonsnow periods. Members of HYD-06 collected only during nonsnow periods and selected measurements sites that tended to best represent the average conditions along the entire 300-m-wide foot path of the area measured by the airborne gamma radiation surveys.

## **12. Application of the Data Set**

These data could be used to evaluate the spatial distribution of soil moisture over the sampled areas.

## **13. Future Modifications and Plans**

None.



## **14. Software**

### **14.1 Software Description**

None given.

### **14.2 Software Access**

None given.

## **15. Data Access**

The HYD-06 ground gravimetric soil moisture 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](mailto:ornldaac@ornl.gov) or [ornl@eos.nasa.gov](mailto: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**

Gamma ray site reference data could be made available on 1600 or 6250 Bytes Per Inch (BPI) Computer Compatible Tapes (CCT).

### **16.2 Film Products**

Video tapes taken over each flight line during calibration showing the area directly under the aircraft are available (at NOHRSC). At the present time, no decision has been made on storing these tapes in BORIS.

### **16.3 Other Products**

Maps showing the flight lines for which gamma data were obtained have been digitized by NOHRSC and submitted to BORIS. 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**

Carroll, T.R., E.L. Peck, and D.M. Lipinski. 1988. Airborne time-series measurements of soil moisture using terrestrial gamma radiation. Proc. Ann. Conf. Am. Soc. Photogram. Remote Sens., St. Louis, MO.

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.

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

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Sellers, P., F. Hall, and K.F. Huemmrich. 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

|        |  |
|--------|--|
| AES    | - Atmospheric Environment Service of Canada                |
| ASCII  | - American Standard Code for Information Interchange       |
| BOREAS | - BOREal Ecosystem-Atmosphere Study                        |
| BORIS  | - BOREAS Information System                                |
| BPI    | - Bytes Per Inch   |
| CCT    | - Computer Compatible Tape                                 |
| CD-ROM | - Compact Disk - Read-Only Memory                          |
| DAAC   | - Distributed Active Archive Center                        |
| EOS    | - Earth Observing System                                   |
| EOSDIS | - EOS Data and Information System                          |
| ESC    | - Eastern Snow Conference                                  |
| EXP    | - Experiment   |
| FIFE   | - First ISLSCP Field Experiment                            |
| FIS    | - FIFE Information System (NASA)                           |
| GIS    | - Geographic Information System                            |
| GMT    | - Greenwich Mean Time                                      |
| GPS    | - Ground positioning system                                |
| GSFC   | - Goddard Space Flight Center                              |
| HTML   | - Hyper-Text Markup Language                               |
| HYD    | - Hydrology (BOREAS science team)                          |
| IFC    | - Intensive Field Campaign                                 |
| ISLSCP | - International Satellite Land Surface Climatology Project |
| MeV    | - Million Electronic Volts                                 |
| NAD27  | - North American Datum of 1927                             |
| NAD83  | - North American Datum of 1983                             |
| NASA   | - National Aeronautics and Space Administration            |
| NOHRSC | - National Operational Hydrologic Remote Sensing Center    |
| NSA    | - Northern Study Area                                      |
| NWS    | - National Weather Service                                 |
| ORNL   | - Oak Ridge National Laboratory                            |
| PANP   | - Prince Albert National Park                              |
| SI     | - System International                                     |
| SM     | - Soil moisture, percent by weight, of the mineral soil    |
| SSA    | - Southern Study Area                                      |
| URL    | - Uniform Resource Locator                                 |
| USGS   | - U.S. Geological Survey                                   |
| WC     | - Water content of the moss/humus layer                    |
| WE     | - Water equivalent of the snow layer                       |
| YJP    | - Young Jack Pine  |

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

Eugene L. Peck, President, Hydrex Corporation Thomas Carroll, Chief, NOHRSC

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

Peck, E.L. and T. Carroll, "Remote Sensing of Hydrologic Variables in Boreal Areas." 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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