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

Forrest G. Hall and David E. Knapp, Editors

Volume 40

BOREAS HYD-9 Streamflow Data

N. Kouwen, R. Soulis, W. Jenkinson, A. Graham, and T. Neff

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

July 2000

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BOREAS HYD-9 Streamflow Data

Nicholas Kouwen, Ric Soulis, Wayne Jenkinson, Allyson Graham, Todd Neff

Summary

The BOREAS HYD-9 team collected several data sets containing precipitation and streamflow measurements over the BOREAS study areas. These streamflow data were collected by the HYD-09 science team to support its research into meltwater supply to the soil during the spring melt period. These data were also collected for HYD-09's research into the evolution of soil moisture, evaporation, and runoff from the end of the snowmelt period through freeze up. Data were collected in the BOREAS SSA and NSA from April until October in 1994, 1995, and 1996. Gauges SW1 and NW1 were operated year-round; however, data may not be available for both gauges for all 3 years. The data are available in tabular ASCII files.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS HYD-09 Streamflow Data

1.2 Data Set Introduction

These streamflow data were collected by the Hydrology (HYD)-09 science team to support its research into meltwater supply to the soil during the spring melt period. These data were also collected for HYD-09's research into the evolution of soil moisture, evaporation, and runoff from the end of the snowmelt period through freeze up. Data were collected in the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) and Northern Study Area (NSA) from April until October in 1994, 1995, and 1996. Gauges SW1 and NW1 were operated year-round; however, data may not be available for both gauges for all 3 years.

1.3 Objective/Purpose

The purpose of this project is to identify, through field measurements and computer modeling, the space-time distribution of meltwater supply to the soil during the spring melt period and the evolution of soil moisture, evaporation, and runoff from the end of the snowmelt period through freeze up. The snow modeling activity will consist of two components. The first will make use of existing "off-the-shelf" models to forecast the onset and spatial extent of snowmelt and meltwater supply to the soil column prior to the 1994 Intensive Field Campaign (IFCs). The second phase will extend, implement, and verify a physically based energy balance snowmelt model of the two sites and will evaluate approaches to aggregating detailed snowmelt predictions and measurements based on the model to larger scales, up to the size of a rectangle of several hundred km containing the northern and southern sites. The soil moisture modeling is based on a grouped response unit method that will allow characterization of soil moisture, evaporation, and runoff for the entire northern and southern sites.

1.4 Summary of Parameters

The following phenomena and their parameters are being reported in this data set: Discharge Rate of Streams.

1.5 Discussion

The locations for 12 tipping bucket measuring devices, 10 Belfort gauges, and 5 stream sites were selected within the two BOREAS study sites (NSA and SSA). These instruments were installed during the 1994 Focused Field Campaign-Thaw (FFC-T) in the last week of April. They were in operation until October 1994, when they were removed from service. The gauges were reinstalled in April 1995 and collected data until October 1995. The tipping buckets and Belfort gauges provided an approximate measure of the precipitation in the study areas and the discharge rates of streams provided a measurement of water leaving the study area. When used together, these data sets provide a balance of the water cycle.

1.6 Related Data Sets

HYD-09 Belfort Rain Gauge Data
HYD-09 Tipping Bucket Rain Gauge Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Prof. Ric Soulis
University of Waterloo
Department of Civil Engineering

2.2 Title of Investigation

From Micro-Scale to Meso-Scale Snowmelt, Soil Moisture and Evapotranspiration from Distributed Hydrologic Models

2.3 Contact Information

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3. Theory of Measurements

To continuously measure the discharge rate of a stream as a function of depth, it is first necessary to construct a stage-discharge rating curve. To find the discharge rate at a specific stage, the cross section of the stream must be divided into subsections. No one subsection should account for more than 10% of the total streamflow. In the center of each subsection, a current meter is lowered into the water at various depths to measure velocity. Two types of current meters were used in this study, a propeller meter and an electromagnetic meter. A propeller meter measures the rate of flow by relating it to the rotation of its propeller, while an electromagnetic meter measures the voltage produced when water passes through a magnetic field produced by the meter. Two different types of meters were used to reduce the error associated with each device.

When the velocities have been determined, the total discharge of the stream can be calculated. This, along with the level of the stream at that time, can be used to compare the rate of flow at that time with other times. The discharge rate must be found at several different stream levels so that a relationship can be established between the height of the stream and its discharge. This relationship is represented graphically as a rating curve.

Once a rating curve is established, the discharge can be found at any time if the height of the stream is known. A float tube and a data logger were used to constantly monitor the stream height. The stream height was manually checked periodically using a staff gauge. From these methods, a detailed description of the stream's water level over several months was possible.

4. Equipment

4.1 Sensor/Instrument Description

Propeller Meter:

The Swoffer 2100 STDX current velocity meter consists of a propeller that rotates about an axis parallel to the flow of the stream. An onboard computer calculates the speed and displays it in the desired units. The computer averages the velocity over a given time (i.e., 90 sec). The propeller meter was used to determine the rating curve for the stream.

Electromagnetic Meter:

The MMI model 2000 flo-mate portable water flowmeter measures the velocity of a liquid using an electromagnetic method. When a fluid that has conductive properties passes through a magnetic field at a right angle, the magnetic field induces an electromotive force in the fluid at right angles to both the magnetic field and the velocity of the fluid. The voltage produced by the movement of the water through the meter is measured by electrodes and is proportional to the average velocity of the fluid. A built-in computer uses this information to calculate and display the velocity. The electromagnetic meter was used to determine the rating curve for the stream.

Float Tube:

A float tube consists of a hollow perforated plastic tube mounted perpendicular to the water's surface near the stream bank where it is accessible to observers. A float inside the tube reacts to different water heights, which the data logger electronically records every 15 minutes. It is used to monitor the height of water over small intervals of time (i.e., 15 minutes) during long periods of field measurement.

Data Logger:

The chart pac CP-X data logger was connected to the float tube so that it could record stream levels every 15 minutes. The data were stored in the logger's memory until they were retrieved.

4.1.1 Collection Environment

The equipment was operated in variable ambient atmospheric conditions at the field sites in Saskatchewan and Manitoba during 1994. The instrumentation was redeployed in 1995 and 1996.

4.1.2 Source/Platform

The propeller meter and the electromagnetic meter were mounted on poles that were lowered manually into a stream. The float tube was mounted in a stream near the bank where observers could reach it easily. The data logger was mounted inside the float tube.

4.1.3 Source/Platform Mission Objectives

A measurement of the stream discharge rate was necessary to make a precise estimate of the total amount of water leaving the watershed because of surface and subsurface flows. The data logger stored the information until it was retrieved.

4.1.4 Key Variables

- Propeller Meter - Water Velocity
- Electromagnetic Meter - Water Velocity
- Float Tube - Stream Height
- Data Logger - Voltage

4.1.5 Principles of Operation

A propeller meter and an electromagnetic meter are manually operated devices that measure the velocity of water. The propeller meter counts the number of propeller revolutions over a given time period. The computer compares this to a calibration coefficient and then displays the resulting velocity. The electromagnetic meter measures the voltage produced by water moving through a magnetic field, which is proportional to the water's velocity. The float tube and the data logger are self-contained devices that automatically record the height of water every hour over an indefinite time period.

4.1.6 Sensor/Instrument Measurement Geometry

The propeller meter and the electromagnetic meter are mounted on a pole and lowered to various depths in a stream. The tester must repeat this for each subsection of the stream so that the average velocity can be calculated. The float tube is mounted near the stream bank so that the tube is perpendicular to the surface of the water. The tube must be in an area that is accessible for data retrieval and can measure high and low water levels. The data logger is attached to the float tube.

4.1.7 Manufacturer of Sensor/Instrument

Propeller Meter - Swoffer Instruments, Inc.
1048 Industry Drive
Seattle, WA 98188 U.S.A
(206) 575-0160
(206) 575-1329 (fax)

Electromagnetic Meter - Marsh-McBirney, Inc.
4539 Metropolitan Court
Frederick, MD 21701 U.S.A.
(301) 874-5599
(301) 874-2172 (fax)

Float Tube - Lakewood Systems
9258-34A Avenue
Edmonton, Alberta, Canada
T6E 5P4

Data Logger - Lakewood Systems
Edmonton, Alberta, Canada

4.2 Calibration

The propeller meter and the electromagnetic meter were calibrated by dragging them through a still body of water (a long tank, or a lake) at a known velocity and then adjusting the instrument as needed. The float tube was calibrated by measuring the height of the water directly with a staff gauge and comparing that to the reading determined by the float gauge.

4.2.1 Specifications

- Propeller Meter - temperature range: -10 °C to 49 °C
- Electromagnetic Meter - analog display: 0.1v per 1 m/sec material: polyurethane shell temperature range: 0 °C to 50 °C
- Float Tube - range: 0 to 4.6 m (0 to 15 feet) accuracy: +/- 1 cm. (0.4 inches) operating temperatures: -66 °F to 140 °F

4.2.1.1 Tolerance

The propeller meter can measure velocities from 0.1 to 25 ft/sec. The electromagnetic meter can measure velocities from -0.5 to 19.99 ft/sec (-0.15 to 6 m/sec). The meter measures the velocity to within 2% of the reading +/- 0.05 ft/sec. The float tube can measure stream heights from 0 to 4.6 meters. The data logger can record voltage from 0 to 2.5 volts D.C. It can store 64,000 samples with an accuracy of 1/4095.

4.2.2 Frequency of Calibration

The propeller meter and the electromagnetic meter were calibrated once before the readings were made and once afterwards. The float tube was calibrated during the beginning of the study period. The staff gauge readings were compared to those of the float tubes.

4.2.3 Other Calibration Information

None.

5. Data Acquisition Methods

Stream discharge measurements were made on five streams within the two study areas. Measurements were made on each stream to determine its rating curve so that stream height could be related to the rate of discharge. A float tube was set up to electronically monitor the height of the stream and record the information on a data logger. The data logger was connected to a notebook computer onsite, where the logger's stored information was transferred to the notebook. The data were then used with the rating curve to determine the rate of discharge every hour and were checked for quality assurance.

6. Observations

6.1 Data Notes
None given.

6.2 Field Notes
None given.

7. Data Description

7.1 Spatial Characteristics
The stream sites were located so that they would give an overall view of water movement throughout the basin. In the large study areas (NSA and SSA), smaller basins were chosen so that a more detailed study could be performed. Two basins were chosen in the NSA and one in the SSA. In each basin, the stream sites were chosen so that the flow contributions from a number of land cover types could be determined.

The stream sites were also selected based on other characteristics: they had to be accessible during all water levels, the location had to be suitable for measuring the water height at high and low water levels, and the river bed had to be uniform in shape and of a material that resists erosion so that the rating curve would not change significantly over the period of observation. In addition, areas that did not overflow their banks and were away from human traffic were given preference.

The stream gauge at SW1 was chosen by HYD-09 Canada before the BOREAS project. During the project, the Environment Canada Water Survey operated the NW1 gauge.

7.1.1 Spatial Coverage
The five stream gauges measured the discharges throughout the two areas. The NSA basins were both 27 km^2, while the SSA basin was 574 km^2. Two additional stream gauges, SW1 and NW1, were operated by the water survey. The stream gauges were located at the following coordinates, which are in the North American Datum of 1983 (NAD83):

SITE_ID	LONGITUDE	LATITUDE	DRAINAGE AREA (km^2)
NSA-NW1-HYD09-STGAN1	98.49168W	55.90877N	433
NSA-NW2-HYD09-STGAN2	98.52746W	55.91528N	35
NSA-NW3-HYD09-STGAN3	98.37563W	55.91683N	31
SSA-SW1-HYD09-STGAS1	104.61986W	53.86453N	595
SSA-SW2-HYD09-STGAS2	104.68167W	53.895N	81
SSA-SW3-HYD09-STGAS3	104.79116W	53.92669N	470
SSA-SW4-HYD09-STGAS4	104.82028W	53.92639N	204

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
The stream discharge rates reported in this data set represent the discharge rate at the point in the stream where they were located. The collected data are designed to provide a reasonable estimate of the total surface and subsurface runoff from the White Gull Creek and Sapochi River watersheds during the study period.

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 from the end of April until October in 1994, 1995, and 1996. Gauges SW1 and NW1 were operated year-round.

7.2.2 Temporal Coverage Map
Not available.

7.2.3 Temporal Resolution
The data were collected at 15-minute intervals over the study period and were converted to hourly flow during the processing phase.

7.3 Data Characteristics

7.3.1 Parameter/Variable
The parameters contained in the data files on the CD-ROM are:

```
         Column Name
------------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME_OBS
DISCHARGE_RATE
PARM_VALUE_FLAGS
CRTFCN_CODE
REVISION_DATE
```

7.3.2 Variable Description/Definition
The descriptions of the parameters contained in the data files on the CD-ROM are:

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

	BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument, e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) when the data were collected.
DISCHARGE_RATE	The discharge rate of a stream measured every hour.
PARM_VALUE_FLAGS	This contains values or codes that indicate special conditions for the data parameters. The following codes are defined. B = backwater/ice conditions E = estimated value O = changing stage Z = B and O
CRTFCN_CODE	The BOREAS certification level of the data. Examples are CPI (Checked by PI), CGR (Certified by Group), PRE (Preliminary), and CPI-??? (CPI but questionable).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

7.3.3 Unit of Measurement

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

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
DISCHARGE_RATE	[meters^3][second^-1]
PARM_VALUE_FLAGS	[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
SITE_NAME	[Assigned by BORIS]
SUB_SITE	[Assigned by BORIS]
DATE_OBS	[Supplied by Investigator]
TIME_OBS	[Supplied by Investigator]
DISCHARGE_RATE	[Supplied by Investigator]
PARM_VALUE_FLAGS	[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 Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	NSA-999-99NW1	SSA-999-99SW4	None	None	None	None
SUB_SITE	HYD09-SGNW1	HYD09-SGSW4	None	None	None	None
DATE_OBS	01-JAN-94	31-DEC-96	None	None	None	None
TIME_OBS	0	2300	None	None	None	None
DISCHARGE_RATE	-0.077	25.4	-99	None	None	None
PARM_VALUE_FLAGS	N/A	N/A	None	None	None	Blank
CRTFCN_CODE	CPI	PRE	None	None	None	None
REVISION_DATE	23-MAY-95	11-JUL-97	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 records from a sample data file on the CD-ROM.

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME_OBS,DISCHARGE_RATE,PARM_VALUE_FLAGS,CRTFCN_CODE,
REVISION_DATE
'NSA-999-99NW2','HYD09-SGNW2',01-OCT-96,0,.494,'','CPI',11-JUN-97
'NSA-999-99NW2','HYD09-SGNW2',01-OCT-96,100,.478,'','CPI',11-JUN-97
```

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 for a given site.

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

To find the average velocity in a subsection:

Velocity = the average of the velocity measured at 0.8 of the depth and at 0.2 of the depth
$u = (u(0.8D)+u(0.2D))/2$

To find the flow in a subsection:

Flow = Average velocity in subsection * area of subsection $Q = u * A$

To find total discharge from velocity readings:

Flow = the sum of the flows in all of the subsections
Q = (sum from i=1 to i=N) of (u to the ith power) * A

To find the flow at a particular stream height:

$$Q = a2(\text{volts}-a1) + a3(\text{volts}-a1)^2 + a4(\text{volts}-a1)^3 + a5(\text{volts}-a1)^4 + a6(\text{volts}-a1)^5$$

where q = flow
a1 to a6 = coefficients of the rating curve
volts = the voltage recorded by the float tube for a specific height

To find the height of the stream from the data logger information:

height of stream = voltage output * calibration coefficient

9.1.1 Derivation Techniques and Algorithms

At frequent intervals during the monitoring period, the flow of the stream (using the propeller and electromagnetic metering devices), the voltage produced by the float tube, and the true height of the stream measured from a staff gauge were recorded. These data showed a relationship between the level of the stream (staff and voltage gauges) and the rate of flow. The voltage produced by the float tube was converted to stream height using a calibration coefficient. The information was entered into a computer program called 'FitFlow' that calculated the coefficients for the rating curve of a stream (a1 to a6). After this was done, it was a simple matter to find the rate of flow using the equation.

9.2 Data Processing Sequence

9.2.1 Processing Steps

The following steps were performed to collect the data:

- Set up necessary equipment.
- Measure the information necessary to develop rating curve.
- Measure the stream height over the desired period of time.
- Perform the necessary data manipulations.
- Calculate the streamflow rates using the rating curve.
- Enter the flow rates into ASCII files with the appropriate identifying information noted beside each row (location, year, day, month).
- Add the necessary column headings.
- Transfer the information to the data base.

BOREAS Information System (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.
- Working with the HYD-09 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

See associated report file "hyd09_report.pdf" (an Adobe Acrobat file).

10. Errors

10.1 Sources of Error

Most errors will occur in the actual measuring of the initial data. Turbulent water flow will affect the velocity readings by causing the meter to measure a larger or smaller velocity than actual. The stream site where the velocity measurements are taken must be a uniform shape to reduce variations in flow. If an instrument is allowed to get dirty, it may become clogged and produce faulty readings. The propeller meter suffers from rotational friction that becomes more apparent at low velocities. Careful cleaning and calibration will prevent this, though. As the temperature of water changes, its volume will also change. Some of the gauges experienced shifting during the observation period. This movement made the development of rating curves more difficult.

10.2 Quality Assessment

10.2.1 Data Validation by Source

The electronic readings of the float gauge were routinely checked with the staff gauge readings taken directly from the stream. To account for the movement of the float tube, shifting of the streambed, or the growth of vegetation, the rating curves were broken up into different time periods. For example, there were different rating curves for the spring thaw than for the fall freezing period. After the information had been collected, it was run through an algorithm to detect any data that were abnormal when compared to the rest of the data.

10.2.2 Confidence Level/Accuracy Judgment

The confidence level of the data varies with the particular stream and the level of the stream at the time of measurement.

10.2.3 Measurement Error for Parameters

None given.

10.2.4 Additional Quality Assessments

None.

10.2.5 Data Verification by Data Center

The data that were loaded into the data tables were spot checked against the original ASCII data to identify any data loading errors.

11. Notes

11.1 Limitations of the Data

None given.

11.2 Known Problems with the Data

For short periods of time some of the monitoring stations were inoperative. The data lost during these periods made the final results less accurate. In April and May there was ice in the streams. This changed the cross section of the stream, thereby affecting the rating curves that relate stage to discharge.

The gauge at NW2 had weed growth cleaned out on 04-Aug-1994, 12-Aug-1994, and 04-Sep-1994. At NW3, several very low flows occurred in September 1994 when the gauge was unattended. These flows were outside the range of the rating curve and are therefore unreliable. On 21-Jun-1994, a culvert was removed in the head waters, resulting in the drainage of a swamp. This caused a sharp peak in the flows that was not caused by rainfall. In 1996, road construction forced a relocation of the float tube approx. 75 m downstream from the original location.

On 23-May-1994 and 25-Aug-1994, storms washed out a beaver dam near the SW2 culvert. The alteration of the flow control resulted in different stage vs. discharge relationships. A beaver dam was built by SW3 in September 1994 that affected the rating curve. Data from this gauge after 07-Sep-1994 cannot be used. Beaver problems persisted after approximately 05-Jun-1995. Between 21-Jun-1994 and 13-Jul-1994, the gauge at SW4 was tampered with and was unserviceable. On 19-Jul-1994, a different cross-section flow was metered because of excessive water levels at the original location.

11.3 Usage Guidance

The float tubes and data loggers were switched to double precision in May 1994. This effected the resolution of the reported data.

11.4 Other Relevant Information

HYD-09 wrote a report stored on this CD-ROM called "hyd09_report.pdf" (an Adobe Acrobat file). It can be referenced as:

Kouwen, N., R. Soulis, W. Jenkinson, A. Graham, and T. Neff. 1997. BOREAS: Boreal Forest Hydrological Research Study. Hydrology 9 Group: From Micro-scale to meso-scale snowmelt, soil moisture and evapotranspiration from distributed hydrological models, University of Waterloo, Dept. of Civil Engineering, August 1997.

12. Application of the Data Set

The discharge rates of streams provide a measurement of water leaving the study area. When used together with precipitation data, these two sets of data provide a balance of the water cycle.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

Several computer programs are required to develop the rating curves and the stream discharge rates. FitFlow is a program written in Quickbasic to fit polynomial functions to stage-discharge tables. This task can be performed by any curve fitting program. This program is not needed by users of this data set.

14.2 Software Access

None given.

15. Data Access

The HYD-09 streamflow data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

ORNL DAAC User Services
Oak Ridge National Laboratory
P.O. Box 2008 MS-6407
Oak Ridge, TN 37831-6407
Phone: (423) 241-3952
Fax: (423) 574-4665
E-mail: ornldaac@ornl.gov or ornl@eos.nasa.gov

15.2 Data Center Identification

Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC) for Biogeochemical Dynamics http://www-eosdis.ornl.gov/.

15.3 Procedures for Obtaining Data

Users may obtain data directly through the ORNL DAAC online search and order system [http://www-eosdis.ornl.gov/] and the anonymous FTP site [ftp://www-eosdis.ornl.gov/data/] or by contacting User Services by electronic mail, telephone, fax, letter, or personal visit using the contact information in Section 15.1.

15.4 Data Center Status/Plans

The ORNL DAAC is the primary source for BOREAS field measurement, image, GIS, and hardcopy data products. The BOREAS CD-ROM and data referenced or listed in inventories on the CD-ROM are available from the ORNL DAAC.

16. Output Products and Availability

16.1 Tape Products

None.

16.2 Film Products

None.

16.3 Other Products

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

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

Hoskin Scientific Limited. 1992. Chart pac Cp-X (price and specification sheet).

Kouwen, N., R. Soulis, W. Jenkinson, A. Graham, and T. Neff. 1997. BOREAS: Boreal Forest Hydrological Research Study. Hydrology 9 Group: From Micro-scale to meso-scale snowmelt, soil moisture and evapotranspiration from distributed hydrological models, University of Waterloo, Dept. of Civil Engineering, August 1997. [an Adobe Acrobat file]

Lakewood Systems Ltd.: float sensor fs-15: data sheet.

Marsh-McBirney, Inc. Flo-Mate Model 2000 Portable Water Flowmeter Instruction Manual. 1990.

Swoffer Model 2100 Indicator Operation Manual

17.2 Journal Articles and Study Reports

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).

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

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AES     - Atmospheric Environment Service of Canada
ASCII   - American Standard Code for Information Interchange
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
CD-ROM  - Compact Disk (optical), Read-Only Memory
DAAC    - Distributed Active Archive Center
DC      - Direct Current
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
FFC-T   - Focused Field Campaign - Thaw
GIS     - Geographical Information System
GMT     - Greenwich Mean Time
GSFC    - Goddard Space Flight Center
HYD     - Hydrology
IFC     - Intensive Field Campaign
NASA    - National Aeronautics and Space Administration
NSA     - Northern Study Area
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
SSA     - Southern Study Area
URL     - Uniform Resource Locator
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Also, cite the BOREAS CD-ROM set as:

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

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13. ABSTRACT *(Maximum 200 words)*

The BOREAS HYD-9 team collected several data sets containing precipitation and streamflow measurements over the BOREAS study areas. These streamflow data were collected by the HYD-09 science team to support its research into meltwater supply to the soil during the spring melt period. These data were also collected for HYD-09's research into the evolution of soil moisture, evaporation, and runoff from the end of the snowmelt period through freeze up. Data were collected in the BOREAS SSA and NSA from April until October in 1994, 1995, and 1996. Gauges SW1 and NW1 were operated year-round; however, data may not be available for both gauges for all 3 years. The data are available in tabular ASCII files.

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