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BOREAS HYD-2 Estimated Snow Water Equivalent (SWE) from Microwave Measurements

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BOREAS HYD-2 Estimated Snow Water Equivalent (SWE) from Microwave Measurements

Hugh Powell, Alfred T. C. Chang

Summary

The surface meteorological data collected at the BOREAS tower and ancillary sites are being used as inputs to an energy balance model to monitor the amount of snow storage in the boreal forest region. The BOREAS HYD-2 team used SWE derived from an energy balance model and in situ observed SWE to compare the SWE inferred from airborne and spaceborne microwave data, and to assess the accuracy of microwave retrieval algorithms. The major external measurements that are needed are snowpack temperature profiles, in situ snow areal extent, and SWE data. The data in this data set were collected during February 1994 and cover portions of the SSA, NSA, and the transect areas. The data are available from BORIS as comma-delimited tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS HYD-02 Estimated Snow Water Equivalent (SWE) from Microwave Measurements

1.2 Data Set Introduction

The estimated Snow Water Equivalent (SWE) data set contains SWE as obtained via airborne measurements. The time period of the experiment was 02-Feb to 18-Feb-1994 during the BOReal Ecosystem-Atmosphere Study (BOREAS) winter focused field campaign (FFC-W). The instrumentation used was a series of microwave radiometers (specifically the 18-, 37-, and 92-GHz channels) that were mounted on a Twin Otter aircraft. The data set also contains other relevant data regarding the conditions under which each measurement was taken. For example, the temperature and dewpoint at the time of the measurement as well as the pitch and roll of the aircraft are also included.

1.3 Objective/Purpose

The objective of this investigation was to quantify the storage of water in snowpacks beneath the forest canopy. Ground water measurements were used as validation for the airborne and spaceborne SWE algorithm. This data set was created based on airborne microwave measurements to help address the question of the extent to which differences in surface cover affect snow storage.

1.4 Summary of Parameters

The specific parameters under observation for this experiment are the snowpack temperature profiles, the snow areal extent, and the SWE measured.

1.5 Discussion

During the 1994 FFC-W, 14 Twin Otter flights were made for the BOREAS project. Each of the 14 flights represents a number of different flight lines. The latitude and longitude of each data record are included with the data. Three microwave radiometers (18-, 37-, and 92-GHz) were mounted onboard the aircraft, in addition to videocameras and a PRT-5 thermal sensor. SWE was derived from the microwave radiometer data that were collected.

1.6 Related Data Sets

Nimbus-7 SMMR derived global snow depth maps (available through the National Snow and Ice Data Center (NSIDC), http://www-nsidc.colorado.edu/NASA/GUIDE/ [Internet Link]).

BOREAS HYD-03 Snow Depths Data
BOREAS HYD-03 Snow PitsData
BOREAS HYD-03 Snow Temperature DataA HREF="../hyd03/hyd03_snow_depths.html">
BOREAS HYD-03 Snow Water Data
BOREAS HYD-04 Areal Snow Course Data
BOREAS HYD-04 Standard Snow Course Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

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Hydrological Sciences Branch

Co-Investigators:
Dr. Dorothy K. Hall
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Hydrological Sciences Branch

Dr. James L. Foster
NASA GSFC
Hydrological Sciences Branch

2.2 Title of Investigation

Validation of a Passive Microwave Snow Water Equivalent Algorithm Using an Energy Balance Model

2.3 Contact Information

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3. Theory of Measurements

Microwave signatures have been used to infer SWE values over Canadian Prairie with some success (Goodison and Walker, 1993). Microwave radiation emanates from features on or near the surface of Earth at an intensity that is proportional to the product of the physical temperature and the emissivity of the surface. The measured value, referred to as the brightness temperature (TB), can simply be expressed as:

$$TB = (R * T_{sky} + (1 - R) * T_{surf} e\text{-}t + T_{atm} \qquad (1)$$

where e-t is the atmospheric transmissivity, R is the surface reflectivity, T_{sky} is the sky radiation, T_{surf} is the surface emission, and T_{atm} is the emission from the intervening atmosphere. In the microwave region, both T_{sky}and T_{atm} are small and can be neglected. Thus, the observed TB is directly related to surface features.

Based on radiative transfer calculations (Chang et al., 1987), a relationship between brightness temperature and the number of snow crystals was developed for SWE retrieval. The differences between the 18- and 37-GHz horizontal polarization brightness temperature are linearly related to the SWE values when SWE is less than 200 mm. The scattering information comes largely from the 37-GHz signal. The 18-GHz signal serves as the background reference. The SWE - brightness temperature relationship of a homogeneous snow layer with crystals having a mean radius of 0.3 mm and density of 300 kg/m^3 for the Scanning Multichannel Microwave Radiometer (SMMR) data can be expressed as follows (Chang et al., 1987);

$$SWE = 4.8 \times (T18H - T37H) \qquad (2)$$

where SWE is the snow water equivalent in mm of equivalent water, and T18H and T37H are the brightness temperatures for the 18- and 37-GHz horizontal polarizations, respectively. Both vertical and horizontal polarization will give generally similar results in Eq. (2). Because of the differences in the surface snow characteristics, researchers have used either vertical or horizontal polarization (Hallikainen and Jolma, 1992; Goodison and Walker, 1994) in retrieving the SWE. Rott and Aschbacher (1989) proposed a more generalized relationship of SWE and brightness temperature:

$$SWE = A + B * DTB \quad (3)$$

where A and B are the offset and slope for brightness temperature difference and DTB is the brightness temperature difference between a high-scattering channel (37- or 85-GHz) and a low-scattering channel (18- or 19-GHz) for vertical or horizontal polarization channels. Based on ground measurements of SWE in forests, A and B were determined for the airborne sensor in the boreal region. For this experiment, A and B are 0.0 and 1.7, respectively, when using the 18- and 37-GHz vertical polarization data.

The brightness temperature difference for forest-covered areas will cancel out if the emissivities of forest for both the high-scattering and the low- scattering channels are approximately the same. This is based on the findings that the emissivities for forest in Finland at 37 and 18 GHz are very similar and have the values of 0.9 to 0.92 (Hallikainen et al., 1988). Thus, only the snow-covered fraction contributes to the brightness temperature difference. For a footprint with a fraction of forest cover (f) and fraction snow cover (1 -f), Eq. (3) will become

$$SWE = 1.7 * DTB /(1 - f) \quad (4)$$

Over the forested pixels, Eq. (3) would underestimate the SWE if not corrected for the forest cover. The amount of underestimation depends on the fraction of forest cover in Eq. (4). This equation was derived by Hallikainen for boreal forests in Finland that have similar forest conditions as the BOREAS sites. Because of the low sun angles for early February in the BOREAS test sites, accurate forest cover determination is difficult to obtain from the video. Therefore, fractional forest cover corrections were not included in this data set and f was set equal to 0. Data users may compute an estimate of the fractional forest cover from other BOREAS data sources and apply Eq. (4) to correct for the forest cover.

4. Equipment

4.1 Sensor/Instrument Description

Three dual polarization microwave radiometers at 18, 37, and 92 GHz were mounted onto a Canadian Twin Otter aircraft. Thermal radiation in the microwave region was measured using Dicke-type radiometers with two reference sources in 18, 37, and 92 GHz. The microwave radiation was received by square wave detectors. A PRT-5 infrared (IR) radiometer was also mounted on the aircraft.

4.1.1 Collection Environment

The data were collected during the BOREAS experiment FFC-W, which occurred from 02-Feb to 18-Feb-1994. The areas over which the data were collected included the BOREAS Northern Study Area (NSA), BOREAS Southern Study Area (SSA), and other surrounding areas. There were 14 flyovers for this particular investigation.

4.1.2 Source/Platform

Radiometers were mounted on the right side of the Twin Otter aircraft with a 45-degree look-angle.

4.1.3 Source/Platform Mission Objective

The mission of the Twin Otter was to serve as a platform for the brightness temperature measurements.

4.1.4 Key Variables

Brightness temperatures, IR temperature, and aircraft locations.

4.1.5 Principles of Operation

Dicke-type radiometers with two reference sources were used to measure brightness temperature. The 18-, 37-, and 92-GHz were Dicke radiometers (Ulaby et al., 1981). It was basically a total-power radiometer with (1) Dicke switch connected at the receiver input and used to modulate the input signal, and (2) a synchronous demodulator placed between the square-law detector and the low-pass filter. The predetection section consisted of the radio frequency (RF) amplifier, mixer, and intermediate frequency (IF) amplifier. It operated like a super-heterodyne radio receiver.

To stabilize the gain of the receiver, two internal microwave references were used, a warm load and a cold load, respectively. The warm loads were the ambient temperatures of the instrument, about 285 K. A noise diode was used as a cold load for the 18- and 37-GHz radiometers. For the 92-GHz radiometer, outside air was used to cool the cold load to about 240 K. Thus, the dynamic range of the 92-GHz radiometer is not optimum.

4.1.6 Instrument Measurement Geometry

The radiometers were set up such that a 45-degree angle looking out of the aircraft to the right was achieved. The pitch and roll of the aircraft were also recorded.

4.1.7 Manufacturer of Instrument

The radiometers were assembled at Goddard Space Flight Center (GSFC) using commercial parts. An Intel 486 IBM-compatible personal computer (PC) was used as the data logger.

4.2 Calibration

For the Dicke radiometer, a warm and a cold reference load are used to stabilize the gain. These international calibration load readings were taken once each minute. During the calibration cycle, no scene data were taken. External calibrations were performed by aiming the radiometer to known brightness temperature targets. Liquid nitrogen (77 K) and ambient Ecosorb target (290 K) were used as references. These calibrations were performed on the ground, while the instruments were mounted on the Twin Otter aircraft, before, during, and after the flight mission. Before and after shipping the instrument package, external calibrations were also done at GSFC. These calibrations were performed to make sure that there was no drift of the instrument during the BOREAS experiment.

4.2.1 Specifications

Radiometers were calibrated with clear sky, liquid nitrogen, and warm ecosorb targets.

4.2.1.1 Tolerance

Accuracy of the radiometers is about 2 K in nominal temperature range.

4.2.2 Frequency of Calibration

During a flight, calibration was done for 6 seconds out of every minute of data recording. External calibration was done twice during the mission.

4.2.3 Other Calibration Information

Losses for each component were measured in the laboratory in 1992.

5. Data Acquisition Methods

Microwave brightness temperatures were taken by aircraft from takeoff to landing, nominally lasting about 2 hours. Data were collected in 1-minute blocks, which included 6 seconds of calibration and 54 seconds of data from target. Data were recorded on the hard disk of a PC and were copied to other computers for further processing.

6. Observations

6.1 Data Notes

At the beginning of February 1994, the temperatures were very cold (about -40 °C), and the snowpack should have been dry. The temperature warmed up slowly during the 2 weeks of experimentation. During Flight 14, the air temperatures were close to 0 °C; thus, surface melting was possible. Data were taken over the NSA and SSA sites during the winter FFC.

6.2 Field Notes

None.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

Data were taken over the BOREAS NSA, SSA, and transect areas. The North American Datum of 1983 (NAD83) coordinates of the areas are:

NSA

Corner	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	55.540° N

SSA

Corner	Longitude	Latitude
Northwest	106.23° W	54.319° N
Northeast	104.24° W	54.223° N
Southeast	104.37° W	53.419° N
Southwest	106.30° W	53.513° N

The following table indicates the study area at which data were collected. 'REGION' indicates that the data were not collected in the SSA, NSA, nor in the area in between; the data for this flight were likely collected south of the SSA, in an agricultural area. 'TRANSECT' indicates that the data were collected in the transect area between the NSA and SSA.

SPATIAL_COVERAGE	DATE_OBS	START_TIME	END_TIME	FLIGHT_NUM
SSA	06-FEB-1994	1527	1723	FLIGHT #1
REGION	06-FEB-1994	1808	1942	FLIGHT #2
SSA	06-FEB-1994	2018	2237	FLIGHT #3
SSA	07-FEB-1994	1537	1758	FLIGHT #4
SSA	07-FEB-1994	1943	2134	FLIGHT #5
SSA	08-FEB-1994	1456	1621	FLIGHT #6
TRANSECT	08-FEB-1994	1834	2006	FLIGHT #7
NSA	08-FEB-1994	2049	2213	FLIGHT #8
NSA	09-FEB-1994	1558	1806	FLIGHT #9
NSA	09-FEB-1994	1856	2012	FLIGHT #10
SSA	09-FEB-1994	2057	2238	FLIGHT #11
SSA	10-FEB-1994	1957	2218	FLIGHT #12
SSA	11-FEB-1994	2040	2308	FLIGHT #13
SSA	13-FEB-1994	1957	2221	FLIGHT #14

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
These data were taken from an aircraft altitude of 2,500 feet, which resulted in a spatial resolution of approximately 350 feet at the 45-degree viewing angle. The spatial resolution of a microwave radiometer depends on the beam width of the antenna. The beam width of the antenna is 6°, which is roughly about one tenth of a radian. Thus, the field of view (FOV) is about one tenth of the aircraft altitude. Normally, the radiometers were looking at 45° to the left side of the aircraft. When the aircraft pitches or rolls, the FOV size and position could be changed greatly. Data with large pitch and roll angles should not be used for SWE study.

7.1.4 Projection
Not applicable.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics
Most of the 14 flight lines were covered once during the mission.

7.2.1 Temporal Coverage
The data were collected from 06-Feb-1994 to 13-Feb-1994.

7.2.2 Temporal Coverage Map
Not available.

7.2.3 Temporal Resolution
In each minute, data values were collected once per second for 53 seconds; the remaining time was used for instrument calibration. Some data gaps exist.

7.3 Data Characteristics

7.3.1 Parameter/Variable

The data contained in the data files are:

```
Parameter
---------
GMT
18V
18H
37V
37H
92V
92H
SWE
Evet
Ralt
PsAlt
AcLat
AcLong
FltLat
FltLong
TAS
GS
Hdg
Wind
Temp
DewP
PRT5
Sun
Ptch
Roll
DX
DY
```

7.3.2 Variable Description/Definition

The descriptions of the parameters in the data files are:

```
Parameter  Definition
---------  ----------
GMT        Greenwich mean time
18V        18 GHz brightness temperature (V)
18H        18 GHz brightness temperature (H)
37V        37 GHz brightness temperature (V)
37H        37 GHz brightness temperature (H)
92V        92 GHz brightness temperature (V)
92H        92 GHz brightness temperature (H)
SWE        Estimated snow water equivalent
Evet       Flight line marker
Ralt       Radar Altitude
PsAlt      Pressure Altitude
AcLat      Latitude of aircraft
AcLong     Longitude of aircraft
FltLat     Latitude of measurement location
```

FltLong	Longitude of measurement location
TAS	True air speed
GS	Ground speed
Hdg	Aircraft heading
Wind	Wind direction and speed
Temp	Air temperature
DewP	Dewpoint temperature
PRT5	IR surface temperature
Sun	Solar input
Ptch	Aircraft Pitch angle
Roll	Aircraft Roll angle
DX	x offset
DY	y offset

7.3.3 Unit of Measurement

The descriptions of the units in the data files are:

Parameter	Units
GMT	[Hr:Min:Sec]
18V	[Kelvin]
18H	[Kelvin]
37V	[Kelvin]
37H	[Kelvin]
92V	[Kelvin]
92H	[Kelvin]
SWE	[millimeters]
Evet	[None]
Ralt	[meters]
PsAlt	[meters]
AcLat	[degrees of latitude]
AcLong	[degrees of longitude]
FltLat	[degrees of latitude]
FltLong	[degrees of longitude]
TAS	[meters][second^-1]
GS	[meters][second^-1]
Hdg	[degrees]
Wind	[degrees][meters][second^-1]
Temp	[degrees Celsius]
DewP	[degrees Celsius]
PRT5	[degrees Celsius]
Sun	[Watts][meter^-2]
Ptch	[degrees]
Roll	[degrees]
DX	[meters]
DY	[meters]

7.3.4 Data Source

The descriptions of the source of the data files are:

Parameter	Source
GMT	WWV radio station
18V	radiometer
18H	radiometer
37V	radiometer
37H	radiometer
92V	radiometer
92H	radiometer
SWE	inferred
Evet	1 flight line 0 non-flight line
Ralt	radar
PsAlt	Barometer
AcLat	GPS
AcLong	GPS
FltLat	GPS
FltLong	GPS
TAS	INS
GS	INS
Hdg	INS
Wind	INS
Temp	Rosemount
DewP	Hygrometer
PRT5	Barnes PRT5
Sun	Pyrometer
Ptch	INS
Roll	INS
DX	GPS
DY	GPS

7.3.5 Data Range

The descriptions of the ranges of the data files are:

Parameter	Range
GMT	00:00:00 - 23:59:59 hours
18V	0-300
18H	0-300
37V	0-300
37H	0-300
92V	0-300
92H	0-300
SWE	0-250 mm
Evet	0-1
Ralt	None given.
PsAlt	None given.
AcLat	None given.
AcLong	None given.
FltLat	None given.
FltLong	None given.

```
TAS         0-150
GS          0-150
Hdg         0-360
Wind Dir.   0-360
Wind Sp.    0-200
Temp        None given.
DewP        None given.
PRT5        None given.
Sun         None given.
Ptch        -90 to 90
Roll        -90 to 90
DX          None given.
DY          None given.
```

7.4 Sample Data Record

The following are wrapped versions of sample data records from one of the data files:

```
GMT,AMMR 18-V,AMMR 18-H,AMMR 37-V,AMMR 37-H,AMMR 92-V,AMMR 92-H,SWE,Evnt,
RadAlt(m),PsAlt(m),AcLat(Deg),AcLon(Deg),FtpLat(Deg),FtpLon(Deg),AirSpd(m/s),
GrSpd(m/s),Hdg(Deg),WinDir(Deg),WinSpd(m/s),AirTemp(C),DewPt(C),PRT5(C),
SolarIn(W/m2),AcPitch(Deg),AcRoll(Deg),XOff(m),YOff(m)
19:57:41,,,,,,,,0,2,429,53.2178,105.684,53.2178,105.684,-0.4,0.2,89,251,0.4,
-2,- 11.7,-15.3,297,-0.8,-0.4,0,-2
19:57:42,,,,,,,,0,2,429,53.2178,105.684,53.2178,105.684,-0.4,0.2,89,251,0.4,
-2,- 11.8,-15.3,297,-1,-0.5,0,-2
19:57:43,,,,,,,,0,2,429,53.2178,105.684,53.2178,105.684,-0.4,0.2,89,251,0.4,
-1.9 ,-11.8,-15.3,297,-1.1,-0.5,0,-2
```

8. Data Organization

8.1 Data Granularity

The smallest amount of data that can be ordered from this data set is the data from one flight.

8.2 Data Format

The Compact Disk-Read-Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) numerical and character fields of varying length separated by commas. 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.

The SWE data set contains 28 columns of data. It is written in ASCII text with two header lines describing the contents of the column beneath it. The data columns are comma delimited. The columns in left-to-right order are:

```
GMT   - Greenwich Mean Time, the time at which the observation was made
18-V  - The 18-GHz vertical channel reading in Kelvin
18-H  - The 18-GHz horizontal channel reading in Kelvin
37-V  - The 37-GHz vertical channel reading in  Kelvin
37-H  - The 37-GHz horizontal channel reading in Kelvin
92-V  - The 92-GHz vertical channel reading in  Kelvin
92-H  - The 92-GHz horizontal channel reading in Kelvin
```

```
SWE    - Snow Water Equivalent, in mm
Evnt   - Event marker, set to 1 over predetermined flight lines
RAlt   - Radar altimeter reading in meters
PsAlt  - Pressure altimeter reading in meters
AcLat  - Recorded latitude of aircraft in degrees
AcLong  - Recorded longitude of aircraft in degrees
FtpLat  - Recorded latitude of footprint in degrees
FtpLong - Recorded longitude of footprint in degrees
TAS   - True air speed in meters per second
GS    - Ground speed in meters per second
Hdg   - Recorded aircraft heading in degrees
Wind  - Direction of wind in degrees
Wind  - Speed of wind in meters per second
Temp  - Recorded air temperature in degrees Celsius
DewP  - Recorded dew point temperature in degrees Celsius
PRT5  - IR surface temperature in degrees Celsius
Sun   - Solar intensity upon surface in Watts per meter squared
Ptch  - Recorded aircraft pitch in degrees
Roll  - Recorded aircraft roll in degrees
DX    - X-offset between aircraft and footprint in meters
DY    - Y-offset between aircraft and footprint in meters
```

9. Data Manipulations

9.1 Formulae

Measured radiometric units have been converted to brightness temperature using the following equations:

$$TB = TH-(dc-hc)/(cc-hc)*(TH-TC)$$

where: dc = data counts
cc = cold counts
hc = hot counts
TC = cold load temperature
TH = hot load temperature

9.1.1 Derivation Techniques and Algorithms

Radiometer calibration was done by pointing the antenna to cold sky and a liquid nitrogen bucket as the cold references; ecosorb at ambient temperature is used as the warm reference target.

9.2 Data Processing Sequence

9.2.1 Processing Steps

The data collected during the flights were processed using the following steps:

- The raw data counts from each radiometer were read from the collected data file.
- These data were then converted to antenna temperature using the calibration equations derived.
- Loss corrections were applied to the antenna temperature to create brightness temperature.
- SWE was derived from equations.
- SWE was merged with aircraft navigation data and PRT-5 IR data.
- Output was saved on 8-mm tape cartridge.
- BOREAS Information System (BORIS) staff read the files from tape, added commas to delimit the different columns, and wrote the data back to tape.

9.2.2 Processing Changes

None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None given.

9.3.2 Calculated Variables

Please refer to Eq. (3) in Section 3 of this document for the equation used to infer the SWE values.

9.4 Graphs and Plots

Brightness temperatures for each flight are plotted as a function of time, as a quick-look product. Please contact personnel at the Hydrological Sciences Branch at GSFC.

10. Errors

10.1 Sources of Error

Errors in the calibrated brightness temperature data may arise from several sources:

- Instrumentation operation temperature: Because of the cold ambient temperature, the instrument temperature could not be controlled accurately.
- Stability of the noise diode.

10.2 Quality Assessment

10.2.1 Data Validation by Source

Comparisons were made with Special Sensor Microwave Imager (SSM/I) data over the same area and available water targets.

10.2.2 Confidence Level/Accuracy Judgment

The 18- and 37-GHz radiometers are believed to be accurate to about +/-3 K. The 92-GHz radiometer may be accurate to approximately +/-10 K. For SWE value, the accuracy is approximately 5 mm.

10.2.3 Measurement Error for Parameters

None given.

10.2.4 Additional Quality Assessments

None given.

10.2.5 Data Verification by Data Center

None given.

11. Notes

11.1 Limitations of the Data

During the aircraft flights, it was found that the 92-GHz brightness temperature was not very stable because of the instability in the cold reference load temperature. There was also a problem with the 37-GHz horizontal polarization data. Therefore, the quality of these data is somewhat uncertain.

11.2 Known Problems with the Data

None given.

11.3 Usage Guidance

None given.

11.4 Other Relevant Information

None given.

12. Application of the Data Set

This data set may be used to study the energy balance for the BOREAS sites.

13. Future Modification and Plans

There are no reprocessing plans at this time.

14. Software

14.1 Software Description

None given.

14.2 Software Access

None given.

15. Data Access

The SWE 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/ [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

The data can be made available on 8-mm tape.

16.2 Film Products

None.

16.3 Other Products

These data are available on the BOREAS CD-ROM series. Videotapes from the Twin Otter flights are also available.

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

None given.

17.2 Journal Articles and Study Reports

Chang, A.T.C., J.L. Foster, and D.K. Hall. 1987. Nimbus-7 derived global snow cover parameters. Annals of Glaciology, 9:39-44.

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

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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
EOS      - Earth Observing System
EOSDIS   - EOS Data and Information System
FFC-W    - Focused Field Campaign - Winter
FOV      - Field of View
GIS      - Geographic Information System
GMT      - Greenwich Mean Time
GPS      - Global Positioning System
GSFC     - Goddard Space Flight Center
HTML     - HyperText Markup Language
HYD      - Hydrology
INS      - Inertial Navigation System
IR       - InfraRed
MTPE     - Mission to Planet Earth
MW       - MicroWave
NASA     - National Aeronautics and Space Administration
NSA      - Northern Study Area
NSIDC    - National Snow and Ice Data Center
ORNL     - Oak Ridge National Laboratory
PANP     - Prince Albert National Park
PC       - Personal Computer
PRT5     - Borneo Model PRT-5 radiation thermometer
SMMR     - Scanning Multichannel Microwave Radiometer
SSA      - Southern Study Area
SSM/I    - Special Sensor Microwave Imager
SWE      - Snow Water Equivalent
URL      - Uniform Resource Locator
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The surface meteorological data collected at the BOREAS tower and ancillary sites are being used as inputs to an energy balance model to monitor the amount of snow storage in the boreal forest region. The BOREAS HYD-2 team used SWE derived from an energy balance model and in situ observed SWE to compare the SWE inferred from airborne and spaceborne microwave data, and to assess the accuracy of microwave retrieval algorithms. The major external measurements that are needed are snowpack temperature profiles, in situ snow areal extent, and SWE data. The data in this data set were collected during February 1994 and cover portions of the SSA, NSA, and the transect areas. The data are available from BORIS as comma-delimited tabular ASCII files.

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