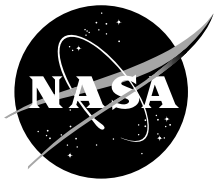
NASA/TM—2000–209891, Vol. 68



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

Forrest G. Hall and Jaime Nickeson, Editors

Volume 68

BOREAS RSS-16 AIRSAR CM Images: Integrated Processor Version 6.1 Level-3b

S. Saatchi, J.A. Newcomer, R. Strub, F. Irani

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

August 2000

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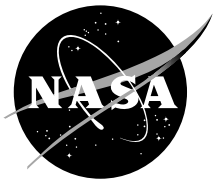

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Jeffrey A. Newcomer and Richard Strub, Raytheon ITSS
Fred Irani, Hughes STX

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

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BOREAS RSS-16 AIRSAR CM Images: Integrated Processor Version 6.1 Level-3b

Sasan Saatchi, Jeffrey A. Newcomer, Richard Strub, Fred Irani

Summary

The BOREAS RSS-16 team used satellite and aircraft SAR data in conjunction with various ground measurements to determine the moisture regime of the boreal forest. RSS-16 assisted with the acquisition and ordering of NASA JPL AIRSAR data collected from the NASA DC-8 aircraft. The NASA JPL AIRSAR is a side-looking imaging radar system that utilizes the SAR principle to obtain high-resolution images that represent the radar backscatter of the imaged surface at different frequencies and polarizations. The information contained in each pixel of the AIRSAR data represents the radar backscatter for all possible combinations of horizontal and vertical transmit and receive polarizations (i.e., HH, HV, VH, and VV). Geographically, the data cover portions of the BOREAS SSA and NSA. Temporally, the data were acquired from 12-Aug-1993 to 31-Jul-1995. The level-3b AIRSAR CM data are in compressed Stokes matrix format, which has 10 bytes per pixel. From this data format, it is possible to synthesize a number of different radar backscatter measurements. The data are stored in binary image-format files.

Note that the level-3b AIRSAR data are not contained on the BOREAS CD-ROM set. An inventory listing file is supplied on the CD-ROM to inform users of the data that were collected. See Sections 15 and 16 for information about how to acquire the data.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS RSS-16 AIRSAR CM Images: Integrated Processor Version 6.1 Level-3b

1.2 Data Set Introduction

The BOReal Ecosystem-Atmosphere Study (BOREAS) Staff Science effort covered those activities that were BOREAS community-level activities or required uniform data collection procedures across sites and time. These activities included the acquisition of the relevant aircraft image data. Data from the Airborne Synthetic Aperture Radar (AIRSAR) system onboard the National Aeronautics and Space Administration (NASA) DC-8 aircraft were acquired by staff at the Jet Propulsion Laboratory (JPL) and provided for use by BOREAS researchers.

The level-3b AIRSAR Compressed Matrix (CM) data set described here was produced at the JPL Synthetic Aperture Radar (SAR) processing facility and delivered to the BOREAS Information System (BORIS) on CD-ROM. This data set represents a replacement to the CM data previously delivered to BORIS. In February of 1998, after the AIRSAR data had been delivered to BORIS, documented, inventoried, and delivered to Oak Ridge National Laboratory (ORNL), we received a letter from JPL notifying us that they had discovered and resolved a problem in the AIRSAR Integrated Processor Versions 5.01 and 5.02, with which BOREAS data had been processed. At this time, the AIRSAR program management offered to reprocess all delivered data with a new processor. This data set represents the reprocessed data, processed with the AIRSAR Integrated Processor Version 6.1.

1.3 Objective/Purpose

The purpose of this data set is to provide multifrequency and multipolarization SAR images over the BOREAS Southern Study Area (SSA). This data set supplements other visible and near-infrared remote sensing images compiled by BOREAS. The level-3b AIRSAR data were acquired at three frequencies of P-band, L-band, and C-band and for all linear polarization combinations (HH, HV, VH, and VV). The level-3b AIRSAR CM image data products contain data from all 12 frequency and polarization combinations. AIRSAR images are used to estimate surface parameters such as canopy water content, soil moisture, and stand biomass and density.

1.4 Summary of Parameters

SAR parameters: incidence angle, aircraft altitude, range resolution, azimuth resolution, frequency, polarization.

1.5 Discussion

AIRSAR image data gathering for BOREAS was conducted in 1993 and 1994 over the two study areas in Canada. BOREAS was designed to study regional land surface climatology and to develop methods for deriving quantitative information about surface variables from remote sensing data. The AIRSAR experiment was devised to provide surface moisture and vegetation variables suitable for the soil-vegetation-atmosphere interaction models. In particular, the high-resolution data obtained by the AIRSAR system can be used to derive information about the variability of the surface parameters, which in turn can be used to address the scaling problem.

1.6 Related Data Sets

BOREAS RSS-16 Level-3b DC-8 AIRSAR SY Images

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Sasan S. Saatchi

2.2 Title of Investigation

Estimation of Evapotranspiration Using SAR Derived Parameters

2.3 Contact Information

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3. Theory of Measurements

The basic quantity measured by a polarimetric radar is a complex (amplitude and phase) scattering matrix for each resolution element of the radar image. This implies that AIRSAR is a multichannel system designed to maintain phase coherence between radar antennas and different channels. The polarization states used in the AIRSAR system are based on horizontal and vertical antennas. The radar is configured to measure all possible combinations available from the horizontal (H) and vertical (V) antennas (i.e., H transmitting, H receiving, and so forth). The complete scattering matrix for a resolution element can then be determined. Knowledge of the scattering matrix permits calculation of the received power for any possible combination.

4. Equipment

4.1 Sensor/Instrument Description

SAR refers to a technique used to synthesize a very long antenna by combining signals (echoes) received by the radar as it moves along its flight track. NASA JPL currently maintains and operates the AIRSAR/Topographic SAR (TOPSAR), which flies on the NASA DC-8 aircraft.

The AIRSAR system is an airborne SAR that operates simultaneously in a fully polarimetric mode at three frequencies (P-, L-, and C- bands). JPL operates the radar aboard the NASA Ames Research Center DC-8 aircraft. The data collected by the AIRSAR system are processed to polarimetric imagery at JPL and provided to BORIS in digital and photographic forms. The AIRSAR system provides several output products, including real-time imagery and the final processed digital products. Two of the most common digital products are the CM products and the Synoptic (SY) products.

The real-time imagery is provided to the investigators for a SAR pass. This is a low-resolution, black-and-white, single-frequency/polarization (typically LHH) image of the entire pass. No digital data of this type are provided. Annotation of the image allows the investigators to select areas for further processing. The information on the data includes run name (name assigned to the data acquisition pass, typically the site name), Greenwich Mean Time (GMT) (day of year followed by GMT), A/C Lat-Lon, frame count, and frequency/polarization.

The standard AIRSAR CM product consists of a 16-look (20-MHz) or 8-look (40-MHz) "polarization compressed" digital file on tape for each frequency (for input to polarization synthesis software provided by JPL) and a color photo product. The frame product corresponds to about 12 km along-track of imagery by 10-15 km across-track. As part of the standard products, the data sets are calibrated by the ground SAR processor.

During the 1993 experiment, only limited data were collected over the BOREAS study areas. In 1994, a large amount of imagery was collected and is summarized in Section 7 below. In 1995, a special collection effort was planned to collect imagery over an area of the SSA that had been burned the previous season.

4.1.1 Collection Environment

The AIRSAR system operates within the fuselage of the DC-8 aircraft during flight. The AIRSAR was flown at medium altitudes aboard NASA's DC-8 aircraft based at NASA's JPL and provided 11-m slant range resolution at an altitude of 8000 m.

4.1.2 Source/Platform

NASA DC-8 aircraft.

4.1.3 Source/Platform Mission Objectives

The objective was to acquire multipolarization and multifrequency SAR images over the BOREAS study areas and transect region.

4.1.4 Key Variables

Polarization, radar frequency, radar look angle, aircraft altitude, range resolution, azimuth resolution, site lat-long coordinates, aircraft geometry.

4.1.5 Principles of Operation

The NASA JPL AIRSAR is a side-looking imaging radar system that utilizes the SAR principle to obtain high-resolution images that represent the radar backscatter of the imaged surface at different frequencies and polarizations.

4.1.6 Sensor/Instrument Measurement Geometry

During the BOREAS experiment, the instrument was located in the NASA DC-8 aircraft approximately 7,800 m above ground. The antennas are located on the port side of the aircraft looking at an angle over the site. The nominal pointing angle was 28 degrees, which covered the ground surface from approximately 28 to 72 degrees. All DC-8 AIRSAR CM level-3b images are produced at

6 m in range and 12 m in azimuth resolutions.

4.1.7 Manufacturer of Sensor/Instrument

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-4321

4.2 Calibration

4.2.1 Specifications

In one mode of operation, this system is capable of simultaneously collecting all four polarizations (HH, HV, VH, and VV) for three frequencies: L-band (lambda ~ 24 cm), C-band (lambda ~ 6 cm), and P-band (lambda ~ 68 cm). In another mode of operation, the AIRSAR/TOPSAR system collects all four polarizations (HH, HV, VH, and VV) for two frequencies: L-band (lambda ~ 24 cm) and P-band (lambda ~ 68 cm), while operating as an interferometer at C-band to simultaneously generate topographic height data.

AIRSAR/TOPSAR also has an along-track interferometer mode that is used to measure current speeds. Typical image sizes for AIRSAR/TOPSAR products are 12 km x 12 km, with 10-m resolution in both dimensions. Topographic map products generated by the TOPSAR system have been shown to have a height accuracy of 1 m in relatively flat areas and 5 m in mountainous areas.

4.2.1.1 Tolerance

Each image contains detailed calibration information in the header information area.

4.2.2 Frequency of Calibration

Much of the data produced by the AIRSAR are now calibrated, so that the radar backscatter measurements are in normalized radar cross-section format (m^2/m^2) or σ^0 (sigma zero). Sigma zero is the radar cross-section (measured in m^2) normalized by the area of the measurement, which in this case is the pixel area in square meters.

4.2.3 Other Calibration Information

Two types of complementary calibration techniques are used for AIRSAR data calibration: internal calibration and external calibration. For the internal calibration, the information collected from the system tests that are performed regularly during the flight is used to obtain calibration parameters to be used in the AIRSAR processor. This will ensure that all the polarization channels are calibrated relative to one another at each frequency. For external calibration, which calibrates the radar cross-section of the scene absolutely and removes channel imbalance and the cross-talk, information from the scene and dihedral corner reflectors as external targets is used. Investigators who are interested in checking the accuracy of the calibration and performing other corrections themselves can request a copy of the POLCAL software and the user's manual directly from JPL.

5. Data Acquisition Methods

The AIRSAR system acquires data during flights of the DC-8 aircraft. The instrument system acquires the data across the various spatial elements while the aircraft motion provides the forward motion for image acquisition.

6. Observations

6.1 Data Notes

None given.

6.2 Field Notes

None given.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

The BOREAS AIRSAR CM Level-3b images cover sections of the SSA and the Northern Study Area (NSA). The SSA and the NSA are located in the southwest and northeast portions of the overall BOREAS region.

Each image covers a 12-km along-track and 10-km across-track area. The images contain 1,280 pixels in each of the approximately 5,000 lines.

Most of the BOREAS AIRSAR level-3b CM imagery is over the SSA. There are two early season dates of level-3b SY imagery of the NSA. The SSA and the NSA are located in the southwest and northeast portions of the overall region.

The North American Datum of 1983 (NAD83) corner coordinates of the SSA are:

	Latitude	Longitude
Northwest	54.321°N	106.228°W
Northeast	54.225°N	104.237°W
Southwest	53.515°N	106.321°W
Southeast	53.420°N	104.368°W

The NAD83 corner coordinates of the NSA are:

	Latitude	Longitude
Northwest	56.249°N	98.825°W
Northeast	56.083°N	97.234°W
Southwest	55.542°N	99.045°W
Southeast	55.379°N	97.489°W

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

Resolution in range: 6.66 m (across-track). Resolution in azimuth: 12.27 m (along-track).

7.1.4 Projection

The Remote Sensing Science (RSS)-16 team informed BORIS personnel that the images have been resampled into a regular spatial grid; however, the details of the projection used are not known.

7.1.5 Grid Description

The RSS-16 team informed BORIS personnel that the images have been resampled into a regular spatial grid; however, the details of the gridding are not known.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

The AIRSAR CM level-3b data were collected during concentrated periods from 12-Aug-1993 to 31-Jul-1995.

7.2.2 Temporal Coverage Map

Date	Study Area
12-Aug-1993	SSA
11-Jun-1994	SSA
17-Apr-1994	NSA
17-Apr-1994	SSA
20-Apr-1994	NSA
21-Jul-1994	SSA
22-Apr-1994	SSA
23-Jul-1994	SSA
26-Apr-1994	SSA
28-Jul-1994	SSA
31-Jul-1995	SSA

7.2.3 Temporal Resolution

Most of the SSA Modeling Sub-Area (MSA) was covered by the AIRSAR CM images on two or three occasions from 12-Aug-1993 to 31-Jul-1995.

7.3 Data Characteristics

7.3.1 Parameter/Variable

The data files contain a mixture of character and binary components. The user is encouraged to contact JPL personnel for detailed format descriptions. For the most part, the actual image data are INTEGER*2 in a format compatible with Sun computer systems. The parameters contained in the inventory listing file on the CD-ROM are:

Column Name
SPATIAL_COVERAGE
DATE_OBS
TIME_OBS
PLATFORM
INSTRUMENT
NUM_BANDS
PLATFORM_ALTITUDE
NW_LATITUDE
NW_LONGITUDE
NE_LATITUDE
NE_LONGITUDE
SW_LATITUDE
SW_LONGITUDE
SE_LATITUDE
SE_LONGITUDE
JPL_PRODUCT_ID
CRTFCN_CODE

7.3.2 Variable Description/Definition

To translate the integer*2 values supplied in the file to radar cross-sections, one has to apply the following calculation:

```
(DN^2)/(General scale factor)
```

where the General scale factor is the general scale factor supplied in field 2 of the calibration header. The descriptions of the parameters contained in the inventory listing file on the CD-ROM are:

Column Name	Description
SPATIAL_COVERAGE	The general term used to denote the spatial area over which the data were collected.
DATE_OBS	The date on which the data were collected.
TIME_OBS	The Greenwich Mean Time (GMT) when the data were collected.
PLATFORM	The object (e.g., satellite, aircraft, tower, person) that supported the instrument.
INSTRUMENT	The name of the device used to make the measurements.
NUM_BANDS	The number of spectral bands in the data.
PLATFORM_ALTITUDE	The nominal altitude of the data collection platform above the target.
NW_LATITUDE	The NAD83 based latitude coordinate of the north-west corner of the minimum bounding rectangle for the data.
NW_LONGITUDE	The NAD83 based longitude coordinate of the northwest corner of the minimum bounding rectangle for the data.
NE_LATITUDE	The NAD83 based latitude coordinate of the north east corner of the minimum bounding rectangle for the data.
NE_LONGITUDE	The NAD83 based longitude coordinate of the north east corner of the minimum bounding rectangle for the data.
SW_LATITUDE	The NAD83 based latitude coordinate of the south west corner of the minimum bounding rectangle for the data.
SW_LONGITUDE	The NAD83 based longitude coordinate of the southwest corner of the minimum bounding rectangle for the data.
SE_LATITUDE	The NAD83 based latitude coordinate of the south east corner of the minimum bounding rectangle for the data.
SE_LONGITUDE	The NAD83 based longitude coordinate of the southeast corner of the minimum bounding rectangle for the data.
JPL_PRODUCT_ID	The JPL Radar Data Center product identifier.
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).

7.3.3 Unit of Measurement

The image values are stored as the amplitude, i.e. as the square root of the power reflected back from the target. The measurement units for the parameters contained in the inventory listing file on the CD-ROM are:

Column Name	Units
SPATIAL_COVERAGE	[none]
DATE_OBS	[DD-MON-YY]
TIME_OBS	[HHMM GMT]
PLATFORM	[none]
INSTRUMENT	[none]
NUM_BANDS	[counts]
PLATFORM_ALTITUDE	[meters]
NW_LATITUDE	[degrees]
NW_LONGITUDE	[degrees]
NE_LATITUDE	[degrees]
NE_LONGITUDE	[degrees]
SW_LATITUDE	[degrees]
SW_LONGITUDE	[degrees]
SE_LATITUDE	[degrees]
SE_LONGITUDE	[degrees]
JPL_PRODUCT_ID	[none]
CRTFCN_CODE	[none]

7.3.4 Data Source

The imagery were collected by the AIRSAR sensor aboard the NASA DC-8 research aircraft and were processed and provided by the Radar Data Center at the Jet Propulsion Laboratory, Pasadena, California. The sources of the parameter values contained in the inventory listing file on the CD-ROM are:

Column Name	Data Source
SPATIAL_COVERAGE	[Derived by BORIS from the image data files]
DATE_OBS	[Extracted from the image data files]
TIME_OBS	[Extracted from the image data files]
PLATFORM	[Constant value]
INSTRUMENT	[Constant value]
NUM_BANDS	[Extracted from the image data files]
PLATFORM_ALTITUDE	[Extracted from the image data files]
NW_LATITUDE	[Derived by BORIS developed software]
NW_LONGITUDE	[Derived by BORIS developed software]
NE_LATITUDE	[Derived by BORIS developed software]
NE_LONGITUDE	[Derived by BORIS developed software]
SW_LATITUDE	[Derived by BORIS developed software]
SW_LONGITUDE	[Derived by BORIS developed software]
SE_LATITUDE	[Derived by BORIS developed software]
SE_LONGITUDE	[Derived by BORIS developed software]
JPL_PRODUCT_ID	[Extracted from the image data files]
CRTFCN_CODE	[Assigned by BORIS]

7.3.5 Data Range

Typically radar images exhibit a dynamic range less than 30 dB. Therefore each data set is scaled by a single value for all pixels such that the dynamic range of the total power elements in the Stokes matrices falls within values between 2-128 and 2127. The total power for each matrix is then coded into two bytes, one for the exponent in the above range and one for the mantissa. The other eight elements stored in the 10-byte sample are then normalized. The following table gives information about the parameter values found in the inventory table on the CD-ROM:

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SPATIAL_COVERAGE	N/A	N/A	None	None	None	None
DATE_OBS	12-AUG-93	31-JUL-95	None	None	None	None
TIME_OBS	910	2141	None	None	None	None
PLATFORM	DC-8	DC-8	None	None	None	None
INSTRUMENT	N/A	N/A	None	None	None	None
NUM_BANDS	3	3	None	None	None	None
PLATFORM_ALTITUDE	7397.7	7770.5	None	None	None	None
NW_LATITUDE	53.9064	56.16305	None	None	None	None
NW_LONGITUDE	-106.96903	-98.40082	None	None	None	None
NE_LATITUDE	53.85669	55.98273	None	None	None	None
NE_LONGITUDE	-106.0159	-97.0018	None	None	None	None
SW_LATITUDE	53.46364	55.99398	None	None	None	None
SW_LONGITUDE	-107.03206	-98.44842	None	None	None	None
SE_LATITUDE	53.41428	55.83307	None	None	None	None
SE_LONGITUDE	-106.09375	-97.01739	None	None	None	None
JPL_PRODUCT_ID	N/A	N/A	None	None	None	None
CRTFCN_CODE	CPI	CPI	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

A sample data record for the level-3b AIRSAR SY images is not available here. The following is a sample of the first few records from the level-3b AIRSAR CM inventory table on the CD-ROM:

```
SPATIAL_COVERAGE,DATE_OBS,TIME_OBS,PLATFORM,INSTRUMENT,NUM_BANDS,
PLATFORM_ALTITUDE,NW_LATITUDE,NW_LONGITUDE,NE_LATITUDE,NE_LONGITUDE,SW_LATITUDE,
SW_LONGITUDE,SE_LATITUDE,SE_LONGITUDE,JPL_PRODUCT_ID,CRTFCN_CODE
'SSA',12-AUG-93,1604,'DC-8','AirSAR',3,7401.3,54.18676,-106.96903,54.15057,
-106.0159,53.5401,-107.03206,53.50446,-106.09375,'5408','CPI'
'SSA',12-AUG-93,1633,'DC-8','AirSAR',3,7479.3,54.12961,-106.81807,54.09205,
-105.86264,53.4834,-106.88333,53.44641,-105.94272,'5396','CPI'
'SSA',12-AUG-93,1700,'DC-8','AirSAR',3,7494.4,54.18495,-106.6663,54.1459,
-105.70355,53.53942,-106.73396,53.50095,-105.78614,'5399','CPI'
'SSA',12-AUG-93,1713,'DC-8','AirSAR',3,7502.7,54.15652,-106.07887,54.11219,
-105.10684,53.50504,-106.15637,53.46139,-105.19952,'5398','CPI'
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data tracked by BORIS was a particular level-3b CM image.

8.2 Data Format(s)

The CD-ROM inventory listing file consists of 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.

Since detailed format information on the AIRSAR data is available from JPL, BORIS personnel have not provided an exhaustive description of the data here. Please contact JPL personnel for further details.

The AIRSAR Integrated Processor Version 6.1 product received from JPL on CD-ROM contains seven files for each acquisition. The files of primary interest for data users are the P, L, and C frequency bands, named *_p.dat, *_L.dat, and *_C.dat, respectively. The other files are *.r, *.g, and a *.b files, which are the red, green, and blue files, respectively, used to create the browse prints (*.gif file), also included. In some cases a *.moc file is included, which is a motion data file, but this was included inconsistently and unintentionally.

Each record of a level-3b AIRSAR CM data file contains 10,240 bytes. The first three records in each file contain header information. The number of data records in a file varies depending on the length of the flight line. Each data record of 10,240 bytes contains a portion of the compressed Stokes matrix data. More specific information is as follows:

```
FILE 1 (the entire scene, headers and image data, is contained in a single file)
     C-band records:

       -  JPL AIRSAR New Header Record (Logical Record 1)
          *  20 records, each containing 50 ASCII characters.
          *  Remainder of the logical record (24,600 bytes) is filler.

       -  JPL AIRSAR Parameter Header Record (Logical Record 2)
          *  100 records, each containing 50 ASCII characters.
          *  Remainder of record (20,600 bytes) is filler.

       -  JPL AIRSAR Calibration Header Record (Logical Record 3)
          *  20 records, each containing 50 ASCII characters.
          *  Remainder of record (24,600 bytes) is filler.
```

- JPL AIRSAR CM Compressed Stokes matrix data records (Logical Record 4 to the end of the band). The end of the band can be determined by using the first five parameters (logical record size, nHeader recs, nLines, nSamples, nBytes per sample) listed in the New Header Record:

$$\frac{\text{logical rec size} * (\text{nHeader recs} - \#\text{ already read(3)}) + \text{nLines} * \text{nSamples} * \text{nBytes per sample}}{\text{Physical Record Size}}$$

Example:

$$\frac{25600 * (6-3) + 6699 * 2560 * 10}{1024}$$

L-band records:

- JPL AIRSAR New Header Record (Logical Record 1)
  * 20 records, each containing 50 ASCII characters.
  * Remainder of the logical record (24,600 bytes) is filler.

- JPL AIRSAR Parameter Header Record (Logical Record 2)
  * 100 records, each containing 50 ASCII characters.
  * Remainder of record (20,600 bytes) is filler.

- JPL AIRSAR Calibration Header Record (Logical Record 3)
  * 20 records, each containing 50 ASCII characters.
  * Remainder of record (24,600 bytes) is filler.

- JPL AIRSAR CM Compressed Stokes matrix data records (Logical Record 4 to the end of the band). The end of the band can be determined by using the first five parameters (logical record size, nHeader recs, nLines, nSamples, nBytes per sample) listed in the New Header Record:

$$\frac{\text{logical rec size} * (\text{nHeader recs} - \#\text{ already read(3)}) + \text{nLines} * \text{nSamples} * \text{nBytes per sample}}{\text{Physical Record Size}}$$

P-band records:

- JPL AIRSAR New Header Record (Logical Record 1)
  * 20 records, each containing 50 ASCII characters.
  * Remainder of the logical record (24,600 bytes) is filler.

- JPL AIRSAR Parameter Header Record (Logical Record 2)
  * 100 records, each containing 50 ASCII characters.
  * Remainder of record (20,600 bytes) is filler.

- JPL AIRSAR Calibration Header Record (Logical Record 3)
  * 20 records, each containing 50 ASCII characters.
  * Remainder of record (24,600 bytes) is filler.

- JPL AIRSAR CM Compressed Stokes matrix data records (Logical Record 4 to the end of the band). The end of the band can be determined by using the first five parameters (logical record size, nHeader recs, nLines, nSamples, nBytes per sample) listed in the New Header Record:

$$\frac{\text{logical rec size} * (\text{nHeader recs} - \#\text{ already read(3)}) + \text{nLines} * \text{nSamples} * \text{nBytes per sample}}{\text{Physical Record Size}}$$

9. Data Manipulations

9.1 Formulae

None.

9.1.1 Derivation Techniques and Algorithms

None given.

9.2 Data Processing Sequence

9.2.1 Processing Steps

BORIS staff makes the AIRSAR CM level-3b images available by:

- Duplicating the JPL delivered images for backup purposes.
- Extracting pertinent header information from the images for use in inventorying the level-3b image by date and time in the online data base.
- Reviewing the content of the extracted header information for potential problems/anomalies.
- Loading the needed information into the online data base.

9.2.2 Processing Changes

In early 1998, a problem was found in the AIRSAR Integrated Processor Versions 5.01 and 5.02. This problem affected the backscatter cross-section σ^0 values in some of the BOREAS products. BORIS personnel have sent both the 5.0x and 6.1 versions of the data to the ORNL DAAC. Users are encouraged to be sure they get the most recent version of the images that were contained on CD-ROM.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None given.

9.3.2 Calculated Variables

None given.

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

In early 1998, a problem was found in the AIRSAR Integrated Processor Versions 5.01 and 5.02. This problem affected the backscatter cross section σ^0 values in some of the BOREAS products. BORIS personnel have sent both the 5.0x and 6.1 versions of the data to the ORNL DAAC. Users are encouraged to be sure they get the most recent version of the images that was contained on CD-ROM.

10.2 Quality Assessment

10.2.1 Data Validation by Source

None given.

10.2.2 Confidence Level/Accuracy Judgment

None given.

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

BORIS staff reviews the images using developed software that was designed based on data product format documents received from JPL. The software reads through the data products on tape and summarizes the contents in ASCII files on disk. These files are reviewed visually by BORIS personnel for anomalous items.

11. Notes

11.1 Limitations of the Data

None given.

11.2 Known Problems with the Data

The data are provided in two different formats (see Section 8.2). Also see Section 9.2.2.

11.3 Usage Guidance

In early 1998, a problem was found in the AIRSAR Integrated Processor Versions 5.01 and 5.02. This problem affected the backscatter cross section σ^0 values in some of the BOREAS products. BORIS personnel have sent both the 5.0x and 6.1 versions of the data to the ORNL DAAC. Users are encouraged to be sure they get the most recent version of the images that were contained on CD-ROM.

11.4 Other Relevant Information

None given.

12. Application of the Data Set

AIRSAR images are used to estimate surface parameters such as canopy water content, soil moisture, and stand biomass and density.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

BORIS staff developed software and command procedures to:

- Check and extract information from level-3b AIRSAR CM images on tape and write the information to ASCII files on disk for both data formats.
- Read the ASCII disk file and log the level-3b AIRSAR CM images into the Oracle data base tables.

The software mentioned under items 1 and 2 is written in the C language and is operational on VAX 6410 and MicroVAX 3100 systems at Goddard Space Flight Center (GSFC). The primary dependencies in the software are the tape input/output (I/O) library and the Oracle data base utility routines.

14.2 Software Access

All of the described software is available upon request. BORIS staff would appreciate knowing of any problems discovered with the software, but cannot promise to fix them.

15. Data Access

The level-3b AIRSAR CM images are available from the Earth Observing System Data and Information System (EOSDIS) 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

The AIRSAR level-3b CM data can be made available on 8-mm or Digital Archive Tape (DAT) media.

16.2 Film Products

None.

16.3 Other Products

Although the inventory is contained on the BOREAS CD-ROM set, the actual level-3b AIRSAR CM images are not. See Section 15 for information about how to obtain the data.

During the data acquisition flight, 35-mm photographs were taken of the areas imaged by the AIRSAR system. Anyone interested in these photographs should contact Dr. Sasan Saatchi (see Section 2.3.)

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

Freeman, T. 1998. What is Imaging Radar? JPL Imaging Radar.

NASA JPL. Date unknown. "AIRSAR Data Formats," Chapter 4.

NASA JPL. 1995. AIRSAR Integrated Processor Documentation: DATA FORMATS. Version 0.01.

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.

van Zyl, J. 1992. The AIRSAR System. JPL document.

van Zyl, J. 1995. AIRSAR Integrated Processor Documentation, Version 0.01, April 21.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

```
AIRSAR  - Airborne Synthetic Aperture Radar
ASCII   - American Standard Code for International 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
CM      - Compressed Matrix
DAAC    - Distributed Active Archive Center
DAT     - Digital Archive Tape
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
GMT     - Greenwich Mean Time
GSFC    - Goddard Space Flight Center
JPL     - Jet Propulsion Laboratory
MSA     - Modeling Sub-Area
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NSA     - Northern Study Area
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
RSS     - Remote Sensing Science
SAR     - Synthetic Airborne Radar
SSA     - Southern Study Area
SY      - Synoptic
TOPSAR  - Topographic SAR
URL     - Uniform Resource Locator
```

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13. ABSTRACT *(Maximum 200 words)*

The BOREAS RSS-16 team used satellite and aircraft SAR data in conjunction with various ground measurements to determine the moisture regime of the boreal forest. RSS-16 assisted with the acquisition and ordering of NASA JPL AIRSAR data collected from the NASA DC-8 aircraft. The NASA JPL AIRSAR is a side-looking imaging radar system that utilizes the SAR principle to obtain high-resolution images that represent the radar backscatter of the imaged surface at different frequencies and polarizations. The information contained in each pixel of the AIRSAR data represents the radar backscatter for all possible combinations of horizontal and vertical transmit and receive polarizations (i.e., HH, HV, VH, and VV). Geographically, the data cover portions of the BOREAS SSA and NSA. Temporally, the data were acquired from 12-Aug-1993 to 31-Jul-1995. The level-3b AIRSAR CM data are in compressed Stokes matrix format, which has 10 bytes per pixel. From this data format, it is possible to synthesize a number of different radar backscatter measurements. The data are stored in binary image-format files.

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