NASA/TM—2000–209891, Vol. 174

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

Forrest G. Hall, Editor

Volume 174

BOREAS TE-18 Biomass Density Image of the SSA

Forrest G. Hall, NASA Goddard Space Flight Center
David Knapp, Raytheon ITSS, NASA Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

October 2000

Available from:

NASA Center for AeroSpace Information
7121 Standard Drive
Hanover, MD 21076-1320
Price Code: A17

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Price Code: A10

BOREAS TE-18 Biomass Density Image of the SSA

Forrest G. Hall, David Knapp

Summary

The BOREAS TE-18 team focused its efforts on using remotely sensed data to characterize the successional and disturbance dynamics of the boreal forest for use in carbon modeling. This biomass density image covers almost the entire BOREAS SSA. The pixels for which biomass density is computed include areas that are in conifer land cover classes only. The biomass density values represent the amount of overstory biomass (i.e., tree biomass only) per unit area. It is derived from a Landsat-5 TM image collected on 02-Sep-1994. The technique that was used to create this image is very similar to the technique that was used to create the physical classification of the SSA. The data are provided in a binary image file format.

Note that some of the data set files on the BOREAS CD-ROMs have been compressed using the Gzip program. See Section 8.2 for details.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-18 Biomass Density Image of the SSA

1.2 Data Set Introduction

This data set depicts biomass density for the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA). It is derived from a Landsat-5 Thematic Mapper (TM) scene collected on 02-Sep-1994 based on a technique developed by Dr. Forrest Hall.

1.3 Objective/Purpose

The objective of this study was to develop a set of biophysical parameter maps from Landsat-5 TM imagery. It is hoped that these products may be useful for determining amounts of carbon in the boreal ecosystem and will provide data for model input.

1.4 Summary of Parameters

Biomass Density

1.5 Discussion

This biomass density image covers almost the entire BOREAS SSA. The pixels for which biomass density is computed include areas that are in conifer land cover classes only. The biomass density values represent the amount of overstory biomass (i.e., tree biomass only) per unit area. The technique that was used to create this image is very similar to the technique that was used to create the physical classification of the SSA. This technique involves the use of trajectories that can be thought of as a set of points in red/near-infrared space. Each of these points represents a linear combination of reflectances of three end members that make up the land surface. The three main surface features include sunlit canopy, sunlit background, and shadow. The points of the trajectory range from 0% canopy to 100% canopy. A geometric optical canopy model was used to determine the areal proportions of each of these elements. The nearest trajectory point to each pixel of the Landsat TM image was determined to derive the biomass density based on the amount of canopy that exists in a pixel.

1.6 Related Data Sets

BOREAS TE-18 Landsat TM Maximum Likelihood Classification Image of the NSA
BOREAS TE-18 Landsat TM Maximum Likelihood Classification Image of the SSA
BOREAS TE-18 Landsat TM Physical Classification Image of the SSA

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Forrest Hall
Biospheric Sciences Branch
National Aeronautics and Space Administration (NASA)
Goddard Space Flight Center (GSFC)

2.2 Title of Investigation

TE-18 Regional Scale Carbon Flux from Modeling and Remote Sensing

2.3 Contact Information

Contact 1:

Dr. Forrest G. Hall
NASA GSFC
Code 923
Greenbelt, MD 20771
(301) 286-2974
(301) 286-0239 (fax)
Forrest.G.Hall@gsfc.nasa.gov

Contact 2:
David Knapp
Raytheon ITSS
NASA GSFC
Code 923
Greenbelt, MD 20771
(301) 286-1424
(301) 286-0239 (fax)
David.Knapp@gsfc.nasa.gov

3. Theory of Measurements

This biomass density image was derived from a Landsat-5 TM scene collected on 02-Sep-1994. A classification image was produced using end member reflectance trajectories. Please refer to the document for the BOREAS Terrestrial Ecology (TE)-18 Landsat TM physical classification image of the BOREAS SSA.

The general theory behind the method for deriving biomass density is very similar to the way that the classification image was created. The reflectance of a pixel is represented in this method as a linear combination of the reflectance of sunlit canopy, sunlit background, and shadow. A model of the canopy geometries was used for the various classes. This model computes the proportions of canopy, background, and shadow that occupy the area in a pixel based on solar and canopy geometry. Using ground and satellite reflectance measurements and the proportions of the end members, model reflectances were produced for each class. These model reflectances form a trajectory in red/near-infrared space within each class as the proportions of canopy cover go from 0% to 100%.

Ground measurements of biomass density were made for several sites in the SSA. These measurements were used to define a relationship between the biomass density and the amount of canopy cover at each site. A scaling factor was determined based on this relationship. The amount of canopy cover at each pixel was determined by finding the model reflectance that has the shortest distance in red/near-infrared space. The scaling factor is then applied to the amount of canopy cover for each pixel, resulting in an estimate of biomass density for that pixel.

4. Equipment

4.1 Instrument Description

The Landsat-5 TM sensor system records radiation in seven bands of the electromagnetic spectrum. It has a telescope that directs the incoming radiant flux obtained along a scan line through a scan line collector to the visible and near-infrared focal plane, or to the mid-infrared and thermal-infrared cooled focal plane. The detectors for the visible and near-infrared bands (1-4) are four staggered linear arrays, each containing 16 silicon detectors. The two mid-infrared detectors are 16 indium-antimonide cells in a staggered linear array, and the thermal-infrared detector is a four-element array of mercury-cadmium-telluride cells.

4.1.1 Collection Environment

The data used to produce this classification were collected by the Landsat-5 TM on 02-Sep-1994. Landsat-5 orbits Earth at an altitude of approximately 705 kilometers.

4.1.2 Source/Platform

Landsat-5 satellite

4.1.3 Source/Platform Mission Objectives

The mission of the Landsat-5 satellite is to measure reflected radiation from Earth's surface at a spatial resolution of 30 meters and to measure the temperature of Earth's surface at a spatial resolution of 120 meters.

4.1.4 Key Variables

Reflected radiation Emitted radiation Temperature

4.1.5 Principles of Operation

The TM is a scanning optical sensor operating in the visible and infrared wavelengths. It contains a scan mirror assembly that directly projects the reflected Earth radiation onto detectors arrayed in two focal planes. The TM achieves better imagery resolution, sharper color separation, and greater inflight geometric and radiometric accuracy for seven spectral bands simultaneously than the previous Multispectral Scanner (MSS). Data collected by the sensor are transmitted to Earth-receiving stations for processing.

4.1.6 Sensor/Instrument Measurement Geometry

The TM depends on the forward motion of the spacecraft for the along-track scan and uses a moving mirror assembly to scan in the cross-track direction (perpendicular to the spacecraft). The Instantaneous Field of View (IFOV) for each detector from bands 1-5 and band 7 is equivalent to a 30-meter square when projected to the ground; band 6 (the thermal-infrared band) has an IFOV equivalent to a 120-meter square.

4.1.7 Manufacturer of Sensor/Instrument

NASA GSFC
Greenbelt, MD 20771

Hughes Aircraft Corporation
Santa Barbara, CA

4.2 Calibration

The internal calibrator, a flex-pivot-mounted shutter assembly, is synchronized with the scan mirror, oscillating at the same 7-Hz frequency. During the turnaround period of the scan mirror, the shutter introduces the calibration source energy and a black direct-current restoration surface into the 100 detector fields of view.

The calibration signals for bands 1-5 and band 7 are derived from three regulated tungsten-filament lamps. The calibration source for band 6 is a blackbody with three temperature selections, commanded from the ground. The method for transmitting radiation to the moving calibration shutter allows the tungsten lamps to provide radiation independently and to contribute proportionately to the illumination of all detectors.

4.2.1 Specifications

The following spectral bands are collected by the TM sensor:

Channel	Wavelength (µm)	Primary Use
1	0.45 - 0.52	Coastal water mapping, soil vegetation differentiation, deciduous/coniferous differentiation.
2	0.52 - 0.60	Green reflectance by healthy vegetation.
3	0.63 - 0.69	Chlorophyll absorption for plant species differentiation.
4	0.76 - 0.90	Biomass surveys, water body delineation.
5	1.55 - 1.72	Vegetation moisture measurement, snow cloud differentiation.
6	10.4 - 12.5	Plant heat stress measurement, other thermal mapping.
7	2.08 - 2.35	Hydrothermal mapping.

Band	Radiometric Sensitivity [NE(dP)]*
1	0.8%
2	0.5%
3	0.5%
4	0.5%
5	1.0%
6	0.5 K [NE(dT)]
7	2.4%

Ground IFOV	30 m (bands 1-5, 7) 120 m (band 6)
Avg. altitude	699.6 km
Data rate	85 Mbps
Quantization levels	256
Orbit angle	8.15 degrees
Orbital nodal period	98.88 minutes
Scan width	185 km
Scan angle	14.9 degrees
Image overlap	7.6 %

* N.B. The radiometric sensitivities are the noise-equivalent reflectance differences for the reflective channels expressed as percentages [NE(dP)] and temperature differences for the thermal-infrared bands [NE(dT)].

4.2.1.1 Tolerance

The TM channels were designed for a noise-equivalent differential represented by the radiometric sensitivity shown in Section 4.2.1.

4.2.2 Frequency of Calibration

The absolute radiometric calibration between bands on both sensors is maintained by using internal calibrators that are located between the telescope and the detectors and are sampled at the end of a scan.

4.2.3 Other Calibration Information

Relative within-band radiometric calibration, to reduce "striping," is provided by a scene-based procedure called histogram equalization. The absolute accuracy and relative precision of this calibration scheme assumes that any change in the optics of the primary telescope or the "effective radiance" from the internal calibrator lamps is insignificant in comparison to the changes in detector sensitivity and electronic gain and bias with time and that the scene-dependent sampling is sufficiently precise for the required within-scan destriping from histogram equalization. Each TM reflective band and the internal calibrator lamps were calibrated prior to launch using lamps in integrating spheres that were in turn calibrated against lamps traceable to calibrated National Bureau of Standards lamps. Sometimes the absolute radiometric calibration constants in the "short-term" and "long-term parameters" files used for ground processing have been modified after launch because of inconsistency within or between bands, changes in the inherent dynamic range of the sensors, or a desire to make quantized and calibrated values from one sensor match those from another.

5. Data Acquisition Methods

These data were acquired from the Landsat-5 TM sensor and received from the Canadian Centre for Remote Sensing (CCRS), who purchased them from the Earth Observation Satellite Company (EOSAT). As received from CCRS, the image had been processed from raw telemetry to a systematically corrected product within the CCRS MOSAICS system.

6. Observations

6.1 Data Notes

This imagery was collected on 02-Sep-1994. This scene is Path 37, Row 22-23 (shifted) in the Landsat Worldwide Reference System (WRS). The solar elevation angle at the time of image acquisition was 40.1 degrees. The solar azimuth angle was 146 degrees. The radiometric quality of this imagery was acceptable.

The TM image from which this classification was produced was atmospherically corrected using aerosol optical thickness data measured by sunphotometers in the study area. These optical thickness data were used in the Second Simulation of the Satellite Signal in the Solar Spectrum (6S) program to determine the spherical albedo, path radiance, gaseous transmission, and scattering transmission. These parameters were used to determine surface reflectance based on equations 4a and 4b of Markham et al. (1992).

6.2 Field Notes

Not applicable.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

The image area that was classified covers an area that is approximately 144 km by 114 km and includes areas just north of Prince Albert, Saskatchewan. The corners of the data set are as follows. The BOREAS Grid coordinates are in the Albers Equal-Area Conic (AEAC) projection described in Section 7.1.4.

Corner	BOREAS Grid X	BOREAS Grid Y	NAD83 Long.	NAD83 Lat.
Northwest	297.810	392.490	106.401W	54.438N
Northeast	441.810	392.490	104.190W	54.333N
Southwest	297.810	278.490	106.515W	53.417N
Southeast	441.810	278.490	104.357W	53.314N

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
Each pixel represents a 30-meter by 30-meter area on the ground.

7.1.4 Projection
The area mapped is projected in the BOREAS Grid projection, which is based on the ellipsoidal version of the AEAC projection. The projection has the following parameters:

```
Datum:    North American Datum of 1983 (NAD83)
Ellipsoid:  Geodetic Reference System of 1980 (GRS80) or Worldwide Geodetic
System of 1984 (WGS84)
Origin:  111.000°W   51.000°N
Standard Parallels:  52° 30' 00"N
                     58° 30' 00"N
Units of Measure:  kilometers
```

7.1.5 Grid Description
The data are referenced to the projection described in Section 7.1.4.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage
This imagery was collected on 02-Sep-1994. This scene is Path 37, Row 22-23 (shifted) in the Landsat WRS. The solar elevation angle at the time of image acquisition was 40.1 degrees. The solar azimuth angle was 146 degrees. The radiometric quality of this imagery was acceptable.

7.2.2 Temporal Coverage Map
Not applicable.

7.2.3 Temporal Resolution
This data set represents the biomass density as it existed on 02-Sep-1994.

7.3 Data Characteristics

7.3.1 Parameter/Variable
Biomass density.

7.3.2 Variable Description/Definition
Biomass density: The amount of biomass per unit area.

7.3.3 Unit of Measurement
Tenths of kilograms of biomass per square meter.

7.3.4 Data Source
Landsat-5 TM scene on 02-Sep-1994 from the CCRS.

7.3.5 Data Range
Data are stored as 8-bit integers ranging from 0 to 255. Values of 254 and 255 represent pixels for which biomass density was not computed (i.e., not conifer). Values of 254 represent water pixels. Valid biomass density values in this image range from 0 to 253 (0.0 to 25.3 kg of overstory biomass per square meter).

7.4 Sample Data Record
Not applicable for image data.

8. Data Organization

8.1 Data Granularity
The smallest amount of data that can be ordered is the entire data set.

8.2 Data Format

8.2.1 Uncompressed Data Files
The SSA classification product contains two files as follows:

File 1: (80-byte American Standard Code for Information Interchange (ASCII) text records)
Text file listing the files on tape

File 2: (3,800 records of 4,800 bytes each) (1 byte per pixel)
Image with values from 0 to 255

8.2.2 Compressed CD-ROM Files
On the BOREAS CD-ROMs, file 1 listed above is stored as ASCII text; however, file 2 has been compressed with the Gzip compression program (file name *.gz). These data have been compressed using gzip version 1.2.4 and the high compression (-9) option (Copyright (C) 1992-1993 Jean-loup Gailly). Gzip (GNU zip) uses the Lempel-Ziv algorithm (Welch, 1994) used in the zip and PKZIP programs. The compressed files may be uncompressed using gzip (-d option) or gunzip. Gzip is available from many Web sites (for example, ftp site prep.ai.mit.edu/pub/gnu/gzip-*.*) for a variety of operating systems in both executable and source code form. Versions of the decompression software for various systems are included on the CD-ROMs.

9. Data Manipulations

9.1 Formulae
Not applicable.

9.1.1 Derivation Techniques and Algorithms
The techniques used to create this biomass image are described in Sections 1.5, 3, and 6.1.

9.2 Data Processing Sequence

9.2.1 Processing Steps

- The TM imagery was converted to surface reflectance before the biomass density image was created. Atmospheric correction coefficients were computed with 6S using optical depths from a sunphotometer (Markham et al., 1992).
- End member reflectances were collected or compiled.
- Trajectories were computed based on end member reflectances, solar geometry, tree height to width ratio, and tree form (i.e., cone or cylinder).
- Ground measurements of biomass density were used to find the relationship between biomass density and canopy cover.
- The trajectories and the image classification were used as input to the image biomass program.
- The biomass image was mapped into the AEAC projection using nearest neighbor resampling.
- The biomass image was written to tape.
- BOREAS Information System (BORIS) staff copied the ASCII and compressed the binary file for release on CD-ROM.

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

None.

10. Errors

10.1 Sources of Error

The sources of error in this classification can be attributed to several factors. In many cases, the reflectance of one feature could be similar to the reflectance of another feature, resulting in errors in the biomass density estimate. The similarity in reflectances could be the result of differences in background components and variations in tree density. Error could also be a result of spectral mixing of various features that fall within a 30-meter pixel.

10.2 Quality Assessment

10.2.1 Data Validation by Source

The imagery was spot checked at various locations, and the image class was compared to the forest cover map. An error assessment was performed on the classification. The auxiliary sites and a few randomly selected sites were used as ground truth. The location of each ground truth site was identified on the georeferenced image as a 3- by 3-pixel area. Each of the 9 pixels in these areas represents a test point. Some classes were not represented by auxiliary sites or randomly selected sites.

10.2.2 Confidence Level/Accuracy Judgment

Although efforts have been made to make this classification as accurate as possible, there is bound to be some confusion between classes, resulting in errors in the biomass density estimates. In some areas, especially around the SSA Old Jack Pine site, there might be large overestimates of biomass density. This is a result of the pixels not matching the model properly. Although efforts have been made to minimize this error, it can still occur in pixels that do not match the model output.

10.2.3 Measurement Error for Parameters

Comparison with ground measurements of biomass density showed that the root mean squared error of biomass density for this image is approximately 3.75 kg/m2 where the tree species is very homogenous. However, errors can vary significantly because of variations in pixel reflectance. This technique is thought to be reasonably accurate, especially in areas where black spruce is relatively pure and not mixed with other species. In areas where different tree species are mixed together, errors can be significant.

10.2.4 Additional Quality Assessments

None.

10.2.5 Data Verification by Data Center

The imagery was visually checked at various locations to see that the biomass density values were reasonable.

11. Notes

11.1 Limitations of the Data

This data set is based on an image that was collected on 02-Sep-1994 and represents the biomass density only as it existed on that day. Please see Section 10.2.3 to determine how the amount of error in this product may affect your results.

11.2 Known Problems With the Data

Clouds in this classification show up in the disturbed class, and cloud shadows show up in the water class. The scene is mostly clear, so this problem has a very limited impact.

11.3 Usage Guidance

Before uncompressing the Gzip files on CD-ROM, be sure that you have enough disk space to hold the uncompressed data files. Then use the appropriate decompression program provided on the CD-ROM for your specific system.

11.4 Other Relevant Information

None.

12. Application of the Data Set

This data set may be used for modeling purposes to get a rough idea of the variation in biomass density in the BOREAS SSA.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

Programs written at NASA GSFC to run under EASI/PACE image processing software from PCI, Inc., were used to classify the image. The trajectories were computed using Microsoft Excel (Version 4.0), a spreadsheet program. Questions related to the specific details of the software written to process this data set should be addressed to David Knapp (see Section 2.3). Gzip (GNU zip) uses the Lempel-Ziv algorithm (Welch, 1994) used in the zip and PKZIP commands.

14.2 Software Access

EASI/PACE is a proprietary software package developed by PCI, Inc. Contact PCI for details.

PCI, Inc.
50 West Wilmot St.
Richmond Hill Ontario, Canada L4B 1M5
(905) 764-0614
(905) 764-9604 (fax)

Microsoft Excel is a proprietary software package that is widely available in the commercial software market. Gzip is available from many Web sites across the Internet (for example, ftp site prep.ai.mit.edu/pub/gnu/gzip-*.*) for a variety of operating systems in both executable and source code form. Versions of the decompression software for various systems are included on the CD-ROMs.

15. Data Access

The SSA biomass density image data set is 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

These data can be made available on 8-mm, Digital Archive Tape (DAT), or 9-track tapes at 1600 or 6250 Bytes Per Inch (BPI).

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

Hall, F.G., D.E. Knapp, and K.F. Huemmrich. 1997. Physically based classification and satellite mapping of biophysical characteristics in the southern boreal forest. Journal of Geophysical Research 102(D24): 29,567-29,580.

Hall, F.G., Y.E. Shimabukuro, and K.F. Huemmrich. 1995. Remote sensing of forest biophysical structure using mixture decomposition and geometric reflectance models. Ecological Applications 5(4): 993-1013.

Markham, B.L., R.N. Halthorne, and S.J. Goetz. 1992. Surface reflectance retrieval from satellite and aircraft sensors: Results of sensor and algorithm comparisons during FIFE. FIFE Special Issue. American Geophysical Union. 18785-18795.

PACE Image Analysis Kernal Version 5.2. 1993. PCI, Inc. Richmond Hill, Ontario.

Richards, J.A. 1986. Remote Sensing Digital Image Analysis: An Introduction. Springer Verlag.

Welch, T.A. 1984. A Technique for High Performance Data Compression. IEEE Computer, Vol. 17, No. 6, pp. 8-19.

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

```
6S       - Second Simulation of the Satellite Signal in the Solar Spectrum
AEAC     - Albers Equal-Area Conic
ASCII    - American Standard Code for Information Interchange
BOREAS   - BOReal Ecosystem-Atmosphere Study
BORIS    - BOREAS Information System
BPI      - Bytes Per Inch
CCRS     - Canadian Centre for Remote Sensing
CD-ROM   - Compact Disk-Read-Only Memory
DAAC     - Distributed Active Archive Center
DAT      - Digital Archive Tape
DEM      - Digital Elevation Model
EOS      - Earth Observing System
EOSAT    - Earth Observing Satellite Company
EOSDIS   - EOS Data and Information System
GIS      - Geographic Information System
GMT      - Greenwich Mean Time
GRS80    - Geodetic Reference System of 1980
GSFC     - Goddard Space Flight Center
IFOV     - Instantaneous Field of View
MSA      - Modeling Sub-Area
MSS      - Multispectral Scanner
NAD27    - North American Datum of 1927
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
SSA - Southern Study Area
TE - Terrestrial Ecology
TM - Thematic Mapper
URL - Uniform Resource Locator
UTM - Universal Transverse Mercator
WGS84 - World Geodetic System of 1984
WRS - Worldwide Reference System
WWW - World Wide Web

20. Document Information

20.1 Document Revision Dates
Written: 27-Aug-1997
Last Updated: 01-Mar-1999

20.2 Document Review Dates
BORIS Review: 05-Jan-1998
Science Review:

20.3 Document ID

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

This biomass image was produced as part of the research of Dr. Forrest Hall of NASA GSFC. This image was produced for the BOREAS project.

Please contact Dr. Hall or David Knapp before using these data in a publication. If using data from the BOREAS CD-ROM series, also reference the data as:

Dr. Forrest Hall, "TE-18 Regional Scale Carbon Flux from Modeling and Remote Sensing." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:

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. NASA. CD-ROM. NASA, 2000.

20.5 Document Curator

20.6 Document URL

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
October 2000

3. REPORT TYPE AND DATES COVERED
Technical Memorandum

4. TITLE AND SUBTITLE
Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)
BOREAS TE-18 Biomass Density Image of the SSA

5. FUNDING NUMBERS
923
RTOP: 923-462-33-01

6. AUTHOR(S)
Forrest G. Hall and David Knapp
Forrest G. Hall, Editor

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)
Goddard Space Flight Center
Greenbelt, Maryland 20771

8. PEFORMING ORGANIZATION REPORT NUMBER
2000-03136-0

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS (ES)
National Aeronautics and Space Administration
Washington, DC 20546-0001

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
TM—2000–209891
Vol. 174

11. SUPPLEMENTARY NOTES
D. Knapp: Raytheon ITSS, NASA Goddard Space Flight Center, Greenbelt, Maryland

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Unclassified–Unlimited
Subject Category: 43
Report available from the NASA Center for AeroSpace Information, 7121 Standard Drive, Hanover, MD 21076-1320. (301) 621-0390.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The BOREAS TE-18 team focused its efforts on using remotely sensed data to characterize the successional and disturbance dynamics of the boreal forest for use in carbon modeling. This biomass density image covers almost the entire BOREAS SSA. The pixels for which biomass density is computed include areas that are in conifer land cover classes only. The biomass density values represent the amount of overstory biomass (i.e., tree biomass only) per unit area. It is derived from a Landsat-5 TM image collected on 02-Sep-1994. The technique that was used to create this image is very similar to the technique that was used to create the physical classification of the SSA. The data are provided in a binary image file format.

14. SUBJECT TERMS
BOREAS, terrestrial ecology, Landsat.

15. NUMBER OF PAGES
14

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39.18
298-102