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

Forrest G. Hall, Editor

Volume 100

BOREAS Level-3s SPOT Imagery: Scaled At-sensor Radiance in LGSOWG Format

R. Strub, J. Nickeson, J.A. Newcomer, and J. Cihlar

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

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BOREAS Level-3s SPOT Imagery: Scaled At-sensor Radiance in LGSOWG Format

Richard Strub, Jaime Nickeson, Jeffrey A. Newcomer, Josef Cihlar

Summary

For BOREAS, the level-3s SPOT data, along with the other remotely sensed images, were collected in order to provide spatially extensive information over the primary study areas. This information includes radiant energy, detailed land cover, and biophysical parameter maps such as FPAR and LAI. The SPOT images acquired for the BOREAS project were selected primarily to fill temporal gaps in the Landsat TM image data collection. CCRS collected and supplied the level-3s images to BORIS for use in the remote sensing research activities. Spatially, the level-3s images cover 60- by 60-km portions of the BOREAS NSA and SSA. Temporally, the images cover the period of 17-Apr-1994 to 30-Aug-1996. The images are available in binary image format files. Due to copyright issues, the SPOT images may not be publicly available.

Note that the level-3s SPOT 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 Level-3s SPOT Imagery: Scaled At-sensor Radiance in LGSOWG Format

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 satellite data. Data from the

High-Resolution Visible (HRV) instruments on the Systeme Pour l'Observation de la Terre (SPOT) satellites were acquired by the Canada Centre for Remote Sensing (CCRS) and provided for use by BOREAS researchers. BOREAS Information System (BORIS) and CCRS personnel subsequently reviewed and inventoried the images described here.

1.3 Objective/Purpose

For BOREAS, the SPOT imagery, along with the other remotely sensed images, was collected in order to provide spatially extensive information over the primary study areas. The SPOT images acquired for the BOREAS project were selected primarily to fill temporal gaps in the Landsat Thematic Mapper (TM) image collection.

1.4 Summary of Parameters

SPOT level-3s data in BORIS contain the following parameters:

Original image header information, image coordinates, gains and offsets for each band for at-sensor radiance derivations, image bands 1 to 3 processed with systematic spatial corrections.

1.5 Discussion

Use and distribution of the level-3s SPOT images are subject to copyright restrictions. CCRS and Radarsat International (RSI) granted permission to BOREAS to place a subset of the level-3a Landsat TM images on the BOREAS CD-ROM series. However, none of the other Landsat TM or level-3s SPOT images are included. The level-3s SPOT images may not be available for public access. Please see Sections 15 and 16 for further details.

BORIS staff processed the SPOT level-3s imagery by:

- Extracting pertinent header information from the level-3s image product and placing it in an American Standard Code for Information Interchange (ASCII) file on disk.
- Reading the information in the ASCII disk file and loading the online data base with pertinent information.

1.6 Related Data Sets

BOREAS Level-3s Landsat TM Imagery: Scaled At-sensor Radiance in LGSOWG Format
BOREAS Level-3a Landsat TM Imagery: Scaled At-sensor Radiance in BSQ Format
BOREAS Level-3b Landsat TM Imagery: At-sensor Radiance in BSQ Format

2. Investigator(s)

2.1 Investigator(s) Name and Title

BOREAS Staff Science

2.2 Title of Investigation

BOREAS Staff Science Satellite Data Acquisition Program

2.3 Contact Information

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3. Theory of Measurements

The launch of France's SPOT satellite system on 22-Feb-1986 gave the remote sensing community the capability of applying high-resolution multispectral imagery to a range of land use and land cover analyses. The SPOT satellite platforms are equipped with two HRV linear array (pushbroom) sensors capable of operating in a panchromatic (PAN) mode with 10-m resolution, or a three-band multispectral (XS) mode with 20-m resolution. The SPOT-1 satellite was retired from active service on 31-Dec-1990 but was reactivated in Jan-1998. SPOT-2 was launched on 22-Jan-1990. SPOT-3 was launched on 25-Sep-1993 and suffered an unrecoverable malfunction on 14-Nov-1997. SPOT-4 was launched on 24-Mar-1998. Currently, SPOT-1, SPOT-2, and SPOT-4 continue to fulfill the SPOT global mission.

Thematic considerations have dictated, within technical constraints, the choice of spectral band position and width in the multispectral mode. Three bands were selected for the multispectral mode: 1) A green (500- to 590-nm) band centered at the 550-nm maximum in the chlorophyll reflectance curve, which is on the long wavelength side of the broad attenuation minimum of water, thus giving access to turbidity assessment and bathymetric evaluation in the first 10 to 20 m of surface water. 2) A red band (610 to 680 nm), similar to the Landsat TM channel 3, which provides much information on crop identification, bare soil, and rocky surfaces. Atmospheric transmittance on a fine day is about 90 percent while water penetration is about 2 m with surface reflectance of 4 percent (attenuation coefficient: $5x10^{-1}/m$). This band corresponds to chlorophyll absorption; i.e., low vegetation reflectance. 3) The near-infrared band (790 to 890 nm), which penetrates best through the atmosphere (transmittance is about 95 percent for a clear atmosphere model) and light haze. Vegetation stands out brightly and water surfaces appear very dark (1 percent reflectance with a high attenuation coefficient: 10 to 50 m). Although silicon spectral sensitivity extends out to 1,100 nm, the band was not extended beyond 900 nm in order to avoid response modulation by atmospheric water vapor and to limit the smearing effect of electron diffusion within the detectors. Vegetation biomass can be evaluated with the red and near-infrared bands taken together. All three color bands are coded linearly on 8 bits, with a choice of ground-controlled preset gains.

For the higher ground-resolution black-and-white, or panchromatic mode, a broader spectral band was required. In order to retain the capability for texture analysis in support of the color mode and a high information content over vegetated areas, the interval 510 to 730 nm was chosen for the broad band. The basic coding scheme is 6-bits linear with a choice of eight selectable preset gains. Higher radiometric resolution can be selected by ground command of a differential Pulse Code Modulation System, which compresses each 3-pixel packet to 18 bits, while retaining an 8-bit equivalent radiometric resolution.

4. Equipment

4.1 Sensor/Instrument Description

The HRV instruments form images without any moving mechanical part (e.g., scanning mirrors, disc choppers, or mechanical modulators). The HRV telescope is a pseudo-Schmidt design, since the corrector plate is a spherical doublet. In this folded arrangement, sufficient room is available in the focal plane for a dichroic prism separator followed by four multilinear array mounts. The spectral regions and bandwidths of each channel are given in the table below:

Channel	Wavelength (µm)
1	0.50 - 0.59
2	0.61 - 0.68
3	0.79 - 0.89

4.1.1 Collection Environment

The BOREAS SPOT level-3s imagery was acquired through the CCRS. The SPOT satellites orbit Earth at a mean altitude of 805 km. Radiometric corrections and systematic geometric corrections are applied to produce the images in a path-oriented, systematically corrected spatial form. A full level-3s SPOT image contains 4,500 pixels in each of 3,000 lines. Before any geometric corrections, the ground resolution is 20 m for bands 1-3 at nadir. The pixel values of the images can range from 0 to 255. This allows each pixel to be stored in a single-byte field. The level-3s images were processed through the CCRS Geocoded Image Correction System (GICS) (Friedel, 1992).

4.1.2 Source/Platform

The BOREAS SPOT images were collected by the HRV instruments on the SPOT-2 and SPOT-3 satellites.

4.1.3 Source/Platform Mission Objectives

The objectives of the SPOT mission are to 1) experiment on desirable characteristics of (operational) remote sensing systems; 2) build up an archive and make available a wide data base for cartographic and Earth exploration purposes; 3) experiment on improving vegetative species discrimination and producing forecasting by frequent access and off-nadir viewing; 4) build up a stereo archive of areas of real interest for purposes of photo-interpretation, planimetric cartography, and cartographic updating at scales of 1/100,000 and 1/50,000; and 5) qualify the multimission platform and solar array camera in space.

4.1.4 Key Variables

Reflected radiation.

4.1.5 Principles of Operation

The SPOT system consists of an orbiting satellite with two HRV instruments as well as ground facilities for image reception, preprocessing, distribution, satellite monitoring, and preparation of imaging programs. The instruments are pointable in the across-track direction in order to allow rapid access to any point on the globe and acquisition of stereoscopic image pairs from different satellite passes. Imaging is accomplished by the Charge-Coupled Device (CCD) linear array using the "pushbroom" scanning principle. In a given spectral mode, the HRV instrument images a single line of the landscape at a given moment: all the points making up one line are analyzed simultaneously. The motion of the orbiting satellite and the corresponding shift of the imaged line allow acquisition of a complete image.

Image acquisitions are commanded by the satellite's onboard computer. An imaging sequence can comprise a succession of images acquired in panchromatic or multispectral mode (note that the satellite cannot operate the HRV sensors in both modes at the same time) and changes in the viewing direction of each of the two HRV instruments (rotation of the strip-selection mirror at the entrance of each

instrument). Data generated by the instruments are transmitted to the ground over the payload-specific X-band telemetry link or stored by means of two onboard recorders for later recovery by the Toulouse imagery receiving facility.

4.1.6 Sensor/Instrument Measurement Geometry

The HRV was designed to achieve a multispectral capability with a nominal nadir ground sampling interval of 20 m x 20 m; a 10-m sampling interval in a panchromatic mode. A ground resolution of 20 m over a 60-km swath is achieved using an array of 3,000 detectors (CCD) per spectral band, sampled every 3 milliseconds, while a ground resolution of 10 m over the same swath width uses 6,000 detectors per line, sampled every 1.5 milliseconds.

4.1.7 Manufacturer of Sensor/Instrument

Centre National d'Etudes Spatiales (CNES)
Centre Spatial de Toulouse
31055 Toulouse, France

4.2 Calibration

The calibration unit is an auxiliary device designed to illuminate the detection unit by providing light at the entrance to the HRV telescope (the strip selection mirror having been previously moved to the calibration position). One of two light sources may be selected: the calibration lamp or the fiber-optic sunlight collector. The calibration lamp illuminates all 16 CCD linear arrays of the HRV detection unit and is used for relative calibration (sometimes referred to as "in-band calibration." The fiber-optic sunlight collector illuminates a small number of detectors in each spectral band with sunlight gathered from outside the HRV instrument at certain periods and is used for absolute, interband, multidate calibration.

4.2.1 Specifications

Main Instrument Parameters

	Color mode	B/W mode
Ground sampling step (m)	20	10
Array sampling period (m/s)	3	1.5
Spectral bands (µm)	XS1 0.50-0.59 XS2 0.61-0.68 XS3 0.79-0.89	P 0.51-0.73
Grey levels	256 (8 bits)	128 (6 bits)
Image data bit rate (Mb/s)	25	25
Number of pixels per line	3000	6000
Swath width (km)	60 (nadir)	
Nominal altitude (km)	832	

4.2.1.1 Tolerance

Central viewing direction	+0.163 and -0.163 deg.
Field steering direction	0+/-45 steps 0.6 deg. apart
Outermost observable direction	+/-29.23 deg.
Corresponding distance to track	+/-475 km
Location accuracy level-1B	650 m (max)
Scale distortion	0.07%
Anisomorphism	0.07%
Multispectral band registration	0.15 pixels
Multidate registration accuracy	2.5 m
Relief plotting accuracy for viewing angles between	0 to 27 deg. 7 m -27 to +27 deg. 3.5 m

4.2.2 Frequency of Calibration

CNES maintains an ongoing calibration monitoring effort. Every 3 to 6 months, analysis results of instrument calibration are released for use by data users.

4.2.3 Other Calibration Information

None given.

5. Data Acquisition Methods

The BOREAS SPOT level-3s imagery was acquired through CCRS. Radiometric and systematic geometric corrections are applied to produce the images in a path-oriented, systematically corrected spatial form. A full level-3s SPOT image contains 4,500 pixels in each of 3,000 lines. Before any geometric corrections, the ground resolution is 20 m for bands 1-3 at nadir. The pixel values of the images can range from 0 to 255. This allows each pixel to be stored in a single-byte field. The level-3s images were processed through the CCRS GICS.

6. Observations

6.1 Data Notes

None.

6.2 Field Notes

Not applicable.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

The BOREAS level-3s SPOT images cover portions of the Northern Study Area (NSA) and the Southern Study Area (SSA), which are located in the northeast and southwest portions of the overall region. A full SPOT scene covers approximately 3,600 square kilometers.

The North American Datum of 1983 (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
```

The 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
```

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

Before any geometric corrections, the spatial resolution is 20 m at nadir. These values increase with scan angle away from the nadir path. The level-3s SPOT images have had geometric corrections applied so that the spatial resolution for all pixels is 20 m in all bands. These level-3s images have a high level of internal spatial integrity, but the actual geographic coordinates contained in the image header can be offset from their actual positions by as much as 10 km (personal communication with CCRS personnel, 1994).

7.1.4 Projection

The level-3s SPOT images are placed in a Universal Transverse Mercator (UTM) projection based on NAD83. Detailed projection parameter information for the individual images is contained in the leader file(s).

7.1.5 Grid Description

The grid spacing for each pixel in the level-3s SPOT images is 20 m in the UTM projection. Detailed grid parameter information for the individual images is contained in the leader file(s).

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

The images cover the period of 17-Apr-1994 to 30-Aug-1996. The SPOT images acquired for the BOREAS project were selected in order to fill temporal gaps in the Landsat image collection.

7.2.2 Temporal Coverage Map

Study Area	Date	Study Area	Date
NSA	28-Apr-94	SSA	17-Apr-94
NSA	09-May-94	SSA	21-Apr-94
NSA	25-May-94	SSA	15-May-94
NSA	06-Jun-94	SSA	06-Jun-94
NSA	06-Jun-94	SSA	06-Jun-94
NSA	26-Jun-94	SSA	21-Jul-94
NSA	26-Jun-94	SSA	24-Jul-94
NSA	12-Jul-94	SSA	21-Aug-94
NSA	18-Jul-94	SSA	23-Aug-94
NSA	23-Aug-94	SSA	13-Sep-94
NSA	23-Aug-94	SSA	16-Sep-94
NSA	08-Sep-94	SSA	16-Sep-94
NSA	16-Sep-94	SSA	05-Aug-95
NSA	17-Sep-94	SSA	05-Aug-95
NSA	29-Jul-95	SSA	09-Jul-96
NSA	26-Jul-96	SSA	09-Jul-96
NSA	27-Jul-96	SSA	09-Jul-96
NSA	30-Aug-96	SSA	30-Jul-96
NSA	30-Aug-96	SSA	30-Jul-96

7.2.3 Temporal Resolution

The SPOT satellite revisit frequency is 26 days for each path/row. During the period of 17-Apr-1994 to 30-Aug-1996, 19 images were acquired for each of the study areas. For the NSA there are 19 images that cover a total of 15 dates, 11 dates in 1994, 1 date in 1995, and 3 dates in 1996. For the SSA there are 19 images that cover a total of 13 dates, 10 in 1994, 1 date in 1995, and 2 dates in 1996.

7.3 Data Characteristics

7.3.1 Parameter/Variable

The main parameter contained in the image data files is scaled at-sensor radiance. The parameters contained in the inventory listing file on the CD-ROM are:

```
         Column Name
------------------------------
SPATIAL_COVERAGE
DATE_OBS
START_TIME
END_TIME
PLATFORM
INSTRUMENT
NUM_BANDS
BAND_QUALITY
CLOUD_COVER
PATH_NUM
ROW_NUM
NW_LATITUDE
NW_LONGITUDE
NE_LATITUDE
NE_LONGITUDE
SW_LATITUDE
SW_LONGITUDE
SE_LATITUDE
SE_LONGITUDE
PLATFORM_ALTITUDE
MIN_SOLAR_ZEN_ANG
MAX_SOLAR_ZEN_ANG
MIN_SOLAR_AZ_ANG
MAX_SOLAR_AZ_ANG
CRTFCN_CODE
```

7.3.2 Variable Description/Definition

For the image data files:

```
Scaled at-sensor radiance - The scaled value representing the quantized DN
                            derived by the TM scanning system from the radiant
                            energy incident on the sensor aperture at the time
                            of data collection in the specific TM wavelength
                            regions.
```

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.
START_TIME	The starting Greenwich Mean Time (GMT) for the data collected.
END_TIME	The ending Greenwich Mean Time (GMT) for the data 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.
BAND_QUALITY	The data analyst's assessment of the quality of the spectral bands in the data.
CLOUD_COVER	The data analyst's assessment of the cloud cover that exists in the data.
PATH_NUM	For Landsat and SPOT, the sequential number given to the orbital paths trending from northeast to southwest and extending around the earth.
ROW_NUM	For Landsat and SPOT, the sequential number given to the nominal scene acquisition points along the orbital paths which trend from northeast to southwest.
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.
PLATFORM_ALTITUDE	The nominal altitude of the data collection plat form above the target.

MIN_SOLAR_ZEN_ANG	The minimum angle from the surface normal (straight up) to the sun during the data collection.
MAX_SOLAR_ZEN_ANG	The maximum angle from the surface normal (straight up) to the sun during the data collection.
MIN_SOLAR_AZ_ANG	The minimum azimuthal direction of the sun during data collection expressed in clockwise increments from North.
MAX_SOLAR_AZ_ANG	The maximum azimuthal direction of the sun during data collection expressed in clockwise increments from North.
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 units for the scaled at-sensor radiance values vary by band. To obtain at-sensor radiance values in Watts/(m^2 * sr * µm) use the formula:

```
At-sensor Radiance = Scaled Value * Gain + Offset
```

where the gain and Offset values are contained in the image leader files. 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]
START_TIME	[HHMM GMT]
END_TIME	[HHMM GMT]
PLATFORM	[none]
INSTRUMENT	[none]
NUM_BANDS	[counts]
BAND_QUALITY	[none]
CLOUD_COVER	[none]
PATH_NUM	[unitless]
ROW_NUM	[unitless]
NW_LATITUDE	[degrees]
NW_LONGITUDE	[degrees]
NE_LATITUDE	[degrees]
NE_LONGITUDE	[degrees]
SW_LATITUDE	[degrees]
SW_LONGITUDE	[degrees]
SE_LATITUDE	[degrees]
SE_LONGITUDE	[degrees]
PLATFORM_ALTITUDE	[meters]
MIN_SOLAR_ZEN_ANG	[degrees]
MAX_SOLAR_ZEN_ANG	[degrees]
MIN_SOLAR_AZ_ANG	[degrees]
MAX_SOLAR_AZ_ANG	[degrees]
CRTFCN_CODE	[none]

7.3.4 Data Source

The data contained in the level-3s SPOT data files come from various portions of the SPOT satellite, the HRV instrument, and the ground processing components. The level-3s SPOT images were supplied to the BOREAS by the CCRS. The sources of the parameter values contained in the inventory listing file on the CD-ROM are:

Column Name	Data Source
SPATIAL_COVERAGE	[Determined by BORIS software from latitude and longitude information contained on the level-3s data files.]
DATE_OBS	[Determined by BORIS software from data and time information contained on the level-3s data files.]
START_TIME	[Determined by BORIS software from data and time information contained on the level-3s data files]
END_TIME	[Determined by BORIS software from data and time information contained on the level-3s data files.]
PLATFORM	[Determined by BORIS software from platform information contained on the level-3s data files.]
INSTRUMENT	[Constant software value]
NUM_BANDS	[Determined by BORIS software from processing of the data files.]
BAND_QUALITY	[Assessed by BORIS personnel from viewing the image.]
CLOUD_COVER	[Assessed by BORIS personnel from viewing the image.]
PATH_NUM	[Determined by BORIS software from location information contained on the level-3s data files.]
ROW_NUM	[Determined by BORIS software from location information contained on the level-3s data files.]
NW_LATITUDE	[Determined by BORIS software from location information contained on the level-3s data files.]
NW_LONGITUDE	[Determined by BORIS software from location information contained on the level-3s data files.]
NE_LATITUDE	[Determined by BORIS software from location information contained on the level-3s data files.]
NE_LONGITUDE	[Determined by BORIS software from location information contained on the level-3s data files.]
SW_LATITUDE	[Determined by BORIS software from location information contained on the level-3s data files.]
SW_LONGITUDE	[Determined by BORIS software from location information contained on the level-3s data files.]
SE_LATITUDE	[Determined by BORIS software from location

	information contained on the level-3s data files.]
SE_LONGITUDE	[Determined by BORIS software from location information contained on the level-3s data files.]
PLATFORM_ALTITUDE	[Determined by BORIS software from platform information contained on the level-3s data files.]
MIN_SOLAR_ZEN_ANG	[Calculated with software from latitude and longitude and time information]
MAX_SOLAR_ZEN_ANG	[Calculated with software from latitude and longitude and time information]
MIN_SOLAR_AZ_ANG	[Calculated with software from latitude and longitude and time information]
MAX_SOLAR_AZ_ANG	[Calculated with software from latitude and longitude and time information]
CRTFCN_CODE	[Assigned by BORIS based on processing.]

7.3.5 Data Range

The maximum range of digital numbers in each level-3s SPOT image band is limited to the range 0 (zero) to 255 so that the values can be stored in a single 8-bit (byte) field. 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	17-APR-94	30-AUG-96	None	None	None	None
START_TIME	1729	1839	None	None	None	None
END_TIME	1729	1839	None	None	None	None
PLATFORM	SPOT 2	SPOT 3	None	None	None	None
INSTRUMENT	N/A	N/A	None	None	None	None
NUM_BANDS	3	3	None	None	None	None
BAND_QUALITY	N/A	N/A	None	None	None	None
CLOUD_COVER	N/A	N/A	None	None	None	None
PATH_NUM	550	566	None	None	None	None
ROW_NUM	236	241	None	None	None	None
NW_LATITUDE	53.9705	56.30094	None	None	None	None
NW_LONGITUDE	-106.42326	-97.80651	None	None	None	None
NE_LATITUDE	53.82529	56.16124	None	None	None	None
NE_LONGITUDE	-105.53683	-96.75452	None	None	None	None
SW_LATITUDE	53.44538	55.791	None	None	None	None
SW_LONGITUDE	-106.69194	-98.04481	None	None	None	None
SE_LATITUDE	53.31475	55.64067	None	None	None	None
SE_LONGITUDE	-105.81544	-97.03178	None	None	None	None
PLATFORM_ALTITUDE	0	833914	None	None	None	None
MIN_SOLAR_ZEN_ANG	31.2	53.7	None	None	None	None
MAX_SOLAR_ZEN_ANG	31.2	53.7	None	None	None	None
MIN_SOLAR_AZ_ANG	153.7	178.2	None	None	None	None
MAX_SOLAR_AZ_ANG	153.7	178.2	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-3s SPOT images is not available here. The following are wrapped versions of the first few records from the level-3s SPOT inventory table on the CD-ROM:

```
SPATIAL_COVERAGE,DATE_OBS,START_TIME,END_TIME,PLATFORM,INSTRUMENT,NUM_BANDS,
BAND_QUALITY,CLOUD_COVER,PATH_NUM,ROW_NUM,NW_LATITUDE,NW_LONGITUDE,NE_LATITUDE,
NE_LONGITUDE,SW_LATITUDE,SW_LONGITUDE,SE_LATITUDE,SE_LONGITUDE,PLATFORM_ALTITUDE,
MIN_SOLAR_ZEN_ANG,MAX_SOLAR_ZEN_ANG,MIN_SOLAR_AZ_ANG,MAX_SOLAR_AZ_ANG,CRTFCN_CODE
'SSA',17-APR-94,1800,1800,'SPOT 2','HRV-2',3,'NOT ASSESSED','NOT ASSESSED',
553,241,54.1706,-105.51248,54.04471,-104.44787,53.64516,-105.72139,53.52115,
-104.66936,822145.0,44.8,44.8,160.5,160.5,'CPI'
'SSA',21-APR-94,1824,1824,'SPOT 2','HRV-2',3,'NOT ASSESSED','NOT ASSESSED',550,
241,54.12612,-106.42326,53.98357,-105.53683,53.61036,-106.69194,53.46976,-105.815
44,822145.0,42.6,42.6,167.2,167.2,'CPI'
```

8. Data Organization

8.1 Data Granularity

The smallest unit of data for level-3s SPOT imagery is a full SPOT scene.

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 within single apostrophe marks. There are no spaces between the fields.

The level-3s SPOT imagery from CCRS is stored in either a band sequential (BSQ) or a band interleaved by line (BIL) form. General information on these two formats is provided in the subsequent sections. Detailed information on these formats can be obtained from the CCRS document, Standard SPOT MLA/PLA Format, referenced in Section 17.1.

8.2.1 Band Sequential Format

The files associated with a BSQ SPOT scene are as follows:

```
File 1  volume directory
File 2  leader file band 1
File 3  SPOT band 1
File 4  trailer file band 1
File 5  leader file band 2
File 6  SPOT band 2
File 7  trailer file band 2
File 8  leader file band 2
File 9  SPOT band 3
File 10 trailer file band 2
File 11 null volume file
```

If there are multiple scenes on a tape, the next scene would occupy files 12-22, 11 files exactly as above. Up to five SPOT scenes (55 files) are contained on one 8-mm tape. There are multiple-volume directory files on one tape media because the 8-mm tapes were generated by copying the original 9-track tapes, and each of the 9-track tapes had its own volume directory. Each image file in BSQ format contains data for one spectral band.

8.2.1.1 BSQ Leader Files

- File descriptor record
- Scene header record
- Map projection (scene-related) ancillary record
- Type 1 radiometric transformation ancillary record
- Type 2 radiometric transformation ancillary record

All leader files contain fixed-length records 6,120 bytes in length and contain both ASCII and binary data. For specific details, see the CCRS documentation referenced in Section 17.1.

8.2.1.2 BSQ Imagery File

The BSQ image files have 3,001 records, with each record containing 4,500 bytes. The first record in this file is a header record, followed by 3,000 image records.

The contents of the Scene Header record are specified by Landsat Ground Station Operations Working Group (LGSOWG) Technical Working Group (LTWG) standards and contain information relating to the mission, sensor parameters, processing options, and geometric parameters for the sensor.

Each image record contains 32 bytes of prefix data, 4,320 bytes of image data, and 36 bytes of suffix data. Image data consist of digital numbers and 0's as fillers. The record size is 4,500 bytes. Although the width of the image is nominally 3,000 pixels, the number of pixels in the image grows proportionally with the view angle. All 4,500 pixels were included because none of the parameters in any of the header records seemed to be reliable for determining how many nonzero pixels there were in a particular record.

Each image is oriented so that pixel 1, line 1 is in the upper left-hand corner (i.e., northwest) of the screen display. Pixels and lines progress left to right and top to bottom so that pixel n, line n is in the lower right-hand corner.

8.2.1.3 BSQ Trailer File

The trailer file contains information associated with the image data not always available before writing the image data, such as data and recording quality and data summaries. Each trailer file contains a file descriptor record and trailer records for all bands of imagery in the associated imagery file. All trailer files contain fixed-length records 4,320 bytes in length and contain both ASCII and binary data.

8.2.2 Band Interleaved by Line Format

The files associated with a BIL SPOT scene are as follows:

```
File 1  volume directory
File 2  leader file bands 1-3
File 3  SPOT bands 1-3
File 4  trailer
File 5  null volume file
```

If there are multiple scenes on a tape, the next scene would occupy files 6-10, five files exactly as above. Up to four TM scenes (20 files) are contained on one 8-mm tape. There are multiple volume directory files on one tape media because the 8-mm tapes were generated from copying the original 9-track tapes, and each of the 9-track tapes had its own volume directory. The image files in BIL format contain image data for all three spectral bands.

8.2.2.1 BIL Leader Files

A detailed description may be found in the SPOT Standard CCT Format document from SPOT Image Corporation.

```
Record 1:      Header File descriptor              3960 bytes
Record 2:      Header                              3960 bytes
Record 3:      Ancillary Ephemeris/Attitude        3960 bytes
Record 4-21:   Ancillary Radiometric/Calibration   3960 bytes
Record 22-24:  Ancillary Histogram                 3960 bytes
Record 25:     Ancillary Map projection            3960 bytes
Record 26:     GCP/RCP                             3960 bytes
Record 27:     Annotation                          3960 bytes
```

8.2.2.2 BIL Imagery File

The BIL image files are contained in a single file of 9,000 5,400-byte records.

Each image is oriented so that pixel 1, line 1 is in the upper left-hand corner (i.e., northwest) of the screen display. Pixels and lines progress left to right and top to bottom so that pixel n, line n is in the lower right-hand corner.

8.2.2.3 BIL Trailer File

The trailer file contains information associated with the image data not always available before writing the image data, such as data and recording quality and data summaries. Each trailer file contains a file descriptor record and trailer records for all bands of imagery in the associated imagery file. All trailer files contain fixed length records 4,320 bytes in length and contain both ASCII and binary data.

9. Data Manipulations

9.1 Formulae

None.

9.1.1 Derivation Techniques and Algorithms

Not applicable.

9.2 Data Processing Sequence

The SPOT data are included in BORIS only as a supplement to the Landsat TM data. Therefore, the SPOT images were not processed beyond level-3s.

9.2.1 Processing Steps

BORIS Staff processes a level-3s SPOT image by:

- Extracting pertinent header information from the level-3s image product andwriting it to a disk file.
- Reading the information in the disk file and loading the data base withneeded information.

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

Errors could arise in the acquired imagery from location inaccuracy, distortion of lengths, anisomorphism, the instrument's local coherence, multispectral registrability, and relief plotting inaccuracy. Other errors could arise from inherent radiometric imperfections of the sensors.

10.2 Quality Assessment

10.2.1 Data Validation by Source

Whatever the processing level, the geometric quality of the image depends on the accuracy of the viewing geometry. Spectral errors could arise from image-wide signal-to-noise ratio, saturation, cross-talk, spikes, response normalization caused by a change in gain.

10.2.2 Confidence Level/Accuracy Judgment

Assessment of accuracy of the absolute radiometric constants is difficult. The uncertainties in prelaunch and postlaunch updates of the absolute calibration constants are nominally specified to be less than 10%. A root mean square (rms) summing of known errors in the prelaunch calibration suggests that this may be a reasonable estimate of overall uncertainty in the prelaunch calibration.

10.2.3 Measurement Error for Parameters

Not available at this revision.

10.2.4 Additional Quality Assessments

Images are screened for level of cloud cover before BORIS processing.

10.2.5 Data Verification by Data Center

BORIS staff used developed software to extract information for logging the data into a relational data base. The software also read through the records of the files checking for proper record sizes. A subset of the images was unpacked and displayed for visual review. None of the displayed images showed any notable abnormalities.

11. Notes

11.1 Limitations of the Data

None.

11.2 Known Problems with the Data

None.

11.3 Usage Guidance

None.

11.4 Other Relevant Information

None.

12. Application of the Data Set

The SPOT images should be useful for anyone interested in high spatial resolution imagery over the entire NSA or SSA in between the Landsat TM acquisitions.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

BORIS staff developed software and command procedures to:

- Extract header information from level-3s SPOT images on tape and write to ASCII files on disk.
- Read the ASCII disk file and log the level-3 SPOT image products into the Oracle data base tables.
- Convert coordinates in the leader file(s) between the geographic systems of (latitude, longitude), UTM (northing, easting), and BOREAS (x,y) grid locations.

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 GSFC. The primary dependencies in the software are the tape input/output (I/O) library and the Oracle data base utility routines.

The geographic coordinate conversion utility (BOR_CORD) has been tested and used on Macintosh, IBM PC, VAX, Silicon Graphics, and Sun workstations.

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 SPOT level-3s data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

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

15.2 Data Center Identification

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

15.3 Procedures for Obtaining Data

Although the BOREAS level-3s SPOT images are being held in a public archive, copyright restrictions limit the distribution and use of the data. The BOREAS CD-ROM series is publicly available and contains some of the level-3a Landsat TM images. However, other Landsat TM and SPOT image products in the collection are available only to official BOREAS project personnel. Please contact the ORNL DAAC User Services office to get the most recent information.

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 SPOT level-3s data can be made available on 8-mm, Digital Archive Tape (DAT), or 9-track tapes at 1600 or 6250 Bytes Per Inch (BPI).

Although the BOREAS level-3s SPOT images are being held in a public archive, copyright restrictions limit the distribution and use of the data. Users interested in high spatial resolution image data will find that the BOREAS CD-ROM series is publicly available and contains some level-3a Landsat TM images. Other Landsat TM and SPOT image products in the collection are available only to official BOREAS project personnel. Please contact the ORNL DAAC User Services office (see Section 15.4) to get the most recent information.

16.2 Film Products

None.

16.3 Other Products

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

17. References

17.1 Platform/Sensor/Instrument/Data Processing Documentation

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Standard SPOT MLA/PLA CCT Format. Technical Memorandum No. DMD-TM-85-428A, 1985. Digital Methods Division Canada Centre for Remote Sensing Dept. of Energy, Mines and Resources.

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Byrne, G.F., P.F. Crapper, and K.K. Mayo. 1980. Monitoring land-cover change by principal component analysis of multitemporal Landsat data. Remote Sens. Environ. 10:175-184.

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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.

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

```
ASCII   - American Standard Code for Information Interchange
BIL     - Band Interleaved by Lines
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
BPI     - Bytes Per Inch
BSQ     - Band Sequential
CCD     - Charge-Coupled Device
CCRS    - Canada for Remote Sensing
CCT     - Computer Compatible Tape
CD-ROM  - Compact Disk-Read-Only Memory
CNES    - Centre National d'Etudes Spatiales
DAAC    - Distributed Active Archive Center
DAT     - Digital Archive Tape
```

```
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
FPAA    - Fraction of Photosynthetically Active Radiation
GICS    - Geocoded Image Correction System
GIS     - Geographic Information System
GMT     - Greenwich Mean Time
GSFC    - Goddard Space Flight Center
HRV     - High-Resolution Visible
I/O     - Input/Output
IFOV    - Instantaneous Field-of-View
LAI     - Leaf Area Index
LGSOWG  - Landsat Ground Station Operations Working Group
LTWG    - LGSOWG Technical Working Group
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
RMS     - Root-Mean-Square
RSI     - Radarsat International
SPOT    - Satellite Pour l'Observation de la Terre
SSA     - Southern Study Area
TIPS    - Thematic Mapper Image Processing System
TM      - Thematic Mapper
URL     - Uniform Resource Locator
UTM     - Universal Transverse Mercator
```

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BOREAS Staff Science, "BOREAS Staff Science Satellite Data Acquisition Program." In Collected Data of The Boreal Ecosystem-Atmosphere Study. Eds. J. Newcomer, D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers. CD-ROM. NASA, 2000.

Also, cite the BOREAS CD-ROM set as:

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13. ABSTRACT *(Maximum 200 words)*

For BOREAS, the level-3s SPOT data, along with the other remotely sensed images, were collected in order to provide spatially extensive information over the primary study areas. This information includes radiant energy, detailed land cover, and biophysical parameter maps such as FPAR and LAI. The SPOT images acquired for the BOREAS project were selected primarily to fill temporal gaps in the Landsat TM image data collection. CCRS collected and supplied the level-3s images to BORIS for use in the remote sensing research activities. Spatially, the level-3s images cover 60- by 60-km portions of the BOREAS NSA and SSA. Temporally, the images cover the period of 17-Apr-1994 to 30-Aug-1996. The images are available in binary image format files. Due to copyright issues, the SPOT images may not be publicly available.

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