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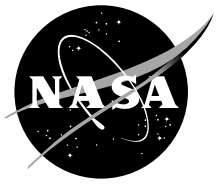

Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS)

Forrest G. Hall, Editor

Volume 102

BOREAS Level-4b AVHRR-LAC Ten-Day Composite Images: At-sensor Radiance

J. Cihlar, J. Chen, J. Nickeson, J.A. Newcomer, and F. Huang

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

September 2000

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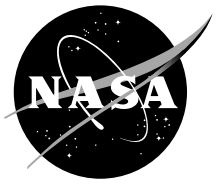

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BOREAS Level-4b AVHRR-LAC Ten-Day Composite Images: At-sensor Radiance

Josef Cihlar, Jing Chen, Jaime Nickeson, Jeffrey A. Newcomer, Fengting Huang

Summary

The BOREAS Staff Science Satellite Data Acquisition Program focused on providing the research teams with the remotely sensed satellite data products they needed to compare and spatially extend point results. MRSC and BORIS personnel acquired, processed, and archived data from the AVHRR instruments on the NOAA-11 and -14 satellites. The AVHRR data were acquired by CCRS and were provided to BORIS for use by BOREAS researchers. These AVHRR level-4b data are gridded, 10-day composites of at-sensor radiance values produced from sets of single-day images. Temporally, the 10-day compositing periods begin 11-Apr-1994 and end 10-Sep-1994. Spatially, the data cover the entire BOREAS region. The data are stored in binary image format files.

Note that some of the data 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 Level-4b AVHRR-LAC Ten-Day Composite Images: At-sensor Radiance

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 Advanced Very High Resolution Radiometer (AVHRR) instrument on the National Oceanic and Atmospheric Association (NOAA)-9, -11, -12, and -14 satellites were acquired by the Canada Centre for Remote Sensing (CCRS) and were provided for use by BOREAS researchers.

1.3 Objective/Purpose

For BOREAS, the level-4b 10-day composite AVHRR-Local Area Coverage (LAC) imagery, along with the other remotely sensed images, was collected in order to provide spatially extensive information over the primary study areas at varying spatial scales. This information includes detailed land cover and biophysical parameter maps such as Fraction of Photosynthetically Active Radiation (FPAR) and Leaf Area Index (LAI). The Manitoba Remote Sensing Center (MRSC) and CCRS processed the level-4b 10-day composite AVHRR-LAC imagery products.

1.4 Summary of Parameters

The level-4b 10-day composite AVHRR-LAC data in the BOREAS Information System (BORIS) contains the following parameters: image header and compositing information; geographic position information; scaled at-sensor radiance values for image bands 1 to 5; Normalized Difference Vegetation Index (NDVI); view and solar angle information.

1.5 Discussion

Level-4b data sets are subsets of 10-day composite images produced by Geocoding and Compositing (GEOCOMP) for the Northern Biosphere Observation and Modeling Experiment (NBIOME) (Cihlar, 1993). While the NBIOME composite covers all of Canada, a bounding rectangle encompassing the BOREAS region has been extracted for the level-4b product.

The level-4b processing starts with single-day raw data. Each image is registered to a map projection (Lambert Conformal Conic [LCC]), resampled, and incorporated into a 10-day composite using the maximum NDVI compositing criterion (e.g., each pixel is retained only if its NDVI is greater than that of the pixel already in the composite; in this manner, the composite contains fewer and fewer contaminated pixels on successive days). Once a pixel is retained, the three angles describing the acquisition geometry and the acquisition date are also saved in separate files.

The level-4b product contains the data exactly as produced by GEOCOMP. Because GEOCOMP processes the data in near-real time, the knowledge of AVHRR calibration is not always the best. In some cases, the calibration becomes known more accurately later (e.g., for NOAA-14 AVHRR). Such knowledge was not incorporated in the level-4b (or level-3b) products but was used to produce level-4c products.

1.6 Related Data Sets

BOREAS Level-3b AVHRR-LAC Imagery: Scaled At-sensor Radiance in LGSOWG Format
BOREAS Level-4c AVHRR-LAC Ten-Day Composite Images: Surface Parameters

2. Investigator(s)

2.1 Investigator(s) Name and Title

Josef Cihlar
Canada Centre for Remote Sensing

2.2 Title of Investigation

BOREAS Staff Science Satellite Data Acquisition Program

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3. Theory of Measurements

The AVHRR is a four- or five-channel scanning radiometer capable of providing global daytime and nighttime information about ice, snow, vegetation, clouds, and the sea surface. These data are obtained on a daily basis primarily for use in weather analysis and forecasting; however, a variety of other applications are possible. The AVHRR data collected for the BOREAS project were from instruments onboard NOAA-9, -11, and -12 polar orbiting platforms. The radiometers measured emitted and reflected radiation in the visible, near-infrared, middle-infrared, and one or two thermal channels.

The primary use of each channel and spectral regions and band widths on the respective NOAA platforms are given in the following tables:

Channel	Wavelength [µm]	Primary Use
1*	0.57 - 0.69	Daytime Cloud and Surface Mapping
2	0.72 - 0.98	Surface Water Delineation, Vegetation Cover
3	3.52 - 3.95	Sea Surface Temperature (SST), Nighttime Cloud Mapping
4**	10.3 - 11.40	Surface Temperature, Day/Night Cloud Mapping
5***	11.4 - 12.40	Surface Temperature

* Channel 1 wavelength for the Television and Infrared Observation Satellite (TIROS)-N flight model was 0.55-0.90 µm.
** For NOAA-7 and -9, channel 4 was 10.3-11.3 µm.
*** For TIROS-N and NOAA-6, -8, -10, and 12, channel 5 duplicates channel 4.

The wavelength ranges at 50 percent relative spectral response (in micrometers) of the bands for the platform-specific instruments are:

Band	NOAA-9	NOAA-11	NOAA-12	NOAA-14
1	0.570 - 0.699	0.572 - 0.698	0.571 - 0.684	0.570 - 0.699
2	0.714 - 0.983	0.716 - 0.985	0.724 - 0.984	0.714 - 0.983
3	3.525 - 3.931	3.536 - 3.935	3.554 - 3.950	3.525 - 3.931
4	10.334 - 11.252	10.338 - 11.287	10.601 - 11.445	10.330 - 11.250
5	11.395 - 12.342	11.408 - 12.386	10.601 - 11.445	11.390 - 12.340

The AVHRR can operate in both real-time and recorded modes. Direct readout data were transmitted to ground stations of the automatic picture transmission (APT) class at low resolution (4 x 4 km) and to ground stations of the high-resolution picture transmission (HRPT) class at high resolution (1 x 1 km). AVHRR HRPT data were received for the BOREAS region by the CCRS Prince Albert Satellite Station (PASS).

4. Equipment

4.1 Sensor/Instrument Description

The AVHRR is a cross-track scanning system featuring one visible, one near-infrared, one middle-infrared, and two thermal channels. The analog data output from the sensors is digitized onboard the satellite at a rate of 39,936 samples per second per channel. Each sample step corresponds to an angle of scanner rotation of 0.95 milliradians. At this sampling rate, there are 1.362 samples per instantaneous field of view (IFOV). A total of 2,048 samples is obtained per channel per Earth scan, which spans an angle of +/-55.4 degrees from nadir.

4.1.1 Collection Environment

The NOAA satellites orbit Earth at an altitude of 833 km. From this space platform, the data are transmitted to a ground receiving station.

4.1.2 Source/Platform

Launch and available dates for the TIROS-N series of satellites from CCRS are:

Satellite	Launch Date	Date Range
TIROS-N	13-Oct-1978	19-Oct-1978 to 30-Jan-1980
NOAA-6	27-Jun-1979	21-Aug-1984 to 23-Jan-1986
NOAA-B	29-May-1980	Failed to achieve orbit
NOAA-7	23-Jun-1981	24-Jul-1983 to 30-Dec-1984
NOAA-8	28-Mar-1983	24-Jul-1983 to 13-Aug-1985
NOAA-9	12-Dec-1984	16-Sep-1985 to 19-Mar-1995
NOAA-10	17-Sep-1986	11-Oct-1986 to 15-Nov-1993
NOAA-11	24-Sep-1988	28-Jun-1989 to 13-Sep-1994
NOAA-12	14-May-1991	11-Aug-1993 to present
NOAA-14	30-Dec-1994	15-May-1995 to present

AVHRR-LAC data used in BOREAS were collected onboard the NOAA-9, -11, and -12 polar orbiting platforms. Only NOAA-11 and -14 data were processed as level-4b products.

4.1.3 Source/Platform Mission Objectives

The AVHRR is designed for multispectral analysis of meteorologic, oceanographic, and hydrologic parameters. The objective of the instrument is to provide radiance data for investigation of clouds, land-water boundaries, snow and ice extent, ice or snow melt inception, day and night cloud distribution, temperatures of radiating surfaces, and SST. It is an integral member of the payload on the advanced TIROS-N spacecraft and its successors in the NOAA series, and as such contributes data required to meet a number of operational and research-oriented meteorological objectives.

4.1.4 Key Variables

Emitted radiation, reflected radiation.

4.1.5 Principles of Operation

The AVHRR is a four- or five-channel scanning radiometer that detects reflected and emitted radiation from Earth in the visible, near-, mid-, and thermal-infrared regions of the spectrum. A fifth channel was added to the follow-on instrument designated AVHRR/2 and flown on NOAA-7, -9, -11, and -14 to improve the correction for atmospheric water vapor. Scanning is provided by an elliptical beryllium mirror rotating at 360 rpm about an axis parallel to that of Earth. A two-stage radiant cooler is used to maintain a constant temperature of 95 K for the infrared detectors. The operating temperature is selectable at either 105 or 110 K. The telescope is an 8-inch afocal, all-reflective Cassegrain system. Polarization is less than 10 percent. Instrument operation is controlled by 26 commands and monitored by 20 analog housekeeping parameters.

4.1.6 Sensor/Instrument Measurement Geometry

The AVHRR is a cross-track scanning system. The IFOV of each sensor is approximately 1.4 milliradians, giving a spatial resolution of 1.1 km at the satellite subpoint. There is about a 36-percent overlap between IFOVs (1.362 samples per IFOV). The scanning rate of the AVHRR is six scans per second, and each scan spans an angle of +/ -55.4 degrees from the nadir.

4.1.7 Manufacturer of Sensor/Instrument

ITT Aerospace
P.O. Box 3700
Fort Wayne, IN 46801-3700

4.2 Calibration

The thermal-infrared channels are calibrated in-flight using a view of a stable blackbody and space as a reference. No in-flight reflective channel calibration is performed. Channel 3 data are noisy because of a spacecraft problem and may not be usable, especially when the satellite is in daylight (Kidwell, 1991).

4.2.1 Specifications

```
IFOV                1.4 mRad
RESOLUTION          1.1 km
ALTITUDE            833 km
SCAN RATE           360 scans/min (1.362 samples per IFOV)
SCAN RANGE          -55.4 to 55.4 degrees
SAMPLES/SCAN        2,048 samples per channel per Earth scan
```

4.2.1.1 Tolerance

The AVHRR infrared channels 3-5 were designed for a Noise Equivalent Differential Temperature (NEdT) of 0.12 K (at 300 K), and a signal-to-noise ratio of 3:1 at 0.5 percent albedo.

4.2.2 Frequency of Calibration

The Naval Research Laboratory's (NRL's) TIROS-N calibration overlay performs the calibration on blocks of telemetry data. For LAC/HRPT acquisitions, a block consists of 20 scan lines. Calibration begins by reading the calibration parameters into memory. For each scan line of telemetry in a block, the following process takes place:

- Telemetry data are extracted and unpacked.
- Ramp calibration data for each of the five channels are decommutated.
- A single Platinum Resistor Thermometer (PRT) count is extracted.
- Ten samples of internal target, or blackbody, data are decommutated and filtered.
- Ten samples of space view data are decommutated and filtered.

After the entire block has been decommutated, the PRTs are checked for pattern correctness. A valid PRT pattern consists of a PRT reference count whose value is less than 10 followed by 4 PRT counts whose values are greater than 10. After decommutation, the PRT counts are filtered, and the mean and standard deviation of each PRT are computed. The mean PRT counts are then converted to temperature using the formula:

$$T(1) = C(0) + C(1)M(j) + C(2)[M(j)^2] + C(3)[M(j)^3] + C(4)[M(j)^4]$$

where: T(1) = the temperature of each of the four PRTs
C(i) = the PRT coefficients from CPIDS
M(j) = the mean count of each of the four PRTs

The mean of the four PRT temperatures is then computed to get the temperature of the blackbody. The blackbody temperature is used to calculate the index of the temperature-to-radiance lookup table using the formula:

INDEX = 10.0 * PRT TEMPERATURE 1798.5

The blackbody radiances for infrared channels are extracted from the table, which was generated from CPIDS. From the decommutated blackbody data, the mean and standard deviation of the internal target are computed. This computation is also done for the mean and standard deviation of space view data. The slopes and intercepts are then calculated using the previously computed data. The slope and intercept for the visible channels are assigned constants. For each of the infrared channels, the slope and intercept are calculated using the formula:

$$\text{SLOPE} = \frac{\text{SPACEVIEW RADIANCE - BLACKBODY RADIANCE}}{\text{SPACEVIEW MEAN - BLACKBODY MEAN}}$$

INTERCEPT = SPACEVIEW RADIANCE SLOPE * SPACEVIEW MEAN

The slopes and intercepts for all five channels are then stored in each scan line in the given block. The calibration overlay then begins this process again for the next block. The final function of the calibration overlay is to determine ramp linearity or nonlinearity. This process reverses the ramp on infrared channels from descending to ascending. The ramp values are then adjusted according to data type (i.e., LAC or Global Area Coverage (GAC)).

4.2.3 Other Calibration Information

None given.

5. Data Acquisition Methods

The BOREAS level-4b AVHRR-LAC images were provided by the CCRS. Some radiometric corrections along with geometric corrections, are applied to produce the imagery in a spatially corrected form (LCC projection). A full level-4b AVHRR-LAC image contains approximately 1,200 pixels in each of approximately 1,200 lines. Before geometric corrections, the ground resolution ranges from 1.1 km at nadir to 2.5 km x 6.8 km at the scanning extremes of 55.4 degrees. The pixel values of the images are stored in 2-byte fields. The level-4b images were processed through the CCRS GEOCOMP system, which applies both radiometric and spatial corrections to the images. Only the raw data are available from the CCRS PASS.

6. Observations

6.1 Data Notes

None.

6.2 Field Notes

None.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

The AVHRR provides for a global (pole to pole) onboard collection of data from all spectral channels. The 110.8-degree scan equates to a swath of 27.2 degrees in longitude (at the Equator) centered on the subsatellite track. This swath width is greater than the 25.3-degree separation between successive orbital tracks and provides overlapping coverage (sidelap) anywhere on the globe.

The BOREAS level-4b AVHRR-LAC images contain 1,200 pixels in each of the 1,200 lines and cover the entire 1,000-km x 1,000-km BOREAS region. This includes the Northern Study Area (NSA), the Southern Study Area (SSA) and the transect between the SSA and NSA.

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

	Latitude	Longitude
Northwest (1,1)	59.36395°N	115.40859°W
Northeast (1,1200)	61.01294°N	93.28553°W
Southwest (1200,1)	48.83387°N	110.25229°W
Southeast (1200,1200)	50.02993°N	93.73857°W

The northwest corner has a distance (1109.76 km west, 7900.04 km north) from the origin (95°W and 0°N) of the LCC coordinate. The pixel size is exactly 1 km.

The NAD83 corner coordinates of the BOREAS region are:

	Latitude	Longitude
Northwest	59.979°N	111.000°W
Northeast	58.844°N	93.502°W
Southwest	51.000°N	111.000°W
Southeast	50.089°N	96.970°W

The NAD83 corner coordinates of the SSA are:

	Latitude	Longitude
Northwest	54.319°N	106.227°W
Northeast	54.223°N	104.236°W
Southwest	53.513°N	106.320°W
Southeast	53.419°N	104.368°W

The NAD83 corner coordinates of the NSA are:

	Latitude	Longitude
Northwest	56.249°N	98.824°W
Northeast	56.083°N	97.241°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

Before any geometric corrections, the spatial resolution varies from 1.1 km at nadir to approximately 2.5 km x 6.8 km at the extreme edges of the scan. The level-4b composite AVHRR-LAC images have had geometric corrections applied so that the size for all pixels is 1 km in all bands.

7.1.4 Projection

The coordinate system is the LCC, with the two standard parallels at 49°N and 77°N, respectively, and the meridian at 95°W.

7.1.5 Grid Description

The BOREAS level-4b composite images are projected into the LCC projection at a spacing of 1.0 km per pixel (grid cell) in both the X and Y directions.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

Historical AVHRR-LAC data have been acquired by CCRS routinely since 1991 and are kept in the CCRS archive. These data can be obtained by contacting CCRS. Statistics Canada also has a historical composite data set of visible, infrared, and NDVI imagery. Contact the Statistics Canada Crop Condition Assessment Program office for more information.

At BOREAS latitudes, at least daily coverage is provided by a given sensor. Virtually all raw data from daytime overpasses were recorded during the BOREAS period (NOAA-11 daytime) and are archived at PASS. The seasonal time period of data acquisition for the level-4b product is nominally 11-Apr through 31-Oct. In 1994, the period was from 11-Apr through 10-Sept. BORIS contains relatively complete AVHRR-LAC coverage from NOAA-11 of central Canada during the snow-free periods in 1993 and 1994.

7.2.2 Temporal Coverage Map

The 1994 compositing periods in this data set are as follows:

April	11 - 20, 21 - 30
May	1 - 10, 11 - 20, 21 - 31
June	1 - 10, 11 - 20, 21 - 30
July	1 - 10, 11 - 20, 21 - 31
August	1 - 10, 11 - 20, 21 - 30
September	1 - 10

7.2.3 Temporal Resolution

AVHRR-LAC data processed as level-4b composite products are daytime images (afternoon passes). Most useful daily images (those containing some clear-sky regions) are used to produce the level-4b product. The daily images are composited into nominally cloud-free images over 10-day periods.

7.3 Data Characteristics

7.3.1 Parameter/Variable

The parameters contained in each image product are:

```
Scaled At-sensor Radiance
NDVI
View Zenith Angle
Solar Zenith Angle
Relative Azimuth Angle
Date of Acquisition
```

7.3.2 Variable Description/Definition

At-sensor radiance is the radiant energy measured by the sensor from its position relative to the target. In this case, it is derived from the signal recorded by the AVHRR sensor, which is then calibrated by the processes described in Section 9 of this document. The following equations were used to calculate the radiance in a given band from the counts given:

```
R(1) =  (625/1023)*DN(1) - 25.0
R(2) =  (415/1023)*DN(2) - 15.0
R(3) = -(1.508988/1023)*DN(3) + 1.504
R(4) = -(175.898/1023)*DN(4) + 170.8
R(5) = -(183.863/1023)*DN(5) + 179.1

where R(i) is the resulting radiance for band (i), and
      DN(i) is the count from band (i) in the digital image.
```

NDVI is the ratio of the difference between the near-infrared band and the visible band and the sum of the two bands [(NIR - VIS) / VIS + NIR)].

The values of the imagery have been scaled such that:

```
NDVI = (DN/10,000) - 1.0
```

View zenith angle is the position of the sensor relative to the nadir (subsatellite point), with 90 degrees indicating the horizontal position and 0 degrees being directly overhead. To calculate view zenith:

```
View Zenith = DN/100
```

Solar zenith angle is the position of the Sun relative to the horizon, with 90 degrees indicating the horizontal position and 0 degrees being directly overhead. To calculate solar zenith:

```
Solar Zenith = DN/100
```

Relative azimuth is equal to the solar azimuth minus the sensor view azimuth. Azimuth angles are measured from North (0 or 360 degrees) and increase clockwise to 90 degrees for east, 180 degrees for south, etc. To calculate
relative azimuth:

```
Relative Azimuth = DN/100
```

Date of acquisition is the day of year on which that particular pixel in the level-4b composite product was acquired.

7.3.3 Unit of Measurement

At-sensor radiance units are W/(m^2 sr μm) for channels 1 and 2, and mW/(m^2 sr cm) for AVHRR channels 3, 4, and 5.

```
NDVI is unitless.
View zenith is measured in degrees.
Solar zenith is measured in degrees.
Relative azimuth is measured in degrees.
Date of acquisition units are days.
```

7.3.4 Data Source

The image data were acquired by CCRS and processed by the MRSC in Winnipeg, Manitoba.

7.3.5 Data Range

At-sensor radiance can range from:

AVHRR Band	Units	DN=0	DN=1023
1	Radiance	-25	600
2	Radiance	-15	400
3	Radiance	1.504	-0.004988
4	Radiance	170.8	-5.098
5	Radiance	179.1	-4.763

- The values of the scaled NDVI imagery range from a DN of 0 to a DN of 20,000.
- The scaled values in the view zenith image range from 0 to 9,000.
- The scaled values of solar zenith DN range from 0 to 9,000.
- The scaled values of relative azimuth range from 0 to 18,000.
- Based on a start date of 01-Jan-1970, the relative date of acquisition ranges from 8866 (11-Apr-1994) to 9018 (10-Sep-1994).

7.4 Sample Data Record

Sample data records are not applicable to image data.

8. Data Organization

8.1 Data Granularity

The smallest unit of data for the level-4b AVHRR-LAC composite is the set of parameters for a given compositing period.

8.2 Data Format(s)

8.2.1 Uncompressed Data Files

A single level-4b AVHRR-LAC composite image product produced by CCRS contains the following 10 files:

File 1 -- Channel 1 radiance
File 2 -- Channel 2 radiance
File 3 -- Channel 3 radiance
File 4 -- Channel 4 radiance
File 5 -- Channel 5 radiance
File 6 -- NDVI
File 7 -- View zenith angle
File 8 -- Solar zenith angle
File 9 -- Relative azimuth angle
File 10 -- Date of acquisition

The images contain 1,200 pixels in each of 1,200 lines. Each pixel value is contained in a 2-byte (16-bit) field ordered as most significant (high-order) byte first. Thus, each image line (file record) contains 2,400 bytes of data.

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

8.2.2 Compressed CD-ROM Files

On the BOREAS CD-ROMs, the image files have been compressed with the Gzip (GNU zip) 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 uses the Lempel-Ziv algorithm (Welch, 1994) also used in the zip and PKZIP programs. The compressed files may be uncompressed using gzip (with the -d option) or gunzip. Gzip is available from many Web sites (for example, the 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

9.1.1 Derivation Techniques and Algorithms

The level-4b composite product uses the level-3 AVHRR-LAC product in LCC projection as input. Daily level-4b products are combined to select the most cloud-free pixels during the 10-day compositing period. By definition, this is the pixel with the highest NDVI value. Once a pixel is selected, it is retained in the composite image, as are the three associated angles, NDVI, and the day of year in which the pixel was imaged. The components are created for three separate periods within a month: 1-10, 11-20, and 21-end of month.

The daily data are not corrected for atmospheric effects prior to creating composites. This is done to avoid selection of pixels with high view zenith angles (Cihlar and Huang, 1994). Only data for view zenith angles 57 degrees or less were used in the composite (except for 1993, when data were used from all zenith angles).

It is important to note that level-4b images were composited from level-3b images processed separately from the level-3b images contained in BORIS. This is because of the differences in projections Albers Equal-Area Conic (AEAC) vs. LCC. However, the same calibration and processing sequences were used, except as noted (e.g., difference in 1995 calibrations).

9.2 Data Processing Sequence

9.2.1 Processing Steps

GEOCOMP created the level-4b composite image by:

- Specifying input parameters for generating the composite image (source images, geographic region, compositing criterion, compositing period)
- Inputting imagery
- Comparing the NDVI of every pixel of the input level-3 image with that of the corresponding composite pixel
- If appropriate, replacing values of a composite pixel by those in the daily image for all channels
- Repeating steps 3 and 4 for all daily images during the compositing period
- Outputting imagery

BORIS staff processed the data by:

- Developing and using software to verify the content of and extract needed information from the image files,
- Compressing the binary files 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

See Section 7.

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

The major source of error is due to two geometric effects, IFOV and image registration. Because the IFOV size at large view zenith angles varies for adjacent level-4 pixels on different dates, the composite pixels represent varying areas (in size and location, thus creating overlaps or gaps) on Earth's surface. This effect can be assessed using the angular information in the level-4 product. The other geometric effect is caused by pixel misregistration. Although the registration of level-3b images is typically done with subpixel accuracy (root mean square [rms]<0.8 km for pixels within 45 degrees of nadir), the accuracy of the composite products accumulates errors from individual images and suffers from the reduced accuracy for pixels farther from nadir. This effect is difficult to quantify as it varies both within the composite image and between composite periods.

The level-4b product is not corrected for atmospheric or bidirectional effects; thus, the composites have numerous radiometric artifacts caused by these phenomena. The level-4b product also suffers from errors in the level-3b product (see level-3b product documentation).

10.2 Quality Assessment

10.2.1 Data Validation by Source

Not available.

10.2.2 Confidence Level/Accuracy Judgment

Refer to the level-3b product specification.

10.2.3 Measurement Error for Parameters

None.

10.2.4 Additional Quality Assessments

Composites are assessed visually.

10.2.5 Data Verification by Data Center

BORIS personnel extracted header information, inventoried the AVHRR data acquisition information in the data base, and viewed some of the imagery to confirm the use of scaling information provided in Section 7.3.2. Lastly, BORIS staff compressed the image data files for distribution on CD-ROM.

11. Notes

11.1 Limitations of the Data
None.

11.2 Known Problems with the Data
None.

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

None given.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description
The GEOCOMP software is written in Pascal and FORTRAN and runs on Digital's VAX computers. Special code also exists for the GEOCOMP array processor. The GEOCOMP software is proprietary. Gzip (GNU zip) uses the Lempel-Ziv algorithm (Welch, 1994) used in the zip and PKZIP commands.

14.2 Software Access
Most of the GEOCOMP software is proprietary. For further information, contact:

MacDonald Dettwiler and Associates
13800 Commerce Parkway
Richmond, BC VGV2J3
(604) 278-3411

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 level-4b AVHRR-LAC 10-day composite images are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

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

15.2 Data Center Identification

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

15.3 Procedures for Obtaining Data

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

15.4 Data Center Status/Plans

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

16. Output Products and Availability

16.1 Tape Products

The AVHRR-LAC level-4b 10-day composite data can be made available on 8-mm media.

16.2 Film Products

None.

16.3 Other Products

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

17. References

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17.2 Journal Articles and Study Reports

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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.

Teillet, P.M. and B.N. Holben. 1994. Towards operational radiometric calibration of NOAA AVHRR imagery in the visible and near-infrared channels. Canadian Journal of Remote Sensing 20: 1-10.

Townshend, J. (Ed.). 1995. Global data sets for the land from AVHRR. International Journal of Remote Sensing 15: 3315-3639 (special issue describing several program-generating composite AVHRR image data sets).

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

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AEAC    - Albers Equal-Area Conic
APC     - Automatic Picture Transmission
ASCII   - American Standard Code for Information Interchange
AVHRR   - Advanced Very High Resolution Radiometer
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
BPI     - Bytes per inch
CCRS    - Canada Centre for Remote Sensing
CCT     - Computer-Compatible Tape
CD-ROM  - Compact Disk-Read-Only Memory
CPIDS   - Calibration Parameter Input Dataset
DAAC    - Distributed Active Archive Center
DAT     - Digital Archive Tape
DN      - Digital Number
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
EROS    - Earth Resources Observation System
FPAR    - Fraction of Photosynthetically Active Radiation
GAC     - Global Area Coverage.
GEOCOMP - Geocoding and Compositing System
GIS     - Geographic Information System
GSFC    - Goddard Space Flight Center
HRPT    - High-Resolution Picture Transmission
IFC     - Intensive Field Campaign
IFOV    - Instantaneous Field-of-View
LAC     - Local Area Coverage
LAI     - Leaf Area Index
LCC     - Lambert Conformal Conic
LGSOWG  - Landsat Ground Station Operational Working Group
MRSC    - Manitoba Remote Sensing Centre
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NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NBIOME  - Northern Biosphere Observation and Modeling Experiment
NDVI    - Normalized Difference Vegetation Index
NEdT    - Noise Equivalent Differential Temperature
NOAA    - National Oceanic and Atmospheric Administration
NRL     - Naval Research Laboratory
NSA     - Northern Study Area
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
PASS    - Prince Albert Satellite Station
PRT     - Platinum Resistor Thermometer
RMS     - Root Mean Square
SSA     - Southern Study Area
SST     - Sea Surface Temperature
TIROS   - Television and Infrared Observation Satellite
URL     - Uniform Resource Locator
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13. ABSTRACT *(Maximum 200 words)*

The BOREAS Staff Science Satellite Data Acquisition Program focused on providing the research teams with the remotely sensed satellite data products they needed to compare and spatially extend point results. MRSC and BORIS personnel acquired, processed, and archived data from the AVHRR instruments on the NOAA-11 and -14 satellites. The AVHRR data were acquired by CCRS and were provided to BORIS for use by BOREAS researchers. These AVHRR level-4b data are gridded, 10-day composites of at-sensor radiance values produced from sets of single-day images. Temporally, the 10-day compositing periods begin 11-Apr-1994 and end 10-Sep-1994. Spatially, the data cover the entire BOREAS region. The data are stored in binary image format files.

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