NASA/TM—2000–209891, Vol. 103

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

Forrest G. Hall, Editor

Volume 103
BOREAS Level-4c AVHRR-LAC Ten-Day Composite Images: Surface Parameters

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

The NASA STI Program Office … in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA Scientific and Technical Information (STI) Program Office plays a key part in helping NASA maintain this important role.

The NASA STI Program Office is operated by Langley Research Center, the lead center for NASA's scientific and technical information. The NASA STI Program Office provides access to the NASA STI Database, the largest collection of aeronautical and space science STI in the world. The Program Office is also NASA's institutional mechanism for disseminating the results of its research and development activities. These results are published by NASA in the NASA STI Report Series, which includes the following report types:

- TECHNICAL PUBLICATION. Reports of completed research or a major significant phase of research that present the results of NASA programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA's counterpart of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- TECHNICAL MEMORANDUM. Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- CONTRACTOR REPORT. Scientific and technical findings by NASA-sponsored contractors and grantees.
- CONFERENCE PUBLICATION. Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or cosponsored by NASA.
- SPECIAL PUBLICATION. Scientific, technical, or historical information from NASA programs, projects, and mission, often concerned with subjects having substantial public interest.
- TECHNICAL TRANSLATION. English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services that complement the STI Program Office's diverse offerings include creating custom thesauri, building customized databases, organizing and publishing research results . . . even providing videos.

For more information about the NASA STI Program Office, see the following:

- Access the NASA STI Program Home Page at http://www.sti.nasa.gov/STI-homepage.html
- E-mail your question via the Internet to help@sti.nasa.gov
- Fax your question to the NASA Access Help Desk at (301) 621-0134
- Telephone the NASA Access Help Desk at (301) 621-0390
- Write to:
  NASA Access Help Desk
  NASA Center for AeroSpace Information
  7121 Standard Drive
  Hanover, MD 21076-1320

NASA/TM—2000–209891, Vol. 103

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

Forrest G. Hall, Editor

Volume 103

BOREAS Level-4c AVHRR-LAC Ten-Day Composite Images: Surface Parameters

Josef Cihlar and Jing Chen, Canada Centre for Remote Sensing, Ottawa, Ontario, Canada
Jaime Nickeson and Jeffrey A. Newcomer, Raytheon ITSS, NASA Goddard Space Flight Center, Greenbelt, Maryland
Fengting Huang, Canada Centre for Remote Sensing, Ottawa, Ontario, Canada

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

September 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 Level-4c AVHRR-LAC Ten-Day Composite Images: Surface Parameters

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-4c data are gridded, 10-day composites of surface parameters 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-4c AVHRR-LAC Ten-Day Composite Images: Surface Parameters

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) instruments on the National Oceanic and Atmospheric Administration (NOAA)-9, -11, -12, and -14 satellites were acquired by the Canada Centre for Remote Sensing (CCRS) and provided for use by BOREAS researchers.

1.3 Objective/Purpose

For BOREAS, the level-4c 10-day composite AVHRR-Local Area Coverage (LAC) image product, along with the other remotely sensed images, was prepared to provide spatially extensive information over the BOREAS region at varying spatial scales. This information includes detailed land cover and biophysical parameter maps such as Fraction of Photosynthetically Active Radiation (FPAR), surface reflectance, surface temperature, and Leaf Area Index (LAI). The CCRS processed the level-4c 10-day composite AVHRR-LAC imagery products.

1.4 Summary of Parameters

The level-4c composite AVHRR-LAC data in the BOREAS Information System (BORIS) contain the following parameters: image header and compositing information; geographic position information: view, solar zenith, and relative azimuth angle information; surface reflectance and temperature; Normalized Difference Vegetation Index (NDVI); and missing data, cloud contamination, and water masks.

1.5 Discussion

The level-4c product is based on level-4b, which is further processed to remove or mitigate some artifacts caused by the input data or the compositing process. The artifacts of concern are atmospheric contamination and bidirectional reflectance effects for AVHRR channels 1 and 2, and atmospheric and surface emissivity effects for AVHRR channel 4. The processing was carried out at CCRS using specifically designed software and procedures (see Section 9 for details). The spatial and temporal coverage of the level-4c product is identical to that of the level-4b product.

1.6 Related Data Sets

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

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

2.3 Contact Information

Contact 1:

Josef Cihlar
Canada Centre for Remote Sensing
588 Booth Street, 4th Floor
Ottawa, Ontario
K1A0Y7 Canada
(613) 947-1265
(613) 947-1406 (fax)
Josef.Cihlar@geocan.emr.ca

Contact 2:
Jaime Nickeson
Raytheon ITSS
NASA GSFC
Code 923
Greenbelt, MD 20771
(301) 286-3373
(301) 286-0239 (fax)
Jaime.Nickeson@gsfc.nasa.gov

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-LAC 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, one middle-infrared, and one or two thermal channels.

The primary use of each channel and the spectral regions and bandwidths 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 - 11.4	Surface Temperature, Day/Night Cloud Mapping
5***	11.4 - 12.4	Surface Temperature

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

The wavelength ranges at 50% 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 is capable of operating 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-4c 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 emitted and reflected radiation from Earth in the visible, near-, middle-, and thermal-infrared regions of the electromagnetic 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 for the infrared detectors of 95 K. 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

Not available at this revision.

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 visible 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 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 four 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-4c AVHRR-LAC images were acquired through the CCRS. Some radiometric corrections along with geometric corrections are applied to produce the imagery in a spatially corrected form (Lambert Conformal Conic [LCC] projection). A full level-4c AVHRR-LAC image contains approximately 1,200 pixels in each of approximately 1,200 lines. Before any geometric corrections, the ground resolution ranges from 1.1 km at nadir to 2.5 km x 6.8 km at the scanning extremes. Each pixel value is stored in a 2-byte field starting with level-4b products. The level-4c images were processed through software developed at CCRS. 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 a global (pole-to-pole) onboard collection of data from all spectral channels. The 110.8-degree scan equates to a swath 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 (side-lap) anywhere on the globe.

The BOREAS level-4c 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 corners 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 North American Datum of 1983 (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 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 pixel size is 1 km in all bands. Only data with view zenith angles 57 degrees or less are used in the level-4c product.

7.1.4 Projection

The coordinate system is the Lambert Conformal Conic (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 level-4 images are projected into the LCC projection at a resolution 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-9, -11, -14 daytime) and are archived at PASS. Most scenes were processed for inclusion in the level-4b and -4c products.

The overall time period of data acquisition in 1994 was from 09-Apr through 10-Sep. CCRS acquired most AVHRR-LAC daytime images from NOAA-9, -11, and -12 for each satellite pass; i.e., two images in each 24-hour cycle.

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 used in the creation of the level-4c composite products were daytime images (afternoon passes). Most useful daily images (i.e., 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

- Surface reflectance (channels 1 and 2)
- Bidirectional Reflectance Distribution Function (BRDF) (channels 1 and 2)
- NDVI (3 versions)
- Surface temperature
- Cloud mask
- Missing data mask

7.3.2 Variable Description/Definition

Surface reflectance: After atmospheric correction, for channels 1 and 2. Based on top of the atmosphere reflectance and the atmospheric correction program called Simplified Method for Atmospheric Correction (SMAC) (Rahman and Dedieu, 1994).

BRDF corrected, interpolated reflectance for channels 1 and 2. Based on surface reflectance (after atmospheric corrections) and BRDF model (channel and land cover specific). Normalized to a solar zenith angle of 45 degrees and view zenith of 0 degrees.

NDVI: The ratio of the difference of the near-infrared and the visible bands and the sum of the two bands [(VIS - IR) / VIS + IR)]. It is an indication of the amount and vigor of vegetation present. Three NDVI channels have been provided:

- NDVI from BRDF corrected interpolated channel 1 and 2 reflectances
- NDVI from the Fourier-Adjustment, Solar zenith angle corrected, Interpolated, Reconstructed (FASIR) model (final corrected, linear interpolated). This NDVI was produced using the FASIR approach of Sellers, et al. For more information, see Cihlar, et al., 1996a.
- NDVI-smoothed FASIR product. Using a smoothing/sliding filter in a 5-day window centered on the date of interest, the highest and lowest values are dropped and the remaining three are averaged.

Surface temperature: Final surface temperature, interpolated, and cut at 330 K. Temperature from channel 4 corrected for atmospheric and surface emissivity effects, with missing/cloudy pixels interpolated. The interpolation used a 330 K cutoff to eliminate 'runaway' cases (e.g., when not enough values were available; it assumed that the temperature would not exceed that value anywhere in Canada).

Cloud mask: A binary image indicating location of cloud contaminated and clear pixels. Produced with the Cloud Elimination from Composites using Albedo and NDVI Trend (CECANT) procedure, see Cihlar, 1996.

Missing data mask: A binary image indicating location of pixels of good and missing data.

7.3.3 Unit of Measurement

- Surface reflectance and BRDF are unitless. To calculate the reflectance values from the scaled integers provided, use reflectance = DN/1000.
- NDVI is unitless. To calculate NDVI values from the scaled integers provided, use NDVI = (DN/10000) -1.
- Surface temperature is measured in K. To convert from scaled to actual temperatures, use Temperature = DN/100.
- Cloud mask is unitless. This is a binary image containing values of either 0 or 255. A value of 0 is a cloudy pixel; 255 indicates a clear pixel.
- Missing data mask is unitless. This is a binary image containing values of either 0 or 255. A values of 0 is a good pixel; 255 indicates a missing pixel.

7.3.4 Data Source

These NOAA AHVRR data were processed and provided by CCRS.

7.3.5 Data Range

No data ranges were given for any of the surface reflectance channels.

- NDVI values range between 0 and 20,000.
- NDVI corrected, linear interpolated: same as above.
- NDVI corrected, linear interpolated, smoothed: same as above.
- No data ranges were given for the surface temperature data.
- Cloud mask values are 0 or 255.
- Missing data mask values are 0 or 255.

7.4 Sample Data Record

Not applicable for image data.

8. Data Organization

8.1 Data Granularity

The smallest unit of data for the level-4c 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-4c AVHRR-LAC composite image product produced by CCRS contains the following 10 files:

```
File  Description
----  -----------------------
  1   AVHRR channel 1 surface reflectance
  2   AVHRR channel 2 surface reflectance
  3   AVHRR channel 1 BRDF-corrected interpolated surface reflectance
  4   AVHRR channel 2 BRDF-corrected interpolated surface reflectance
  5   NDVI from channel 1,2 BRDF-corrected, interpolated surface reflectance
  6   NDVI, FASIR model (final corrected, linearly interpolated)
  7   NDVI, FASIR model, smoothed
  8   Surface temperature, linearly interpolated
  9   Cloud mask
 10   Mask of missing data
```

The image files contain 1,200 pixels in each of 1,200 lines. Each pixel value in files 1 through 8 is contained in a 2-byte (16-bit) field ordered as most significant (high-order) byte first. Thus, each image line (file record) is 2,400 bytes in length. Files 9 and 10 (the masks) for each period are single-byte images with each line containing 1,200 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

Using the BOREAS level-4b AVHRR-LAC product as input, the data are processed to correct radiometric artifacts. These include atmospheric and bidirectional effects in channels 1 and 2, and atmospheric end emissivity effects in AVHRR channel 4. For channel 1 and 2, the atmospheric effects of concern are absorption and scattering by cloud-free atmosphere as well as the presence of variable amounts of clouds (full pixels or subpixel) or snow on the ground. In channel 4, atmospheric water vapor and surface emissivity are the main effects to be corrected for. The rationale and processing sequence are described in Cihlar, et al. (1996).

The major difference between the BOREAS level-3b product and the input data for this product is the projection (the input data for the level-4c product are in the LCC projection). Daily level-3b products were combined to select the most cloud-free pixel during the 10-day compositing period. By definition, this is the pixel with the maximum NDVI value. Once a pixel is selected, it is retained in the composite image, as are the three associated angles, NDVI, and the date when the pixel was imaged.

The level-4b data are further processed to create the level-4c data set, as described in Section 9.2.

9.2 Data Processing Sequence

The level-4c processing sequence is called Atmosphere, Bidirectional and Contamination Corrections of CCRS (ABC3) and is described in more detail in Cihlar, et al. (1996, 1997).

9.2.1 Processing Steps

Step 1: Top-of-the-Atmosphere (TOA) reflectance

TOA reflectance for channel 1 or 2 is calculated from the corrected TOA radiance, L*(new), with the formula given by Teillet (1992). Values of gain G and offset O were calculated with consideration of postlaunch sensor degradation (Teillet and Holben, 1994).

Step 2: Atmospheric correction of AVHRR channels 1 and 2

The SMAC algorithm was used in the processing. The processing was carried out assuming water content of 2.3 g/cm^2 and ozone content 0.319 cm-atm. A constant value of 0.05 was used for optical depth at 550 nm. The corrections were computed on a pixel basis using solar zenith, view zenith, and relative azimuth channels.

Step 3: Identification of contaminated pixels

A new procedure called CECANT was developed to identify the 'contaminated' pixels; i.e., pixels where the surface vegetation or soil signal is obscured (Cihlar, 1996). The procedure is based on the high sensitivity of NDVI to the presence of clouds, aerosol and snow. Three features of the annual surface reflectance trend are used: the high contrast between the albedo (represented by AVHRR channel 1) of land, especially when fully covered by green vegetation and clouds or snow/ice; the average NDVI value (expected value for that pixel and compositing period); and the monotonic trend in NDVI. Four thresholds are required in CECANT to identify partially contaminated pixel (i,j,t) where i and j are pixel coordinates and t is the compositing period:

- C1(t): the maximum channel 1 reflectance of a clear-sky, snow- or ice-free land pixel in the data set.
- Rmin(t): the maximum acceptable deviation of the measured value NDVI(i,j,t) below the estimated NDVIa(i,j,t).
- Rmax(t): the maximum acceptable deviation of the measured value NDVI(i,j,t) above the estimated NDVIa(i,j,t).
- Zmax(t): the maximum acceptable deviation of the measured value NDVI(i,j,t) above the estimated NDVImax(i,j,t).

NDVImax(i,j,t) and NDVIa(i,j,t) were calculated using the FASIR model of Sellers et al. (1994), which approximates the seasonal NDVI curve with a third-order Fourier transform. Before the computation, missing NDVI values between first and last measurements were replaced through linear interpolation after finding the seasonal peak for each pixel, using the rationale and algorithm of Cihlar and Howarth (1994). A constant value of 0.30 was used for C1. The upper and lower limits for R and Z were determined separately for each composite period using R and Z histograms (Cihlar, 1996). Using these thresholds, a cloud mask was prepared for each composite period.

Step 4: Corrections for bidirectional reflectance effects in channels 1 and 2

The model of Roujean, et al. (1992) as modified by Wu, et al. (1995) was used to characterize the seasonal BRDF for each cover type. Land cover-dependent model coefficients were derived (Li, et al., 1995) using a map of Canada with a pixel size of 1 km prepared with AVHRR data (Pokrant, 1991). Only cloud-free pixels were included in the derivation of the model coefficients, and no bidirectional corrections for snow- or ice-covered areas were made. The resulting models were used to compute channel 1 and 2 reflectance for view zenith of 0 degrees and solar zenith of 45 degrees.

Step 5: Replacement of contaminated pixels for AVHRR channels 1 and 2

Two cases were recognized: pixels contaminated either during or at the end of the growing season. For pixels contaminated during the growing season, the new values were found through linear interpolation for both channels 1 and 2. At the end of the growing season, it was assumed that the annual trajectory for individual channels as well as for NDVI could be approximated by a second-degree polynomial. The polynomial was fitted to the plot of corrected reflectance for all clear-sky periods, starting with the first clear-sky composite period after 1-Aug. After determining the best fit coefficients, the new values were calculated using the polynomial coefficients to replace contaminated pixels in each channel prior to the first clear pixel or after the last such pixel.

Step 6: NDVI processing

Because of imperfections in the bidirectional corrections of channels 1 and 2, the NDVI computed from atmospherically corrected NDVI were also retained. However, corrections for solar zenith angle were desirable in view of the known dependence of the NDVI on the solar zenith angle. The coefficients of Sellers, et al. (1994) were used for the various land cover classes. The new set of NDVI values was then computed for a reference solar zenith angle of 45 degrees based on the equations of Sellers, et al. (1994). The NDVI values for the missing or contaminated pixels were interpolated as in Step 5 above.

Step 7: Channel 4 correction

The modified split window method of Coll, et al. (1994) was used which accounts for both atmospheric and surface emissivity effects. Coefficients estimating atmospheric effects were derived by Coll, et al. (1994), alpha and beta were obtained from Figure 2 in Coll, et al.. Surface emissivity was estimated using a log-linear relationship between NDVI and emissivity; the emissivity coefficients were derived from literature data. The formulas and coefficients were:

$$Ts = T4 + (a0 + a1*(T4-T5))*(T4-T5) + B(eps)$$

$$B(eps) = alpha * (1-eps4) - beta * (eps4 - eps5)$$

$$eps4 = 0.98968 + 0.0288 * \ln(final\_NDVI)$$

$$eps4-eps5 = 0.010185 - 0.013443 * \ln(final\_NDVI)$$

where: Ts is surface temperature.
T4, T5 are brightness temperatures TOA in AVHRR channels 4,5
eps4, eps5 are emissivities in in AVHRR channels 4 and 5
Coefficients a0 = 1.29, a1 = 0.28, alpha = 45 K, beta = 40 K.

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

See Section 9.2.1.

9.3.1 Special Corrections/Adjustments

See Section 9.2.1.

9.3.2 Calculated Variables

See Section 9.2.1.

9.4 Graphs and Plots

None.

10. Errors

10.1 Sources of Error

The major sources of error are due to the imprecise knowledge of atmospheric conditions during image acquisition (and thus the use of nominal values for atmospheric corrections) and imperfect modeling of the bidirectional effects.

The level-4c product also suffers from errors in the level-3b and 4-b products (see level-3b product documentation).

10.2 Quality Assessment

10.2.1 Data Validation by Source

Comparing the composite image data (md) with a single-date, near-nadir, cloud-free image (sd) in midsummer, the following equations were obtained for channels 1 and 2 on a per-pixel basis (see Cihlar et al., 1996 and 1997, for discussion):

$C1(md) = 0.04 + 0.26*C1(sd)$; $r^2 = 0.06$, s.e. = 0.014
$C2(md) = 0.09 + 0.74*C2(sd)$; $r^2 = 0.45$, s.e. = 0.04
$NDVI(md) = 0.27 + 0.60*NDVI(sd)$; $r^2 = 0.33$, s.e. = 0.066

For 5 x 5 pixel mean values, the following relations were obtained:

$C1(md) = 0.03 + 0.48 * C1 (sd)$; $r^2 = 0.10$, s.e. = 0.06
$C2(md) = 0.06 + 0.90 * C2(sd)$; $r^2 = 0.69$, s.e. = 0.017
$NDVI(md) = 0.17 + 0.74 * NDVI (sd)$; $r^2 = 0.55$, s.e. = 0.024

10.2.2 Confidence Level/Accuracy Judgment

An evaluation of the resulting data set (Cihlar et al., 1996) showed significant improvement in the consistency and reduced noise in the data compared to level-4b. However, the level-4c data set does not approximate a single-date image closely enough and is therefore not a sound substitute for single-date, near-nadir images where such uncontaminated images are available and where neither timeliness nor the multitemporal observations are required.

10.2.3 Measurement Error for Parameters

Refer to level-3b and level-4b product specifications.

10.2.4 Additional Quality Assessments

Level-4c products are also assessed through seasonal statistics (comparison of mean values per compositing period of various parameters); see Cihlar, et al. (1996).

10.2.5 Data Verification by Data Center

BORIS personnel viewed randomly selected images on a video display. No anomalous items were found. In addition, BORIS personnel compressed the data files for distribution on CD-ROM.

11. Notes

11.1 Limitations of the Data

None given.

11.2 Known Problems with the Data

None.

11.3 Usage Guidance

Two primary NDVI data sets were provided to BOREAS, BRDF-corrected and FASIR approach, because there was uncertainty about the BRDF corrections at the time. The BRDF-corrected NDVI (produced the same way as those provided to BOREAS) is now used in BOREAS work because it corrects for all angular effects, not just view zenith angle, and it was found to increase the NDVI somewhat, as it should. However, there are still questions about the accuracy of the 1994 BRDF-corrected channel 1 and 2 reflectances. The very late local overpass time may have affected both the compositing and the BRDF corrections. Because the solar zenith angle was greater than 55 degrees in most cases and is normalized to 45 degrees, small BRDF correction errors would be magnified in the process of deriving NDVI. Of course, these problems would affect both of the NDVI products.

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 given.

14. Software

14.1 Software Description

The ABC3 software for level-4c products was written in-house using C, FORTRAN, and the visualization package pvWave. The CECANT algorithm used software provided by S. Los from the University of Maryland and is written in C.

BORIS staff developed software and command procedures for:

- Extracting header information from level-4c AVHRR-LAC images on tape and writing it to American Standard Code for Information Interchange (ASCII) files on disk.
- Reading the ASCII disk file and logging the level-4c AVHRR-LAC image products into the Oracle data base tables.
- Converting between the geographic systems of (latitude, longitude), Universal Transverse Mercator (UTM) (northing, easting), and BOREAS (x,y) grid locations.

The software mentioned under items 1 and 2 is written in C 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.

Gzip (GNU zip) uses the Lempel-Ziv algorithm (Welch, 1994) used in the zip and PKZIP commands.

14.2 Software Access

The software used by CCRS is not available for distribution, but the algorithms can be found in the published literature.

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-4c 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 HRPT level-4c 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

17.1 Platform/Sensor/Instrument/Data Processing Documentation

Buffam, A. 1994. GEOCOMP User Manual. Internal Report, Canada Centre for Remote Sensing, Ottawa, Ontario.

Cihlar, J. 1996. Identification of contaminated pixels in AVHRR composite images for studies of land biosphere. Remote Sensing of Environment (in press).

Cihlar, J. and J. Howarth. 1994. Detection and removal of cloud contamination from AVHRR composite images. IEEE Transactions on Geoscience and Remote Sensing 32: 427-437.

Cihlar, J., H. Ly, Z. Li, J. Chen, H. Pokrant, and F. Huang. 1996. Multitemporal, multichannel data sets for land biosphere studies: artifacts and corrections. Remote Sensing of Environment (in press).

Cihlar, J., J. Chen, and Z. Li, 1997. Seasonal AVHRR multichannel data sets and products for studies of surface-atmosphere interactions. Journal of Geophysical Research 102(D24):29,625-29,640.

Coll, C., V. Caselles, J.A. Sobrino, and E. Valor. 1994. On the atmospheric dependence of the split-window equation for land surface temperature. International Journal for Remote Sensing 15(1): 105-122.

Kidwell, K. 1991. NOAA Polar Orbiter Data User's Guide, NCDC/SDSD. (Updated from original 1984 edition.)

Teillet, P.M. 1992. An algorithm for the radiometric and atmospheric correction of AVHRR data in the solar reflective channels. Remote Sensing of Environment 41: 185-195.

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.

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

Cihlar, J. and P.M. Teillet. 1995. Forward piecewise linear calibration model for quasi-real time processing of AVHRR data. Canadian Journal of Remote Sensing 21: 22-27.

Li, Z., J. Cihlar, X. Zheng, L. Moreau, and H. Ly. 1996. The bidirectional effects of AVHRR measurements over northern regions. IEEE Transactions on Geoscience and Remote Sensing (accepted).

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.

Pokrant, H. 1991. Land cover map of Canada derived from AVHRR images. Manitoba Remote Sensing Centre, Winnipeg, Manitoba, Canada.

Rahman, H. and G. Dedieu. 1994. SMAC: a simplified method for the atmospheric correction of satellite measurements in the solar spectrum. International Journal for Remote Sensing 15: 123-143.

Robertson, B., A. Erickson, J. Friedel, B. Guindon, T. Fisher, R. Brown, P. Teillet, M. D'Iorio, J. Cihlar, and A. Sancz. 1992. GEOCOMP, a NOAA AVHRR geocoding and compositing system. Proceedings of the ISPRS Conference, Commission 2, Washington, DC, 223-228.

Roujean, J.-L., M. Leroy, and P.-Y. Deschamps. 1992. A bidirectional reflectance model of the Earth's surface for the correction of remote sensing data. Journal of Geophysical Research 97(D18): 20,455-20,468.

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.

Sellers, P.J., S.O. Los, C.J. Tucker, C.O. Justice, D.A. Dazlich, J.A. Collatz, and D.A. Randall. 1994. A global 1° by 1° NDVI data set for climate studies. Part 2: The generation of global fields of terrestrial biophysical parameters from the NDVI. International Journal of Remote Sensing 15: 3519-3545.

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

Wu, A., Z. Li, and J. Cihlar. 1995. Effects of land cover type and greenness on advanced very high resolution radiometer bidirectional reflectances: analysis and removal. Journal of Geophysical Research 100(D): 9179-9192.

17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

```
ABC3    - Atmosphere, Bidirectional and Contamination Corrections of CCRS
AEAC    - Albers Equal Area Conic
APT     - 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
BRDF    - Bidirectional Reflectance Factor
BSQ     - Band Sequential
CCRS    - Canada Centre for Remote Sensing
CCT     - Computer Compatible Tape
CD-ROM  - Compact Disk-Read-Only Memory
CECANT  - Cloud Elimination from Composites using Albedo and NDVI Trend
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
FASIR   - Fourier-Adjustment, Solar Zenith Angle Corrected, Interpolated,
          Reconstructed
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
I/O     - Input/Output
```

```
IFC     - Intensive Field Campaign
IFOV    - Instantaneous Field-of-View
ISLSCP  - International Satellite Land Surface Climatology Project
LAC     - Local Area Coverage
LAI     - Leaf Area Index
LCC     - Lambert Conformal Conic
LGSOWG  - Landsat Ground Station Operational Working Group
MRSC    - Manitoba Remote Sensing Centre
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
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
SMAC    - Simplified Method for Atmospheric Correction
SSA     - Southern Study Area
SST     - Sea Surface Temperature
TIROS   - Television and Infrared Observation Satellite
TOA     - Top-of-the-Atmosphere
URL     - Uniform Resource Locator
UTM     - Universal Transverse Mercator
```

20. Document Information

20.1 Document Revision Date

Written: 25-Jul-1995
Last Updated: 16-Jul-1999

20.2 Document Review Date(s)

BORIS Review: 14-Jan-1998
Science Review: 12-Sep-97

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 level-4c product was created by CCRS staff using the ABC3 method developed at CCRS. The respective contributions of the above individuals and agencies to completing this data set are greatly appreciated.

If using data from the BOREAS CD-ROM series, also reference the data as:

Cihlar, J., "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:

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

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 2000	Technical Memorandum

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS) BOREAS Level-4c AVHRR-LAC Ten-Day Composite Images: Surface Parameters	923 RTOP: 923-462-33-01
6. AUTHOR(S) Josef Cihlar, Jing Chen, Jaime Nickeson, Jeffrey A. Newcomer, and Fengting Huang 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. 103

11. SUPPLEMENTARY NOTES

J. Cihlar, J. Chen, and F. Huang: Canada Centre for Remote Sensing, Ottawa, Ontario, Canada;
J. Nickeson and J.A. Newcomer: Raytheon ITSS, NASA Goddard Space Flight Center,
Greenbelt, Maryland

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

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-4c data are gridded, 10-day composites of surface parameters 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: Some of the data files on the BOREAS CD-ROMs have been compressed using the Gzip program. See section 8.2 for details.

14. SUBJECT TERMS	15. NUMBER OF PAGES
BOREAS, remote sensing science, AVHRR.	20
	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