



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

*Forrest G. Hall, Editor*

### **Volume 91**

## **BOREAS Level-0 TIMS Imagery: Digital Counts in BIL Format**

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# **BOREAS Level-0 TIMS Imagery: Digital Counts in BIL Format**

Jeffrey A. Newcomer, Roseanne Dominguez

## **Summary**

For BOREAS, the TIMS imagery, along with the other remotely sensed images, was collected to provide spatially extensive information over the primary study areas. The level-0 TIMS images cover the time periods of 16-Apr-1994 to 20-Apr-1994 and 06-Sep-1994 to 17-Sep-1994. The images are available in their original uncalibrated format.

Note that the level-0 TIMS 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 Section 15 for information about how to acquire actual level-0 TIMS images.

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## **1. Data Set Overview**

### **1.1 Data Set Identification**

BOREAS Level-0 TIMS Imagery: Digital Counts in BIL 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, processing, and archiving of six-band Thermal Infrared Multispectral Scanner (TIMS) image data collected on the National Aeronautics and Space Administrator's (NASA's) C-130 aircraft.

### **1.3 Objective/Purpose**

For BOREAS, the TIMS imagery, along with the other remotely sensed images, was collected to provide spatially extensive information over the primary study areas. This information includes detailed land cover, biophysical parameter maps such as fraction of Photosynthetically Active Radiation (fPAR) and Leaf Area Index (LAI), and surface thermal properties.

### **1.4 Summary of Parameters**

Level-0 TIMS image data in the BOREAS Information System (BORIS) contain the following parameters: original housekeeping information, calibration information, and bands 1-6 in the NASA Ames Research Center (ARC) BIL format.

### **1.5 Discussion**

BORIS staff processed the level-0 TIMS images by:

- Extracting pertinent header information from the level-0 image product and placing it in an American Standard Code for Information Interchange (ASCII) file on disk
- Reading the information in the disk file and loading the online data base with needed information

### **1.6 Related Data Sets**

BOREAS Level-0 C-130 Aerial Photography

BOREAS Level-0 NS001 TMS Imagery: Digital Counts in BIL Format

BOREAS Level-1b TIMS Imagery: At-sensor Radiance Values in BSQ Format

BOREAS Level-1b ASAS Imagery: At-sensor Radiance Values in BSQ Format

## **2. Investigator(s)**

### **2.1 Investigator(s) Name and Title**

BOREAS Staff Science

### **2.2 Title of Investigation**

BOREAS Staff Science Aircraft Data Acquisition Program

### **2.3 Contact Information**

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### 3. Theory of Measurements

According to Planck's equation, all objects emit radiation, depending on their temperature and emissivity. The temperature of an object is of interest in determining the radiation balance at Earth's surface. The emissivity of an object as a function of wavelength can provide information on the object's composition. Though much of the radiation emitted from an object is absorbed by the atmosphere, a few good atmospheric windows from 3 to 5 micrometers (m) and 8 to 14 m exist for the remote sensing of emitted surface radiation.

The NASA Earth Resources Aircraft Program at ARC operates the C-130 aircraft to acquire data for Earth science research. The TIMS instrument used on the C-130 aircraft collects radiance measurements in six spectral bands covering the infrared spectrum from 8.2 to 12.2  $\mu\text{m}$ .

Thematic considerations have dictated, within technical constraints, the choice of spectral band position and width in the TIMS sensor. These bands were chosen after many years of analysis for their value in discrimination of geologic features, and they correspond to the emissivity anomalies associated with silicate and carbonate rocks.

### 4. Equipment

#### 4.1 Sensor/Instrument Description

The TIMS instrument is an optomechanical scanner designed to collect multispectral thermal imagery for geologic mapping. The TIMS is generally flown at medium altitudes and provides 3- to 20-m resolution at nadir at an altitude of 1,200 to 8,000 m, respectively. The TIMS is flown aboard NASA's C-130 aircraft based at ARC. The six spectral channels of the TIMS sensor have the following bandpasses:

TIMS Channel	Wavelength, $\mu\text{m}$
1	8.2-8.6
2	8.6-9.0
3	9.0-9.4
4	9.4-10.2
5	10.2-11.2
6	11.2-12.2

#### 4.1.1 Collection Environment

As part of the BOREAS Staff Science data collection effort, BORIS distributed six-band level-0 TIMS image data. The TIMS was flown on NASA's C-130 aircraft during the BOREAS mission (see the BOREAS Experiment Plan for flight pattern details and objectives). Maintenance and operation of the instrument are the responsibility of ARC. The C-130 Experimenter's Handbook (supplemental) produced by the Medium Altitude Missions Branch at ARC provides a description of the instrument, calibration procedures, and data format.

#### 4.1.2 Source/Platform

NASA's C-130 Earth Resources Aircraft.

#### 4.1.3 Source/Platform Mission Objectives

The original purpose of the TIMS scanner was to provide low-altitude data in the thermal infrared region of the electromagnetic spectrum for use in geologic mapping. For BOREAS, the TIMS was flown on the C-130 with a set of other scanners to provide full coverage of the reflected and emitted surface energy.

#### 4.1.4 Key Variables

Emitted radiation, reflected radiation, temperature.

#### 4.1.5 Principles of Operation

Design parameters of the TIMS are based on the specifications of Dr. Anne B. Kahle of the NASA Jet Propulsion Laboratory (JPL). A rotating scan mirror scans the instrument's Instantaneous Field-Of-View (IFOV) across track as the motion of the aircraft moves the sensor along the data collection path.

#### 4.1.6 Sensor/Instrument Measurement Geometry

IFOV	2.5 mrad
Total Scan Angle	76.56°
Pixels/Scan Line	638

Sensor footprint is 10 x 10 m at nadir at 4,000 m altitude.

#### 4.1.7 Manufacturer of Sensor/Instrument

The TIMS instrument was built by Daedalus Enterprises, of Ann Arbor, Michigan. It was further modified by the NASA Stennis Space Flight Center.

### 4.2 Calibration

#### General Calibration Information:

After the First International Satellite Land Surface Climatology Project (ISLSCP) Field Experiment (FIFE), BOREAS staff attempted to further relate remotely sensed radiances to land surface radiometers. The instrument carries two onboard blackbody sources, which fill the full aperture of the system with energy of a preset, known temperature. The two blackbody sources are viewed by the TIMS once every scan line. The spectral bandpass of each channel was determined by the calibration laboratory at Stennis on an annual basis.

TIMS data may be intentionally overscanned, e.g., operated at some integral multiple of the desired scan rate and then subsampled in preprocessing. The subsampling factor is reported as a "demagnification factor."

#### 4.2.1 Specifications

The wavelength ranges (in micrometers) of the bands for the TIMS are:

Band	Detector	Wavelength	Noise Equivalent Change in Temperature (NEdT)
1	HgCdTe	8.2-8.6	0.2°C
2	"	8.6-9.0	0.2°C
3	"	9.0-9.4	0.2°C
4	"	9.4-10.2	0.2°C
5	"	10.2-11.2	0.2°C
6	"	11.2-12.2	0.2°C

#### DESIGN DATA:

IFOV	2.5 mrads
Across-track Field-Of-View	76.56°
Nominal aperture diameter	7.5 inches
Effective aperture area	59.8 cm <sup>2</sup>
f/number	Not available
Primary focal length	Not available
Inflight calibration	Two controllable blackbodies



V/H range	Variable, 0.025 to 0.25
Scan rate	Variable, 7.3 to 25 scans/sec.
Scan speed ability	One-third of the IFOV, scan line to scan line
Data quantization	8 bits (256 discrete levels)
Number of video samples/scan line	638
Roll compensation	+/-15°
Scan mirror	45° rotating mirror
NEdT	0.25 K

#### **4.2.1.1 Tolerance**

The TIMS channels were designed for noise-equivalent temperature differences for the channels, represented by the radiometric sensitivity (NEdT) of 0.25 K.

#### **4.2.2 Frequency of Calibration**

The TIMS was spectrally calibrated prior to each flight season at Stennis to determine the spectral response function of each channel.

#### **4.2.3 Other Calibration Information**

The TIMS instrument periodically viewed an extended-area precision blackbody source at ARC to verify linearity of response over the range of 0-50 °C.

## **5. Data Acquisition Methods**

As part of the BOREAS Staff Science data collection effort, BORIS distributed 6-band level-0 TIMS image data. The TIMS was flown on NASA's C-130 aircraft during the BOREAS mission (see the BOREAS Experiment Plan for flight pattern details and objectives). Maintenance and operation of the instrument are the responsibility of ARC. The C-130 Experimenter's Handbook (supplemental) produced by the Medium Altitude Missions Branch at ARC provides a description of the instrument, calibration procedures, and data format.

## **6. Observations**

### **6.1 Data Notes**

Flight summary reports and verbal records on videotapes are available for the BOREAS TIMS data.

### **6.2 Field Notes**

Flight summary reports and verbal records on videotapes are available for the BOREAS TIMS data.

## **7. Data Description**

### **7.1 Spatial Characteristics**

The BOREAS level-0 TIMS images primarily cover the Southern Study Area (SSA) and the Northern Study Area (NSA). A few images were acquired for the transect area between the SSA and the NSA. The SSA and the NSA are located in the southwest and northeast portions of the overall region.

### 7.1.1 Spatial Coverage

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

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

The NAD83 corner coordinates of the NSA are:

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

### 7.1.2 Spatial Coverage Map

Not available.

### 7.1.3 Spatial Resolution

Typical altitudes for BOREAS flights were 5,000 and 3,000 m above ground level (surface elevation of 400 m), which normally required 25 scan lines per second. These altitudes produced 12.5 m and 7.5 m pixels at nadir given the TIMS's 2.5-mrad IFOV.

### 7.1.4 Projection

The BOREAS level-0 TIMS images are stored in their original data collection frame with increasing pixel sizes from nadir to the scanning extremes based on the scan angle.

### 7.1.5 Grid Description

The BOREAS level-0 TIMS images are stored in their original data collection frame with increasing pixel sizes from nadir to the scanning extremes based on the scan angle.

## 7.2 Temporal Characteristics

### 7.2.1 Temporal Coverage

The data were collected during the BOREAS Focused Field Campaign - Thaw (FFC-T) and Intensive Field Campaign (IFC)-3, covering the periods of 16- to 20-Apr-1994 and 06- to 16-Sep-1994.

### 7.2.2 Temporal Coverage Map

IFC#	Dates
-----	-----
FFC-T	16-Apr-1994 -- 20-Apr-1994
IFC-3	06-Sep-1994 -- 17-Sep-1994

### 7.2.3 Temporal Resolution

Images were acquired on at least one day during the field campaigns.

## 7.3 Data Characteristics

### 7.3.1 Parameter/Variable

The main parameter contained in the image data files is: Digital Number (DN)

The other parameters contained in the TIMS housekeeping are described in section 8.2. The descriptions of 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
PLATFORM_ALTITUDE
MIN_SOLAR_ZEN_ANG
MAX_SOLAR_ZEN_ANG
MIN_SOLAR_AZ_ANG
MAX_SOLAR_AZ_ANG
C130_MISSION_ID
C130_LINE_NUM
C130_RUN_NUM
C130_SITE
BAND_QUALITY
CLOUD_COVER
TIMS_MEAN_FRAME_STATUS
NW_LATITUDE
NW_LONGITUDE
NE_LATITUDE
NE_LONGITUDE
SW_LATITUDE
SW_LONGITUDE
SE_LATITUDE
SE_LONGITUDE
CRTFCN_CODE

### 7.3.2 Variable Description/Definition

For the image data files:

Digital Number (DN) - The quantized DN derived by the NS001 TMS scanning system for the respective channel.

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,

INSTRUMENT	person) that supported the instrument. The name of the device used to make the measurements.
NUM_BANDS	The number of spectral bands in the data.
PLATFORM_ALTITUDE	The nominal altitude of the data collection platform above the target.
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.
C130_MISSION_ID	The mission identifier assigned to the C130 mission in the form of YY-DDD-FF where YY is the last two digits of the fiscal year, DDD is the deployment number for "official" C130 missions and is day of year for non-"official" C130 missions (i.e., no site coverage), and FF is the flight number within the given deployment (00 is given for non-"official" C130 missions). An example would be 94-006-04.
C130_LINE_NUM	The number of the C130 line in its flights over the BOREAS area as given in the flight logs. Zero values are given for non-"official" C130 missions and for data between C130 sites or lines.
C130_RUN_NUM	The number of the C130 run in its flights over the BOREAS area as given in the flight logs. Zero value is given for non-"official" C130 missions and data between C130 sites, lines or runs.
C130_SITE	The C130 site designator as given in the flight logs. PRE is used for data taken from the airport to the first "official" C130 site, BTW is used for data taken between two "official" C130 sites, DSC is used for data taken after the last "official" C130 site, TRN is used for transect data, and YTH and YPA are used for data taken at the YTH and YPA airports (aircraft never left the ground).
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.
TIMS_MEAN_FRAME_STATUS	The mean framestatus calculated from the values on the digital tape of TIMS data collected during the flight.
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.
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

For the image data files: Digital Number (DN) - counts

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]
PLATFORM_ALTITUDE	[meters]
MIN_SOLAR_ZEN_ANG	[degrees]
MAX_SOLAR_ZEN_ANG	[degrees]
MIN_SOLAR_AZ_ANG	[degrees]
MAX_SOLAR_AZ_ANG	[degrees]
C130_MISSION_ID	[none]
C130_LINE_NUM	[none]
C130_RUN_NUM	[none]
C130_SITE	[none]
BAND_QUALITY	[none]
CLOUD_COVER	[none]
TIMS_MEAN_FRAME_STATUS	[none]
NW_LATITUDE	[degrees]

NW_LONGITUDE	[degrees]
NE_LATITUDE	[degrees]
NE_LONGITUDE	[degrees]
SW_LATITUDE	[degrees]
SW_LONGITUDE	[degrees]
SE_LATITUDE	[degrees]
SE_LONGITUDE	[degrees]
CRTFCN_CODE	[none]

### 7.3.4 Data Source

The level-0 TIMS data were collected by the TIMS instrument on the C-130 aircraft. The data were processed from the aircraft tapes and supplied to BOREAS by the Medium Altitude Aircraft Branch at ARC. The source of the parameter values contained in the inventory listing file on the CD-ROM are:

Column Name	Data Source
SPATIAL_COVERAGE	[Determined from latitude and longitude information provided in the NASA Ames flight summary reports]
DATE_OBS	[Software derived from TIMS housekeeping data]
START_TIME	[Software derived from TIMS housekeeping data]
END_TIME	[Software derived from TIMS housekeeping data]
PLATFORM	[Data base constant]
INSTRUMENT	[Data base constant]
NUM_BANDS	[Data base constant]
PLATFORM_ALTITUDE	[Determined from latitude and longitude information provided in the NASA Ames flight summary reports]
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]
C130_MISSION_ID	[Taken from the delivered tape label and the NASA Ames Flight Summary Reports]
C130_LINE_NUM	[Taken from the delivered tape label and the NASA Ames Flight Summary Reports]
C130_RUN_NUM	[Taken from the delivered tape label and the NASA Ames Flight Summary Reports]
C130_SITE	[Taken from the delivered tape label and the NASA Ames Flight Summary Reports]
BAND_QUALITY	[Constant software parameter value]
CLOUD_COVER	[Constant software parameter value]
NS001_MEAN_FRAME_STATUS	[Software derived from TIMS housekeeping data]
NW_LATITUDE	[Calculated with software from the C130 altitude and heading, starting and ending flight line latitude and longitude, and the static NS001 scan angle information]
NW_LONGITUDE	[Calculated with software from the C130 altitude and heading, starting and ending flight line latitude and longitude, and the static TIMS scan

	angle information]
NE_LATITUDE	[Calculated with software from the C130 altitude and heading, starting and ending flight line latitude and longitude, and the static TIMS scan angle information]
NE_LONGITUDE	[Calculated with software from the C130 altitude and heading, starting and ending flight line latitude and longitude, and the static TIMS scan angle information]
SW_LATITUDE	[Calculated with software from the C130 altitude and heading, starting and ending flight line latitude and longitude, and the static TIMS scan angle information]
SW_LONGITUDE	[Calculated with software from the C130 altitude and heading, starting and ending flight line latitude and longitude, and the static TIMS scan angle information]
SE_LATITUDE	[Calculated with software from the C130 altitude and heading, starting and ending flight line latitude and longitude, and the static TIMS scan angle information]
SE_LONGITUDE	[Calculated with software from the C130 altitude and heading, starting and ending flight line latitude and longitude, and the static TIMS scan angle information]
CRTFCN_CODE	[Constant data base value]

### 7.3.5 Data Range

The maximum range of DNs in each level-0 TIMS image band is limited from 0 to 255 so that the values can be stored in a single 8-bit (1-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	16-APR-94	17-SEP-94	None	None	None	None
START_TIME	1538	2217	None	None	None	None
END_TIME	1543	2237	None	None	None	None
PLATFORM	C130	C130	None	None	None	None
INSTRUMENT	N/A	N/A	None	None	None	None
NUM_BANDS	6	6	None	None	None	None
PLATFORM_ALTITUDE	4640	7716.3	None	None	None	None
MIN_SOLAR_ZEN_ANG	42.3	61.4	None	None	None	None
MAX_SOLAR_ZEN_ANG	42.6	61.7	None	None	None	None
MIN_SOLAR_AZ_ANG	123.5	240.2	None	None	None	None
MAX_SOLAR_AZ_ANG	124.1	242.9	None	None	None	None
C130_MISSION_ID	94-004-09	94-009-09	None	None	None	None
C130_LINE_NUM	1	703	None	None	None	None
C130_RUN_NUM	1	3	None	None	None	None
C130_SITE	429	433	None	None	None	None
BAND_QUALITY	N/A	N/A	None	None	None	None
CLOUD_COVER	N/A	N/A	None	None	None	None

TIMS_MEAN_FRAME_	0	20	None	None	None	None
STATUS						
NW_LATITUDE	53.32609	56.17763	None	None	None	None
NW_LONGITUDE	-106.53088	-97.96291	None	None	None	None
NE_LATITUDE	53.31297	56.12803	None	None	None	None
NE_LONGITUDE	-106.09913	-97.77578	None	None	None	None
SW_LATITUDE	53.06474	55.95072	None	None	None	None
SW_LONGITUDE	-106.61678	-98.02344	None	None	None	None
SE_LATITUDE	53.0517	55.94053	None	None	None	None
SE_LONGITUDE	-106.13012	-97.83714	None	None	None	None
CRTFCN_CODE	PRE	PRE	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-0 TIMS images is not available here. The following are wrapped versions of the first few records from the level-0 TIMS inventory table on the CD-ROM:

```
SPATIAL_COVERAGE,DATE_OBS,START_TIME,END_TIME,PLATFORM,INSTRUMENT,NUM_BANDS,
PLATFORM_ALTITUDE,MIN_SOLAR_ZEN_ANG,MAX_SOLAR_ZEN_ANG,MIN_SOLAR_AZ_ANG,
MAX_SOLAR_AZ_ANG,C130_MISSION_ID,C130_LINE_NUM,C130_RUN_NUM,C130_SITE,
BAND_QUALITY,CLOUD_COVER,TIMS_MEAN_FRAME_STATUS,NW_LATITUDE,NW_LONGITUDE,
NE_LATITUDE,NE_LONGITUDE,SW_LATITUDE,SW_LONGITUDE,SE_LATITUDE,SE_LONGITUDE,
CRTFCN_CODE
'SSA',16-APR-94,1606,1610,'C130','TIMS',6,4753.1,56.0,56.3,123.5,124.1,
'94-004-09',301,1,'429','NOT ASSESSED','NOT ASSESSED',0,53.71754,-106.37024,
53.6996,-105.93603,53.52663,-106.39161,53.50878,-105.95939,'PRE'
'SSA',16-APR-94,1615,1618,'C130','TIMS',6,4771.0,55.0,55.3,125.7,126.3,
'94-004-09',303,1,'429','NOT ASSESSED','NOT ASSESSED',0,53.65307,-106.48068,
53.6305,-105.92932,53.62535,-106.48372,53.60279,-105.93272,'PRE'
```



## 8. Data Organization

### 8.1 Data Granularity

The smallest unit of data for level-0 TIMS images is a single image. Although the image inventory is contained on the BOREAS CD-ROM set, the actual level-0 TIMS images are not. See Section 15 for information about how to obtain the data.

### 8.2 Data Format(s)

The CD-ROM inventory listing file consists of numerical and character fields of varying length separated by commas. The character fields are enclosed with single apostrophe marks. There are no spaces between the fields.

Each level-0 TIMS image from a given flight is contained in one file. A physical record of 4,188 bytes contains six logical records of 698 bytes each that contain the image data (638 bytes) and housekeeping information (60 bytes) from the six TIMS spectral bands in BIL order. The bytes of the 16-bit and 32-bit values in the housekeeping information are ordered as high-order byte first. For computer systems using low-order byte first ordering, the bytes in these fields need to be swapped before they can be interpreted properly. The specific logical record structure is:

Bytes	Description
Bytes 1 - 60:	Housekeeping Information
1 - 2 :	Status (16-bit integer) 0 implies the data are good; nonzero bad 10 Interpolated data 20 Repeated data 30 Zero fill data
3 - 4 :	Filler (16-bit integer)
5 - 8 :	Scan line count (32-bit integer)
9 - 12 :	Thumbwheel switches (32-bit integer) Consists of 8 digits of the form DDMYSSS where DD is day of month MM is the month Y is last digit of the year SSS is generally the mission number but could also be the sortie/flight line number
13 - 14 :	Blackbody #1 Thermal Reference Temperature (16-bit integer) (hundredths of degrees C)
15 - 16 :	Blackbody #2 Thermal Reference Temperature (16-bit integer) (hundredths of degrees C)
17 - 18 :	Scan Speed (16-bit integer) (tenths of scans per second)
19 - 20 :	Greenwich Mean Time (GMT) hours (16-bit integer)
21 - 22 :	Minutes of the hour (16-bit integer)
23 - 24 :	Tenths of seconds (16-bit integer)
25 - 26 :	Filler (16-bit integer) (Set to 100) (Reserved for Demagnification)
27 - 28 :	Filler (16-bit integer)
29 - 30 :	Gain Value (times 1000) (16-bit integer)
31 - 32 :	Channel Number (16-bit integer)
33 - 36 :	Time (32-bit integer) (7 digits in the form of hhmmssst where hh is the hour, mm is the minute, ss is the second, and t is the tenth of a second)
37 - 38 :	Blackbody #1 Response (16-bit integer) (Count) (What the sensor sees when it looks at Blackbody #1)

39 - 40 : Blackbody #2 Response (16-bit integer) (Count)  
 (What the sensor sees when it looks at Blackbody #2)

41 - 42 : Aircraft Roll angle (16-bit integer)  
 (tenths of degrees)  
 (Positive values indicate clockwise rotation of the aircraft  
 when viewed from the front; negative values indicate  
 counterclockwise rotation)

43 - 44 : Aircraft Pitch Angle (16-bit integer)  
 (tenths of degrees)  
 (Positive values indicate upward movement of the  
 front of the aircraft from a horizontal position;  
 negative values indicate downward movement)

45 - 46 : True heading (16-bit integer)  
 (tenths of degrees)  
 (0 or 360 = North; 90 = East; 180 = South; 270 = West)

47 - 48 : Latitude degrees (16-bit integer)  
 (Positive values indicate latitudes N of the Equator)

49 - 50 : Latitude tenths of minutes (16-bit integer)

51 - 52 : Longitude degrees (16-bit integer)  
 (Positive values indicate longitudes E of the  
 central meridian)

53 - 54 : Longitude tenths of minutes (16-bit integer)

55 - 56 : Ground speed (16-bit integer) (nautical miles per hour)

57 - 58 : Drift angle (16-bit integer)  
 (tenths of degrees)  
 (Positive values indicate left drift)

59 - 60 : Navigation data status bits  
 (Bit on implies valid data)  
 1 bit -- Latitude  
 2 bit -- Longitude  
 4 bit -- Ground speed  
 8 bit -- Drift angle

Bytes 61 - 698: Image data for the 638 pixels across a given scan line

## 9. Data Manipulations

### 9.1 Formulae

#### 9.1.1 Derivation Techniques and Algorithms

None.

### 9.2 Data Processing Sequence

#### 9.2.1 Processing Steps

BORIS staff processed the level-0 TIMS images by:

- Extracting pertinent header and calibration information from the level-0 image product and writing it to a disk file
- Reading the information in the disk file and loading the online data base with needed information

#### 9.2.2 Processing Changes

None.

## **9.3 Calculations**

### **9.3.1 Special Corrections/Adjustments**

The TIMS data are not geometrically corrected. The data contain both panoramic distortion, as a function of the 76.56 degree total FOV, and other spatial perturbations induced by a moving aircraft.

### **9.3.2 Calculated Variables**

None.

## **9.4 Graphs and Plots**

None.

## **10. Errors**

### **10.1 Sources of Error**

See Section 9.3.1. Other sources of error include possible nonunity emissivity of the onboard blackbodies and inexact knowledge of the exact blackbody temperatures in flight conditions.

### **10.2 Quality Assessment**

#### **10.2.1 Data Validation by Source**

Spectral errors could arise because of image-wide signal-to-noise ratio, saturation, cross-talk, spikes, and response normalization caused by a change in gain.

#### **10.2.2 Confidence Level/Accuracy Judgment**

System optical focus is continually monitored by close observation of the apparent sharpness and resolution of objects appearing in scenes after data processing. Although this approach is somewhat subjective, it has proven to be a viable alternative compared to the classical resolution measurement method, which requires removing the scanner system from the C-130 airplane with subsequent setup. This is not a practical option during the flying/deployment portion of the year. However, any observed focus degradation would be corrected by focus adjustment.

#### **10.2.3 Measurement Error for Parameters**

The NEdT for the channels is typically 0.2 °C or less, depending on aircraft flight regime, with variations caused by vibration.

#### **10.2.4 Additional Quality Assessments**

The TIMS has periodically viewed a precision extended-area blackbody calibration source to verify linearity over the 0-50 °C. range.

#### **10.2.5 Data Verification by Data Center**

The only data verification consisted of reviewing the values extracted from the tape files and loaded into the data base.

## **11. Notes**

### **11.1 Limitations of the Data**

None.

### **11.2 Known Problems with the Data**

To date, no discrepancies or problems have been noted in the data.

### **11.3 Usage Guidance**

Because of variable conditions found in different flight regimes on the C-130 aircraft, the onboard blackbody temperatures reported in the housekeeping data may be artificially high, which will result in apparently elevated ground temperatures. This is caused by cold air blasting on the front surface of these reference sources.

The TIMS data are not geometrically corrected. The data contain both panoramic distortion, as a function of the 76-degree total FOV, and other spatial perturbations induced by a moving aircraft.

### **11.4 Other Relevant Information**

None.

## **12. Application of the Data Set**

The TIMS data can be used to analyze the thermal properties of various surface targets.

## **13. Future Modifications and Plans**

None.

## **14. Software**

### **14.1 Software Description**

BORIS staff developed software and command procedures for:

- Extracting header and calibration information from level-0 TIMS images on tape and writing it to ASCII files on disk
- Reading the ASCII disk file and logging the level-0 TIMS image products into the Oracle data base tables

### **14.2 Software Access**

The software is written in C and is operational on VAX 6410 and MicroVAX 3100 systems at Goddard Space Flight Center (GSFC). The primary dependencies in the software are the tape Input/Output (I/O) library and the Oracle data base utility routines.

## **15. Data Access**

The level-0 TIMS imagery is available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

### **15.1 Contact Information**

For BOREAS data and documentation please contact:

ORNL DAAC User Services  
Oak Ridge National Laboratory  
P.O. Box 2008 MS-6407  
Oak Ridge, TN 37831-6407  
Phone: (423) 241-3952  
Fax: (423) 574-4665  
E-mail: [ornldaac@ornl.gov](mailto:ornldaac@ornl.gov) or [ornl@eos.nasa.gov](mailto: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 BOREAS level-0 TIMS data can be made available on 1600- or 6250-Bytes Per Inch (BPI) Digital Archive Tape (DAT), 9-track, or 8-mm tapes.

## **16.2 Film Products**

Color aerial photographs and video records were made during data collection. The video record includes aircraft crew cabin intercom conversations and an audible tone that was initiated each time the sensor was triggered. The BOREAS data base contains an inventory of available BOREAS aircraft flight documentation, such as flight logs, videotapes, and photographs.

## **16.3 Other Products**

Although the image inventory is contained on the BOREAS CD-ROM set, the actual level-0 NS001 images are not. See Section 15 for information about how to obtain the data.

# **17. References**

## **17.1 Platform/Sensor/Instrument/Data Processing Documentation**

There is a Daedalus Operator's Manual for TIMS, but it is proprietary and may not be reproduced without their permission. Contact Daedalus Enterprises, Ann Arbor, MI, for details.

Airborne Instrumentation Research Project. Flight Summary Reports for Flight No. 94-004-09 to 94-009-09 or April 16, 1994, to September 19, 1994. NASA Ames Research Center, Airborne Missions and Applications Division, Moffett Field, California, 94035.

NASA. 1990. C-130 Earth Resources Aircraft Experimenter's Handbook. National Aeronautics and Space Administration, Ames Research Center. Moffett Field, California.

## **17.2 Journal Articles and Study Reports**

Newcomer, J., D. Landis, S. Conrad, S. Curd, K. Huemmrich, D. Knapp, A. Morrell, J. Nickeson, A. Papagno, D. Rinker, R. Strub, T. Twine, F. Hall, and P. Sellers, eds. 2000. Collected Data of The Boreal Ecosystem-Atmosphere Study. NASA. CD-ROM.

Sellers, P. and F. Hall. 1994. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1994-3.0, NASA BOREAS Report (EXPLAN 94).

Sellers, P. and F. Hall. 1996. Boreal Ecosystem-Atmosphere Study: Experiment Plan. Version 1996-2.0, NASA BOREAS Report (EXPLAN 96).

Sellers, P., F. Hall, and K.F. Huemmrich. 1996. Boreal Ecosystem-Atmosphere Study: 1994 Operations. NASA BOREAS Report (OPS DOC 94).

Sellers, P., F. Hall, and K.F. Huemmrich. 1997. Boreal Ecosystem-Atmosphere Study: 1996 Operations. NASA BOREAS Report (OPS DOC 96).

Sellers, P., F. Hall, H. Margolis, B. Kelly, D. Baldocchi, G. den Hartog, J. Cihlar, M.G. Ryan, B. Goodison, P. Crill, K.J. Ranson, D. Lettenmaier, and D.E. Wickland. 1995. The boreal ecosystem-atmosphere study (BOREAS): an overview and early results from the 1994 field year. Bulletin of the American Meteorological Society. 76(9):1549-1577.

Sellers, P.J., F.G. Hall, R.D. Kelly, A. Black, D. Baldocchi, J. Berry, M. Ryan, K.J. Ranson, P.M. Crill, D.P. Lettenmaier, H. Margolis, J. Cihlar, J. Newcomer, D. Fitzjarrald, P.G. Jarvis, S.T. Gower, D. Halliwell, D. Williams, B. Goodison, D.E. Wickland, and F.E. Guertin. 1997. BOREAS in 1997: Experiment Overview, Scientific Results and Future Directions. Journal of Geophysical Research 102 (D24): 28,731-28,770.

### **17.3 Archive/DBMS Usage Documentation**

None.

## **18. Glossary of Terms**

None.

## **19. List of Acronyms**

ARC	- Ames Research Center
ASCII	- American Standard Code for Information Interchange
BIL	- Band Interleaved by Line
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
DAAC	- Distributed Active Archive Center
DAT	- Digital Archive Tape
DN	- Digital Number
EOS	- Earth Observing System
EOSDIS	- EOS Data and Information System
FFC-T	- Focused Field Campaign - Thaw
FIFE	- First ISLSCP Field Experiment
FOV	- Field-Of-View
fPAR	- fraction of Photosynthetically Active Radiation
GMT	- Greenwich Mean Time
GSFC	- Goddard Space Flight Center

HgCdTe - mercury-cadmium-tellurium  
 IFC - Intensive Field Campaign  
 IFOV - Instantaneous Field-of-View  
 I/O - Input/Output  
 ISLSCP - International Satellite Land Surface Climatology Project  
 JPL - Jet Propulsion Laboratory  
 LAI - Leaf Area Index  
 NAD83 - North American Datum of 1983  
 NASA - National Aeronautics and Space Administration  
 NEdt - Noise-Equivalent Change in Temperature  
 NSA - Northern Study Area  
 ORNL - Oak Ridge National Laboratory  
 PANP - Prince Albert National Park  
 SSA - Southern Study Area  
 TIMS - Thermal Infrared Multispectral Scanner  
 TM - Thematic Mapper  
 TMS - Thematic Mapper Simulator  
 URL - Uniform Resource Locator

## 20. Document Information

### 20.1 Document Revision Date(s)

Written: 21-Mar-1995

Last Updated: 05-Feb-1999

### 20.2 Document Review Date(s)

BORIS Review: 06-Jan-1997

Science Review: 07-Feb-1997

### 20.3 Document ID

### 20.4 Citation

When using these data, please include the following acknowledgement as well as citations of relevant papers in Section 17.2: The BOREAS level-0 TIMS data were collected and processed from the original aircraft tapes by personnel of the Medium Altitude Aircraft Branch at NASA ARC. Their contributions to providing this data set are greatly appreciated.

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. 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 September 2000		3. REPORT TYPE AND DATES COVERED Technical Memorandum
4. TITLE AND SUBTITLE Technical Report Series on the Boreal Ecosystem-Atmosphere Study (BOREAS) BOREAS Level-0 TIMS Imagery: Digital Counts in BIL Format			5. FUNDING NUMBERS  923 RTOP: 923-462-33-01	
6. AUTHOR(S) Jeffrey A. Newcomer and Roseanne Dominguez Forrest G. Hall, Editor				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS (ES)  Goddard Space Flight Center Greenbelt, Maryland 20771			8. PERFORMING 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. 91	
11. SUPPLEMENTARY NOTES J.A. Newcomer: Raytheon ITSS, NASA Goddard Space Flight Center, Greenbelt, Maryland; R. Dominguez: ATAC, Inc., NASA Ames Research Center, Moffett Field, California				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Unclassified—Unlimited Subject Category: 43 Report available from the NASA Center for AeroSpace Information, 7121 Standard Drive, Hanover, MD 21076-1320. (301) 621-0390.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words)  For BOREAS, the TIMS imagery, along with the other remotely sensed images, was collected to provide spatially extensive information over the primary study areas. The level-0 TIMS images cover the time periods of 16-Apr-1994 to 20-Apr-1994 and 06-Sep-1994 to 17-Sep-1994. The images are available in their original uncalibrated format.				
14. SUBJECT TERMS BOREAS, remote sensing science, TIMS imagery.			15. NUMBER OF PAGES 19	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL	



