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

Forrest G. Hall and Jaime Nickeson, Editors

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BOREAS RSS-3 Reflectance Measured from a Helicopter-Mounted SE-590

Charles L. Walthall, Sara Loechel

Summary

The BOREAS RSS-3 team collected multiple remotely sensed data sets from the NASA UH-1 helicopter. This data set includes helicopter-based radiometric measurements of forested sites acquired during BOREAS made with an SE-590 processed to reflectance factors. The data used in this analysis were collected in 1994 during the three BOREAS IFCs at numerous tower and auxiliary sites in both the NSA and the SSA. The 15-degree FOV of the SE-590 yielded a ground resolution of approximately 79 m at the 300-m nominal altitude. The data are provided in tabular ASCII files.

Note: An extensive helicopter log (in Acrobat format) is available for the 1994 IFC's. Environmental, technical, instrumental, and operational conditions are noted for each observation where applicable. It is strongly recommended that any researcher doing extended work with this data set review this helicopter log.

Table of Contents

1. Data Set Overview

1.1 Data Set Identification

BOREAS RSS-03 Reflectance Measured from a Helicopter-Mounted SE-590

1.2 Data Set Introduction

Radiometer measurements of BOReal Ecosystem-Atmosphere Study (BOREAS) forested tower and auxiliary sites were taken from a helicopter platform at nadir. The data were collected in 1994 during the green-up, peak, and senescent stages of the growing season at numerous tower and auxiliary sites in both the Northern Study Area (NSA) and the Southern Study Area (SSA). The 15-degree field of view (FOV) of the Spectron Engineering Spectroradiometer (SE-590) yielded an

Instantaneous Field of View (IFOV) of approximately 79 m from the 300 m altitude typically flown. The SE-590 has a spectral range of 362.7 to 1122.7 nm, although the "usable" SE-590 range is actually ~400 to 900 nm. The SE-590 bandwidth is ~15 nm and the spacing between bands ~3 nm.

The helicopter-measured SE-590 radiances and sunphotometer data were used as input to Version 4.0 of the Second Simulation of the Satellite Signal in the Solar Spectrum (6S) atmospheric correction software to obtain at-surface reflectance factors. The data cover the three Intensive Field Campaign (IFC) periods: 31-May through 10-June (IFC-1), 21-July through 08-August (IFC-2), and 06-September through 16-September (IFC-3).

1.3 Objective/Purpose

The objective of the study was to acquire multispectral, bidirectional reflectance data of the study sites for assessments of spectral, spatial, and temporal variability and the impacts of these variabilities on vegetation indices. A helicopter with a pointable stabilized mount was used to carry a spectrometer (visible and near-infrared), a spectroradiometer, an infrared thermometer, and a video camera. An autotracking sunphotometer was also deployed to provide data for calculations of irradiance and for atmospheric correction of the data. The latest available version of the 6S atmospheric model was used for the calculations of irradiance and for atmospheric corrections.

1.4 Summary of Parameters

Helicopter-based measurements of at-helicopter radiances and standard deviations, at-helicopter and at-surface (atmospherically corrected) reflectances and conditions (surface physical, geometric, and atmospheric) at the time of the observation.

1.5 Discussion

These measurements were collected as part of the effort to evaluate models that estimate surface biophysical characteristics from remotely measured optical signatures.

1.6 Related Data Sets

BOREAS RSS-01 PARABOLA SSA Surface Reflectance and Transmittance Data
BOREAS RSS-02 Level-1b ASAS Imagery: At-sensor Radiance in BSQ Format
BOREAS RSS-03 Reflectance Measured from a Helicopter-Mounted Barnes MMR
BOREAS RSS-03 Atmospheric Measurements from a Helicopter-Mounted Sunphotometer
BOREAS RSS-03 Video Imagery Acquired from a Helicopter Platform
BOREAS RSS-11 Ground Network of Sun Photometer Measurements
BOREAS RSS-12 Automated Ground Sun Photometer Measurements in the SSA
BOREAS RSS-19 1994 Seasonal Understory Reflectance Data
BOREAS RSS-20 POLDER Measurements of Surface BRDF

2. Investigator(s)

2.1 Investigator(s) Name and Title

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2.2 Title of Investigation

Biophysical Significance of Spectral Vegetation Indices in the Boreal Forest

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3. Theory of Measurements

Radiation striking a vegetative canopy interacts with individual phytoelements (leaves, stems, branches) and the underlying substrate. The interaction depends on light quality, radiative form (direct or diffuse), illumination incidence angle, vegetative component optical properties, and canopy architecture. Radiation is reflected, transmitted, or absorbed.

At-sensor radiances are converted to surface reflectance using the 6S atmospheric correction model. Using measurements of optical depth as input, this model accounts for the combined effects of scattering (molecular and aerosol) and absorption by the atmosphere.

The helicopter missions were designed to provide a rapid means of intensive spectral characterization of sites and to provide an intermediate scale of sampling between the surface measurements and the higher altitude aircraft and spacecraft multispectral imaging devices. The SE-590 instrumentation was chosen to provide compatibility with surface-based radiometers and Thematic Mapper (TM) spaceborne sensors.

4. Equipment

4.1 Sensor/Instrument Description

The primary instruments for the BOREAS Remote Sensing Science (RSS)-03 deployment are the SE-590, a Barnes Modular Multiband Radiometer (MMR), a color Charge-Coupled Device (CCD)-based video camera, and a sun-tracking photometer. The downward-looking sensor heads, along with a color video camera, are mounted on an operator-controlled pointable mount that gives variability in the view zenith and view azimuth directions independent of the heading of the aircraft.

The SE-590 is a field portable, microprocessor-controlled spectroradiometer developed in the early 1980s. The sensor is a CCD area array detector with a diffraction grating serving as the spectral dispersion component. The complete system consists of a microprocessor-based controller connected by cable to two optical cameras containing the sensors. Lenses are used as collimators for the optical cameras. Although three different optical heads are available for the unit, only two can be used at once with a single controller. The primary unit of interest is the visible/near-infrared (VIS/NIR) optical component, which employs a silicon sensor and is sensitive to radiation in the 400 nm to 1100 nm region. The short-wave infrared (SWIR) optical camera uses a lead sulfide detector with a cooling device for temperature stability and is sensitive to radiation in the 1100 nm to 2500 nm spectral region. Lenses for 1-degree and 15-degree FOV are available as standard attachments for the VIS/NIR system. A 15 degree FOV lens for the SWIR system was specially fabricated for BOREAS. The serial number of the instrument used was 2071.

For the BOREAS deployment, a temperature-controlled box was built to counter the effects of ambient temperature on radiometric response of the VIS/NIR optical heads. Two VIS/NIR optical heads were housed in the temperature control box for the final configuration, one with a 1-degree FOV lens and one with a 15-degree FOV lens. The SWIR optical head was mounted external to the box with a 15-degree FOV lens. The SWIR head was moved outside the temperature control box to avoid conflicts between its temperature control system and the system of the temperature control box. The configuration of the system was such that two of the three optical heads could be operated at once using a single SE-590 controller. The choice of optical heads (two VIS/NIR or one VIS/NIR and the SWIR) also required a change in software because the data stream from the SWIR optical head is different from that of the VIS/NIR optical heads.

For helicopter use, the SE-590 is operated in a slave mode by a dedicated PC running DOS. The data stream from the SE-590 is communicated via RS-232 cable to the computer, where it is stored on a hard disk. The unit operates on AC power available from the aircraft via inverters with self-contained rechargeable batteries inside the controller available for backup. Sensor integration time is set automatically via calculations made on a spectral scan prior to each data collection scan.

The data stream from this device includes digital numbers (DNs) for each channel, sensor dwell/integration time, date, time, and maximum signal level in DNs. The PC software adds an operator-specified header and the SE-590 time is replaced with time from the computer's clock as the data are stored.

4.1.1 Collection Environment

In general, the helicopter was flown during relatively clear days when possible. Data collection was attempted during conditions of highest possible solar elevation. All observations were attempted from a nadir observation point and usually at 300 m above ground level (AGL). Exceptions are noted in the helicopter log.

4.1.2 Source/Platform

The UH-1 "Huey" series of helicopters has been available as a platform for the system in many field campaigns. The first 10 years of the system development and use were with two UH-1B Huey helicopters, while the aircraft used for BOREAS was a UH-1H model Huey helicopter. Wallops Flight Facility (WFF) changed to the H-model helicopter because of its increased payload capability, the good availability of spare parts, and its widespread use by other organizations. The Bell UH-1H "Iroquois" helicopter, call number N415, was built in 1965 and was acquired by WFF in 1993. Upon acquisition, the aircraft was slightly modified for use as a scientific platform.

Helicopter N415 operates with standard or low mount, rear-leaning skids. The engine is a Lycoming T53/L13, which provides 1,400 shaft HP with 1,290 transmission HP. The fuel capacity provides 2.0 hours of flying time with a 20-minute fuel reserve under normal modes of operation. The addition of an auxiliary fuel tank in the port-side door crewman's position provided an additional 15 minutes of flight time during BOREAS given optimum flight conditions.

The instrument platform controllers, power supplies and data loggers are mounted on 54-inch wide, 72-inch-high steel rack mounts fabricated at WFF. Three racks are situated directly in front of the instrument operators. Seats for the instrument operators are located across the front of the transmission and main rotor mast housing. Whenever possible, existing hard points are used for attaching hardware both internally and externally.

The weight of the entire helicopter system with full instrumentation, full fuel, and crew members was 9,500 lbs.

4.1.3 Source/Platform Mission Objectives

The helicopter missions were designed to provide a rapid means of intensive spectral characterization of sites and to provide an intermediate scale of sampling between the surface measurements and the higher altitude aircraft and spacecraft multispectral imaging devices. The instruments were chosen to provide compatibility with surface-based radiometers and TM spacecraft sensors.

4.1.4 Key Variables

Surface reflectance.

4.1.5 Principles of Operation

Computer control of the instruments provides precise, automatic control and ensures proper timing of data collection. The radiometric instruments are configured such that all sensors except the photographic camera can be triggered near-simultaneously with a single computer keyboard keystroke. The command sent from the keyboard is first sent to the SE-590, then to the A/D systems. Raw data from each of the instruments are displayed via graphics and tabular listings on the main computer screen immediately after scanning. The system is configured for multiple sensor data collection. The MMR, SE-590, infrared thermometer, autotracking sunphotometer, and video sensor were the primary payload during BOREAS.

4.1.6 Sensor/Instrument Measurement Geometry

The National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC)/WFF helicopter-based optical remote sensing system was deployed to acquire canopy multispectral data with an SE-590 while hovering approximately 300 meters AGL (Walthall et al., 1996). The 15-degree FOV of the SE-590 yielded a ground resolution of approximately 79 m at this altitude.

4.1.7 Manufacturer of Sensor/Instrument

SE-590:
Spectron Engineering, Inc.
25 Yuma Court
Denver, CO 80223
(303) 733-1060

4.2 Calibration

4.2.1 Specifications

Spectral Characteristics	
SE-590 Range	362.7 to 1122.7 nm
"Usable" SE-590 Range	~400 to 900 nm
Bandwidth	~15 nm
Spacing between bands	~3 nm
Filter function	Gaussian (best approximation)

Spectral bands (reported in data set) [nm]:

```
402.6 405.3 408.0 410.7 413.4 416.1 418.8 421.5 424.2 426.9 429.6
432.3 435.0 437.8 440.5 443.2 446.0 448.7 451.4 454.2 456.9 459.7
462.4 465.2 467.9 470.7 473.4 476.2 479.0 481.8 484.5 487.3 490.1
492.9 495.7 498.5 501.3 504.1 506.9 509.7 512.5 515.3 518.1 520.9
523.7 526.5 529.4 532.2 535.0 537.9 540.7 543.5 546.4 549.2 552.1
554.9 557.8 560.7 563.5 566.4 569.3 572.1 575.0 577.9 580.8 583.7
586.5 589.4 592.3 595.2 598.1 601.0 603.9 606.8 609.8 612.7 615.6
618.5 621.4 624.4 627.3 630.2 633.2 636.1 639.1 642.0 645.0 647.9
650.9 653.8 656.8 659.8 662.7 665.7 668.7 671.6 674.6 677.6 680.6
683.6 686.6 689.6 692.6 695.6 698.6 701.6 704.6 707.6 710.6 713.7
716.7 719.7 722.8 725.8 728.8 731.9 734.9 738.0 741.0 744.1 747.1
750.2 753.2 756.3 759.4 762.4 765.5 768.6 771.7 774.8 777.8 780.9
784.0 787.1 790.2 793.3 796.4 799.5 802.7 805.8 808.9 812.0 815.1
818.3 821.4 824.5 827.7 830.8 834.0 837.1 840.2 843.4 846.6 849.7
852.9 856.0 859.2 862.4 865.6 868.7 871.9 875.1 878.3 881.5 884.7
887.9 891.1 894.3 897.5 900.7
```

4.2.1.1 Tolerance

None given.

4.2.2 Frequency of Calibration

Radiometric calibration and spectral calibration procedures were performed before and after the field season to check for changes in sensor radiometric response. In-field calibration checks were periodically made with a large, portable integrating sphere system. This sphere was used to calibrate the airborne instruments on other aircraft and some of the surface-based radiometric instrumentation.

4.2.3 Other Calibration Information

SE-590 coefficients from the second IFC were calculated in the field. Conditions did not change much from the beginning of the first IFC until the end of the last IFC; thus, any of the calibration files are sufficient. The table of calibration coefficients is output from a software module that supplied default wavelengths, instead of the exact wavelengths of this instrument. In practice, they apply to the closest band as given in the SE-590 data set.

Wavelength Coefficient (offset of zero) and r^2 from regression

WAVE	COEF	r^2	WAVE	COEF	r^2
401.5	177.877	0.944291	535.3	485.763	0.999395
404.3	195.617	0.953270	538.3	486.522	0.999378
407.1	212.354	0.959176	541.2	487.035	0.999372
409.9	240.441	0.969660	544.1	481.228	0.999428
412.7	281.806	0.976171	547.0	471.868	0.999408
415.5	329.396	0.983505	549.9	464.951	0.999458
418.3	362.033	0.985738	552.8	456.612	0.999396
421.1	383.876	0.987624	555.8	454.872	0.999417
423.9	406.884	0.989234	558.7	459.347	0.999432
426.7	427.885	0.990205	561.6	467.344	0.999438
429.5	446.648	0.991536	564.5	478.390	0.999478
432.3	454.986	0.992297	567.5	489.023	0.999479
435.1	476.587	0.994173	570.4	496.558	0.999513
438.0	493.344	0.994685	573.3	505.392	0.999555
440.8	511.822	0.995202	576.3	507.749	0.999551
443.6	522.264	0.995745	579.2	504.828	0.999536
446.4	523.222	0.996257	582.2	498.284	0.999541
449.3	519.927	0.996496	585.1	489.910	0.999553
452.1	514.144	0.997100	588.1	480.059	0.999562
454.9	515.135	0.997069	591.0	470.787	0.999550
457.8	507.969	0.997500	594.0	463.137	0.999574
460.6	497.376	0.997683	596.9	457.157	0.999541
463.5	492.863	0.997825	599.9	454.545	0.999552
466.3	492.648	0.997897	602.9	455.709	0.999546
469.2	487.060	0.998084	605.8	458.806	0.999567
472.0	481.766	0.998269	608.8	463.753	0.999581
474.9	478.953	0.998335	611.8	469.958	0.999595
477.7	469.324	0.998460	614.7	477.498	0.999620
480.6	456.215	0.998530	617.7	482.404	0.999643
483.4	447.377	0.998650	620.7	482.992	0.999660
486.3	441.005	0.998666	623.7	480.767	0.999653
489.2	438.226	0.998647	626.7	477.871	0.999653
492.0	441.260	0.998873	629.6	473.047	0.999663
494.9	449.451	0.998914	632.6	464.294	0.999626
497.8	456.074	0.998928	635.6	456.748	0.999657
500.6	459.451	0.999010	638.6	448.964	0.999647
503.5	454.181	0.999101	641.6	442.057	0.999641
506.4	446.948	0.999090	644.6	436.108	0.999634
509.3	440.210	0.999098	647.6	433.334	0.999650
512.2	434.007	0.999064	650.6	426.841	0.999646
515.1	433.951	0.999189	653.6	424.231	0.999654
518.0	434.958	0.999175	656.6	418.953	0.999628
520.8	441.795	0.999182	659.6	417.769	0.999646
523.7	452.507	0.999234	662.6	419.553	0.999671
526.6	461.811	0.999292	665.7	418.793	0.999664
529.5	470.346	0.999288	668.7	418.464	0.999665
532.4	481.618	0.999324	671.7	418.540	0.999691

WAVE	COEF	r^2	WAVE	COEF	r^2
674.7	419.266	0.999675	788.3	288.519	0.999602
677.7	414.472	0.999683	791.4	287.586	0.999618
680.8	408.282	0.999666	794.5	286.344	0.999597
683.8	402.339	0.999697	797.7	284.828	0.999584
686.8	394.407	0.999663	800.8	282.668	0.999593
689.9	383.948	0.999669	803.9	279.686	0.999592
692.9	377.904	0.999662	807.1	277.144	0.999604
695.9	371.917	0.999645	810.2	275.932	0.999587
699.0	366.746	0.999641	813.3	271.085	0.999558
702.0	362.821	0.999658	816.5	266.655	0.999554
705.1	364.155	0.999659	819.6	262.913	0.999582
708.1	361.576	0.999668	822.7	257.784	0.999555
711.2	364.754	0.999664	825.9	250.574	0.999536
714.2	370.359	0.999676	829.0	244.616	0.999500
717.3	372.134	0.999673	832.2	237.477	0.999479
720.4	376.100	0.999686	835.3	228.120	0.999470
723.4	381.964	0.999712	838.5	219.124	0.999430
726.5	383.358	0.999717	841.6	211.521	0.999392
729.6	385.283	0.999733	844.8	204.434	0.999410
732.6	387.747	0.999745	848.0	195.746	0.999362
735.7	389.354	0.999746	851.1	189.681	0.999332
738.8	385.004	0.999735	854.3	187.142	0.999297
741.8	379.187	0.999740	857.5	185.715	0.999299
744.9	371.829	0.999722	860.6	183.007	0.999294
748.0	363.352	0.999721	863.8	181.422	0.999319
751.1	354.343	0.999710	867.0	180.540	0.999299
754.2	347.139	0.999680	870.2	176.893	0.999283
757.3	340.538	0.999703	873.4	171.383	0.999210
760.4	336.410	0.999688	876.5	167.060	0.999245
763.5	329.992	0.999674	879.7	163.815	0.999196
766.6	325.867	0.999690	882.9	160.072	0.999179
769.7	319.102	0.999647	886.1	156.389	0.999145
772.8	311.361	0.999645	889.3	154.292	0.999143
775.9	305.954	0.999653	892.5	151.666	0.999141
779.0	299.664	0.999634	895.7	147.559	0.999065
782.1	296.534	0.999644	898.9	143.946	0.999039
785.2	292.414	0.999615	902.1	138.765	0.998934

5. Data Acquisition Methods

The use of off-the-shelf field instruments aboard airborne platforms is a cost-effective and efficient approach to assembling a data collection system. The instruments are generally rugged enough for the harsh operating environment of a helicopter, provide data comparable to data sets on the surface, and are easy to use and versatile during operation. The system developed jointly at NASA GSFC and WFF uses several widely accepted field-portable radiometric instruments. The system is configured such that instruments from other investigators can be deployed on the helicopter with little or no interference with the primary instrument system. An autotracking sunphotometer system, developed specifically for use on helicopters, is the newest addition to the system.

The NASA GSFC/WFF helicopter-based optical remote sensing system was deployed to acquire canopy multispectral data with an SE-590 while hovering approximately 300 meters AGL (Walthall et al., 1996). The 15-degree FOV of the SE-590 yielded an IFOV at this altitude of approximately 79 m. Observations were made over various tower and auxiliary sites during all three IFCs.

Measurements were collected as conditions permitted during each IFC. In general, the helicopter would hover 1-2 minutes for each observation (consisting of an average number of 20-25 scans).

6. Observations

6.1 Data Notes

See Section 6.2.

6.2 Field Notes

An extensive helicopter log is available for each IFC. Environmental, technical, instrumental, and operational conditions are noted for each observation where applicable.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

The helicopter visited all of the NSA and SSA tower and category-1 auxiliary sites. Each site listed below was observed by this instrument at least once during the 1994 campaign at BOREAS. The coordinates provided are based on the North American Datum of 1983 (NAD83).

Site Id	Grid Id	Longitude	Latitude	UTM Easting	UTM Northing	UTM Zone
Flux Tower Sites						
Southern Study Area:						
SSA-FEN-MMR01	F0L9T	104.61798° W	53.80206° N	525159.8	5961566.6	13
SSA-OBS-MMR01	G8I4T	105.11779° W	53.98717° N	492276.5	5982100.5	13
SSA-OJP-MMR01	G2L3T	104.69203° W	53.91634° N	520227.7	5974257.5	13
SSA-YJP-MMR01	F8L6T	104.64529° W	53.87581° N	523320.2	5969762.5	13
SSA-9OA-MMR01	C3B7T	106.19779° W	53.62889° N	420790.5	5942899.9	13
SSA-9YA-MMR01	D0H4T	105.32314° W	53.65601° N	478644.1	5945298.9	13

Site Id	Grid Id	Longitude	Latitude	UTM Easting	UTM Northing	UTM Zone
Flux Tower Sites						
Northern Study Area:						
NSA-OBS-MMR01	T3R8T	98.48139° W	55.88007° N	532444.5	6192853.4	14
NSA-OJP-MMR01	T7Q8T	98.62396° W	55.92842° N	523496.2	6198176.3	14
NSA-YJP-MMR01	T8S9T	98.28706° W	55.89575° N	544583.9	6194706.9	14
NSA-BVP-MMR01	T4U6T	98.02747° W	55.84225° N	560900.6	6188950.7	14
NSA-FEN-MMR01	T7S1T	98.42072° W	55.91481° N	536207.9	6196749.6	14
Auxiliary Sites						
Southern Study Area:						
SSA-9BS-MMR01	D0H6S	105.29534° W	53.64877° N	480508.7	5944263.4	13
SSA-9BS-MMR01	G2I4S	105.13964° W	53.93021° N	490831.4	5975766.3	13
SSA-9BS-MMR01	G2L7S	104.63785° W	53.90349° N	523793.6	5972844.3	13
SSA-9BS-MMR01	G6K8S	104.75900° W	53.94446° N	515847.9	5977146.9	13
SSA-9BS-MMR01	G9I4S	105.11805° W	53.99877° N	492291.2	5983169.1	13
SSA-9JP-MMR01	F5I6P	105.11175° W	53.86608° N	492651.3	5968627.1	13
SSA-9JP-MMR01	F7J0P	105.05115° W	53.88336° N	496667.0	5970323.3	13
SSA-9JP-MMR01	F7J1P	105.03226° W	53.88211° N	497879.4	5970405.6	13
SSA-9JP-MMR01	G1K9P	104.74812° W	53.90880° N	516546.7	5973404.5	13
SSA-9JP-MMR01	G4K8P	104.76401° W	53.91883° N	515499.1	5974516.6	13
SSA-9JP-MMR01	G7K8P	104.77148° W	53.95882° N	514994.2	5978963.8	13
SSA-9JP-MMR01	G8L6P	104.63755° W	53.96558° N	523778.0	5979752.7	13
SSA-9JP-MMR01	G9L0P	104.73779° W	53.97576° N	517197.7	5980856.0	13
SSA-9JP-MMR01	I2I8P	105.05107° W	54.11181° N	496661.4	5995963.1	13
SSA-ASP-MMR01	B9B7A	106.18693° W	53.59098° N	421469.8	5938447.2	13
SSA-ASP-MMR01	D6H4A	105.31546° W	53.70828° N	479177.5	5951112.1	13
SSA-ASP-MMR01	D6L9A	104.63880° W	53.66879° N	523864.0	5946733.2	13
SSA-ASP-MMR01	D9G4A	105.46929° W	53.74019° N	469047.1	5954718.4	13
SSA-MIX-MMR01	D9I1M	105.20643° W	53.72540° N	486379.7	5952989.7	13
SSA-MIX-MMR01	F1N0M	104.53300° W	53.80594° N	530753.7	5962031.8	13
SSA-MIX-MMR01	G4I3M	105.14246° W	53.93750° N	490677.3	5976354.9	13

Site Id	Grid Id	Longitude	Latitude	UTM Easting	UTM Northing	UTM Zone
Auxiliary Sites						
Northern Study Area:						
NSA-9BS-MMR01	S8W0S	97.84024° W	55.76824° N	572761.9	6180894.9	14
NSA-9BS-MMR01	T0P7S	98.82345° W	55.88371° N	511043.9	6193151.1	14
NSA-9BS-MMR01	T0P8S	98.80225° W	55.88351° N	512370.1	6193132.0	14
NSA-9BS-MMR01	T0W1S	97.80937° W	55.78239° N	574671.7	6182502.0	14
NSA-9BS-MMR01	T3U9S	97.98339° W	55.83083° N	563679.1	6187719.2	14
NSA-9BS-MMR01	T4U8S	97.99325° W	55.83913° N	563048.2	6188633.4	14
NSA-9BS-MMR01	T4U9S	97.98364° W	55.83455° N	563657.5	6188132.8	14
NSA-9BS-MMR01	T5Q7S	98.64022° W	55.91610° N	522487.2	6196800.5	14
NSA-9BS-MMR01	T6R5S	98.51865° W	55.90802° N	530092.0	6195947.0	14
NSA-9BS-MMR01	T6T6S	98.18658° W	55.87968° N	550887.9	6192987.9	14
NSA-9BS-MMR01	T7R9S	98.44877° W	55.91506° N	534454.5	6196763.6	14
NSA-9BS-MMR01	T7T3S	98.22621° W	55.89358° N	548391.8	6194505.6	14
NSA-9BS-MMR01	T8S4S	98.37111° W	55.91689° N	539306.4	6197008.6	14
NSA-9BS-MMR01	U5W5S	97.70986° W	55.90610° N	580655.5	6196380.8	14
NSA-9BS-MMR01	U6W5S	97.70281° W	55.91021° N	581087.8	6196846.5	14
NSA-9JP-MMR01	99O9P	99.03952° W	55.88173° N	497527.8	6192917.5	14
NSA-9JP-MMR01	Q3V3P	98.02473° W	55.55712° N	561517.9	6157222.2	14
NSA-9JP-MMR01	T7S9P	98.30037° W	55.89486° N	543752.4	6194599.1	14
NSA-9JP-MMR01	T8Q9P	98.61050° W	55.93219° N	524334.5	6198601.4	14
NSA-9JP-MMR01	T8S9P	98.28385° W	55.90456° N	544774.3	6195688.9	14
NSA-9JP-MMR01	T8T1P	98.26269° W	55.90539° N	546096.3	6195795.3	14
NSA-9JP-MMR01	T9Q8P	98.59568° W	55.93737° N	525257.1	6199183.2	14
NSA-9OA-MMR01	T2Q6A	98.67479° W	55.88691° N	520342.0	6193540.7	14
NSA-ASP-MMR01	P7V1A	98.07478° W	55.50253° N	558442.1	6151103.7	14
NSA-ASP-MMR01	Q3V2A	98.02635° W	55.56227° N	561407.9	6157793.5	14
NSA-ASP-MMR01	R8V8A	97.89260° W	55.67779° N	569638.4	6170774.8	14
NSA-ASP-MMR01	S9P3A	98.87621° W	55.88576° N	507743.3	6193371.6	14
NSA-ASP-MMR01	T4U5A	98.04329° W	55.84757° N	559901.6	6189528.2	14
NSA-ASP-MMR01	T8S4A	98.37041° W	55.91856° N	539348.3	6197194.6	14
NSA-ASP-MMR01	V5X7A	97.48565° W	55.97396° N	594506.1	6204216.6	14
NSA-ASP-MMR01	W0Y5A	97.33550° W	56.00339° N	603796.6	6207706.6	14
NSA-MIX-MMR01	Q1V2M	98.03769° W	55.54568° N	560718.3	6155937.3	14
NSA-MIX-MMR01	T0P5M	98.85662° W	55.88911° N	508967.7	6193747.3	14

7.1.2 Spatial Coverage Map
Not available.

7.1.3 Spatial Resolution
The 15-degree FOV of the SE-590 yielded a ground resolution of 79 m from the 300 m altitude.

7.1.4 Projection
Not applicable.

7.1.5 Grid Description
Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

Observations were made during all three BOREAS 1994 IFCs, which occurred during the following periods:

- IFC-1 24-May - 16-June
- IFC-2 19-July - 10-August
- IFC-3 30-August - 19-September

Measurements were made as conditions permitted during each IFC.

7.2.2 Temporal Coverage Map

Observations were made at several sites on the following dates:

Date	Study Area
31-May-1994	SSA
01-Jun-1994	SSA
04-Jun-1994	SSA
06-Jun-1994	SSA
07-Jun-1994	SSA
08-Jun-1994	NSA
10-Jun-1994	NSA
21-Jul-1994	NSA
22-Jul-1994	SSA
23-Jul-1994	SSA
24-Jul-1994	SSA
25-Jul-1994	SSA
28-Jul-1994	SSA
04-Aug-1994	NSA
08-Aug-1994	NSA
06-Sep-1994	NSA
08-Sep-1994	NSA
09-Sep-1994	NSA
13-Sep-1994	NSA
15-Sep-1994	SSA
16-Sep-1994	SSA

7.2.3 Temporal Resolution

Measurements were collected as conditions permitted during each IFC. In general, the helicopter would hover 1-2 minutes for each observation (consisting of an average number of 20-25 scans). Each site was visited as often as possible during each IFC, with priority given to tower flux sites and category 1 auxiliary sites. Helicopter flight time was limited to approximately 2 hours by fuel constraints. As many sites as possible were visited during each flight.

7.3 Data Characteristics

7.3.1 Parameter/Variable

The parameters contained in the data files on the CD-ROM are:

```
Reference File
          Column Name
------------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME
OP_GRID_INFO
PLATFORM_ALTITUDE
ELEVATION
SOLAR_ZEN_ANG
SOLAR_AZ_ANG
SUN_PHOTO_SOURCE
SUN_PHOTO_TIME
INTERP_AEROSOL_OPT_THICK_550
COLUMN_WATER_VAPOR
COVER_TYPE
HELO_LOG_TRIP_ID
CRTFCN_CODE
REVISION_DATE

Data File
         Column Name
------------------------------
SITE_NAME
SUB_SITE
DATE_OBS
TIME
WAVELENGTH
MEAN_RADIANCE
SDEV_RADIANCE
MEAN_REFL
MEAN_SURF_REFL
GASEOUS_TRANSMITTANCE
CRTFCN_CODE
REVISION_DATE
```

7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files on the CD-ROM are:

Reference File

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME	The Greenwich Mean Time (GMT) when the data were collected.
OP_GRID_INFO	The site identifier used by this RSS team during the execution of field operations. This is used to further link data to site information contained elsewhere..
PLATFORM_ALTITUDE	The nominal altitude of the data collection platform above the target.
ELEVATION	The elevation of the site above mean sea level.
SOLAR_ZEN_ANG	The angle from the surface normal (straight up) to the sun during data collection.
SOLAR_AZ_ANG	Direction referred to as a circular scale of degrees read clockwise describing the position of the sun where 0=north, 90=east, 180=south, and 270=west.
SUN_PHOTO_SOURCE	Indicator of the source of the sun photometer measurements used in atmospheric correction, where helo=helicopter sunphotometer, NSA-YJP = NSA-YJP tower site, Thom = Thompson airport (NSA), SSA-YJP = SSA-YJP tower site.
SUN_PHOTO_TIME	The time of the sun photometer measurement used in atmospheric correction.
INTERP_AEROSOL_OPT_THICK_550	The aerosol optical depth interpolated to 550 nanometers, used in the atmospheric correction.
COLUMN_WATER_VAPOR	The amount of precipitable water within a vertical column of air with a cross-section of 1 centimeter squared and a fixed depth (usually from the ground to the top of the atmosphere).
COVER_TYPE	The dominant species, vegetation or type of land cover that exists at the location.
HELO_LOG_TRIP_ID	Identifier, given as Mon-Day-(A/B/C), whose letter identifies the particular flight on a given day, used in the helo log file.
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).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

Data File

Column Name	Description
SITE_NAME	The identifier assigned to the site by BOREAS, in the format SSS-TTT-CCCCC, where SSS identifies the portion of the study area: NSA, SSA, REG, TRN, and TTT identifies the cover type for the site, 999 if unknown, and CCCCC is the identifier for site, exactly what it means will vary with site type.
SUB_SITE	The identifier assigned to the sub-site by BOREAS, in the format GGGGG-IIIII, where GGGGG is the group associated with the sub-site instrument e.g. HYD06 or STAFF, and IIIII is the identifier for sub-site, often this will refer to an instrument.
DATE_OBS	The date on which the data were collected.
TIME	The Greenwich Mean Time (GMT) when the data were collected.
WAVELENGTH	Spectral wavelength at which measurement was acquired.
MEAN_RADIANCE	The mean at-sensor radiance.
SDEV_RADIANCE	The standard deviation at-sensor radiance.
MEAN_REFL	The mean reflectance factor.
MEAN_SURF_REFL	The mean surface reflectance factor (atmospherically corrected).
GASEOUS_TRANSMITTANCE	One minus the absorptance and reflectance of the atmosphere (two-way) due to global gases (primarily water vapor and ozone).
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).
REVISION_DATE	The most recent date when the information in the referenced data base table record was revised.

The OP_GRID_INFO in the SE590 reference data are tightly linked to the Helicopter log documentation; much information relevant to the location of the observation and the conditions at the time are available in the log.

7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files on the CD-ROM are:

Reference File

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME	[HHMMSS GMT]
OP_GRID_INFO	[none]
PLATFORM_ALTITUDE	[meters]
ELEVATION	[meters]
SOLAR_ZEN_ANG	[degrees]
SOLAR_AZ_ANG	[degrees]
SUN_PHOTO_SOURCE	[none]
SUN_PHOTO_TIME	[HHMMSS GMT]
INTERP_AEROSOL_OPT_THICK_550	[unitless]
COLUMN_WATER_VAPOR	[millimeters]
COVER_TYPE	[none]
HELO_LOG_TRIP_ID	[none]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

Data File

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
DATE_OBS	[DD-MON-YY]
TIME	[HHMMSS GMT]
WAVELENGTH	[micrometers]
MEAN_RADIANCE	[Watts][meter^-2][steradian^-1][micrometer^-1]
SDEV_RADIANCE	[Watts][meter^-2][steradian^-1][micrometer^-1]
MEAN_REFL	[percent]
MEAN_SURF_REFL	[percent]
GASEOUS_TRANSMITTANCE	[unitless]
CRTFCN_CODE	[none]
REVISION_DATE	[DD-MON-YY]

7.3.4 Data Source

The sources of the parameter values contained in the data files on the CD-ROM are:

Reference File

Column Name	Data Source
SITE_NAME	[Assigned by BORIS Staff]
SUB_SITE	[Assigned by BORIS Staff]
DATE_OBS	[Controller]
TIME	[Controller]
OP_GRID_INFO	[RSS03 team]
PLATFORM_ALTITUDE	[NASA Helicopter]
ELEVATION	[Experiment Plan]
SOLAR_ZEN_ANG	[Calculated by software]

SOLAR_AZ_ANG	[Calculated by software]
SUN_PHOTO_SOURCE	[RSS03 team]
SUN_PHOTO_TIME	[Helo or RSS11 sunphotometer]
INTERP_AEROSOL_OPT_THICK_550	[Helo or RSS11 sunphotometer]
COLUMN_WATER_VAPOR	[Calculated by software]
COVER_TYPE	[Experiment Plan]
HELO_LOG_TRIP_ID	[RSS03 team]
CRTFCN_CODE	[Assigned by BORIS Staff]
REVISION_DATE	[Assigned by BORIS Staff]

Data File

Column Name	Data Source
SITE_NAME	[Assigned by BORIS Staff]
SUB_SITE	[Assigned by BORIS Staff]
DATE_OBS	[Controller]
TIME	[Controller]
WAVELENGTH	[SE-590 spectroradiometer]
MEAN_RADIANCE	[SE-590 spectroradiometer]
SDEV_RADIANCE	[Calculated by software]
MEAN_REFL	[Calculated by software]
MEAN_SURF_REFL	[Calculated by software]
GASEOUS_TRANSMITTANCE	[Calculated by software]
CRTFCN_CODE	[Assigned by BORIS Staff]
REVISION_DATE	[Assigned by BORIS Staff]

7.3.5 Data Range

The following table gives information about the parameter values found in the data files on the CD-ROM.

Reference File

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	NSA-9BS-9TETR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	RSS03-SE501	RSS03-SE501	None	None	None	None
DATE_OBS	31-MAY-94	16-SEP-94	None	None	None	None
TIME	143212	225100	None	None	None	None
OP_GRID_INFO	N/A	N/A	None	None	None	None
PLATFORM_ALTITUDE	304.8	304.8	None	None	None	None
ELEVATION	136	650.44	None	None	None	None
SOLAR_ZEN_ANG	32.827	63.215	None	None	None	None
SOLAR_AZ_ANG	96.059	253.65	None	None	None	None
SUN_PHOTO_SOURCE	Helo	Thom	None	None	None	None
SUN_PHOTO_TIME	143300	223200	None	None	None	None
INTERP_AEROSOL_OPT_THICK_550	.0315	.7464	None	None	None	None
COLUMN_WATER_VAPOR	6.35	27.01	None	None	None	None
COVER_TYPE	N/A	N/A	None	None	None	None
HELO_LOG_TRIP_ID	531A	916B	None	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	13-JUN-98	13-JUN-98	None	None	None	None

Data File

Column Name	Minimum Data Value	Maximum Data Value	Missng Data Value	Unrel Data Value	Below Detect Limit	Data Not Cllctd
SITE_NAME	NSA-9BS-9TETR	SSA-YJP-FLXTR	None	None	None	None
SUB_SITE	RSS03-SE501	RSS03-SE501	None	None	None	None
DATE_OBS	31-MAY-94	16-SEP-94	None	None	None	None
TIME	143212	225100	None	None	None	None
WAVELENGTH	.4026	.9007	None	None	None	None
MEAN_RADIANCE	1.5	112.11	None	None	None	None
SDEV_RADIANCE	.034	10.011	None	None	None	None
MEAN_REFL	.4	44.9	None	None	None	None
MEAN_SURF_REFL	0	49.3	-999	None	None	None
GASEOUS_ TRANSMITTANCE	.77	1	None	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	02-JUN-98	05-JUN-98	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

The following is a sample of the first few records from the data table on the CD-ROM:

Reference File

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME,OP_GRID_INFO,PLATFORM_ALTITUDE,ELEVATION,
SOLAR_ZEN_ANG,SOLAR_AZ_ANG,SUN_PHOTO_SOURCE,SUN_PHOTO_TIME,
INTERP_AEROSOL_OPT_THICK_550,COLUMN_WATER_VAPOR,COVER_TYPE,HELO_LOG_TRIP_ID,
CRTFCN_CODE,REVISION_DATE
'SSA-9OA-FLXTR','RSS03-SE501',31-MAY-94,151500,'C3B7T',304.8,600.63,53.01,
103.522,'Helo',152300,.0584,11.73,'A','531A','CPI',13-JUN-98
'SSA-ASP-AUX02','RSS03-SE501',31-MAY-94,152309,'B9B7A',304.8,572.0,51.83,
105.375 ,'Helo',152300,.0584,11.73,'A','531A','CPI',13-JUN-98
'SSA-OJP-FLXTR','RSS03-SE501',31-MAY-94,161810,'G2L3T',304.8,579.27,43.681,
121.2 01,'Helo',161500,.073,12.375,'JP','531A','CPI',13-JUN-98
```

Data File

```
SITE_NAME,SUB_SITE,DATE_OBS,TIME,WAVELENGTH,MEAN_RADIANCE,SDEV_RADIANCE,
MEAN_REFL,MEAN_SURF_REFL,GASEOUS_TRANSMITTANCE,CRTFCN_CODE,REVISION_DATE
'SSA-ASP-AUX05','RSS03-SE501',13-SEP-94,201824,.4026,2.82,.073,1.0,.6,1.0,'CPI',
02-JUN-98
'SSA-ASP-AUX05','RSS03-SE501',13-SEP-94,201824,.4053,3.09,.07,1.0,.7,1.0,'CPI',
02-JUN-98
'SSA-ASP-AUX05','RSS03-SE501',13-SEP-94,201824,.408,3.2,.07,1.0,.7,1.0,'CPI',
02-JUN-98
```

8. Data Organization

8.1 Data Granularity

The smallest amount of data that can be ordered from this data set is a day's worth of data for a given site.

8.2 Data Format

The Compact Disk-Read Only Memory (CD-ROM) files contain American Standard Code for Information Interchange (ASCII) 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 data file on the CD-ROM has four header lines of Hyper-Text Markup Language (HTML) code at the top. When viewed with a Web browser, this code displays header information (data set title, location, date, acknowledgments, etc.) and a series of HTML links to associated data files and related data sets. Line 5 of each data file is a list of the column names, and line 6 and following lines contain the actual data.

9. Data Manipulations

9.1 Formulae

9.1.1 Derivation Techniques and Algorithms

From Vermote et al. (1997):

"Two atmospheric processes modify the solar radiance reflected by a target when viewed from space: absorption by the gases (when observation bands are overlapping gaseous absorption bands) and scattering by the aerosols and the molecules. If the gaseous absorption can be de-coupled from scattering as if the absorbents were located above the scattering layers, as assumed in the 6S code, the equation of transfer for a Lambertian homogeneous target of reflectance P_SFC at sea level altitude viewed by a satellite sensor (under zenith angle of view theta_v and azimuth angle of view phi_v) and illuminated by sun (theta_s, phi_s) is...:

P_TOA(theta_s, theta_v, phi_s-phi_v) = T_g(theta_s, theta_v) * [P_R+A + T_dn(theta_s) *
T_up(theta_v) * {P_SFC / (1 - S*P_SFC)}]. (1)

The various quantities are expressed in terms of equivalent reflectance P defined as P = pi * L /mu_s* E_s where L is the measured radiance, E_s is the solar flux at the top of the atmosphere, and mu_s = cos(theta_s) where theta_s is the solar zenith angle."

In addition, note the following notation (Vermote et al, 1997):

```
T_g    Gaseous transmission of water vapor, carbon dioxide,
       oxygen, and ozone.
P_TOA  Reflectance at the top of the atmosphere.
P_R+A  Intrinsic reflectance of the molecule+aerosol layer.
T_dn   Total transmission of the atmosphere on the path
       between the sun and the surface.
T_up   Total transmission of the atmosphere on the path
       between the surface and the sensor.
S      Spherical albedo of the atmosphere.
```

9.2 Data Processing Sequence

9.2.1 Processing Steps

The SE-590 sensor voltages were processed to at-sensor radiances (W/m^2 sr mm) following procedures described in Markham et al. (1988). Calibration coefficients were obtained before and after the deployment at NASA GSFC and onsite during the deployment using a portable calibration apparatus. The individual data scans were examined and those with obvious spurious values (i.e., outliers in the distribution) were removed.

The mean helicopter SE-590 radiances and sunphotometer data from either the helicopter or the nearest RSS-11 ground sunphotometer were then input into Version 4.0 of the 6S software (Vermote et al., 1997) to obtain at-surface reflectance factors corrected for atmospheric effects. There was close agreement between the helicopter-mounted sunphotometer and nearby RSS-11 measurements.

9.2.2 Processing Changes

None.

9.3 Calculations

9.3.1 Special Corrections/Adjustments

None.

9.3.2 Calculated Variables

See Section 9.1.1.

9.4 Graphs and Plots

Not included here. See Loechel et al., 1996.

10. Errors

10.1 Sources of Error

Potential sources of error include radiometric calibration; spectral calibration; physical (environmental and human) conditions (including helicopter vibration, minor changes in helicopter altitude and inclination); atmospheric conditions, including atmospheric parameters estimated from the surface sunphotometer network; and the atmospheric correction algorithm (Vermote et al., 1997). Confidence intervals for the visible/near-infrared at-sensor radiance values presented in this data set are within 3%. The possibility of errors being introduced into the data set increases with additional manipulations of the data. For an in-depth discussion of error considerations, see Markham et al. (1988).

10.2 Quality Assessment

Visual quality assessment was performed during data collection. See reference list and helicopter logs.

10.2.1 Data Validation by Source

None given.

10.2.2 Confidence Level/Accuracy Judgment

A thorough quantitative error analysis of this kind of data set is given in Markham et al. (1988).

10.2.3 Measurement Error for Parameters

Confidence intervals for the at-sensor radiance values presented in this data set are within 3%.

10.2.4 Additional Quality Assessments

See helicopter logs. Also, see reference: Walthall et al., 1997.

10.2.5 Data Verification by Data Center

A visual examination of all of the helicopter-mounted SE-590 at-surface reflectances reveals artifacts from the atmosphere in all of the spectra. This is especially obvious in the oxygen and water absorption regions in the near-infrared. That all the atmospheric effects have not been removed from the near-infrared bands causes one to suspect the atmospheric corrections in the visible bands as well.

While the atmospheric effects on at-surface reflectance at any given wavelength may be small, these effects may cause significant problems in some types of hyperspectral analyses. Some analysis techniques look at band-to-band covariances or derivatives. The atmospheric effects are nonlinear with wavelength, and thus, by not completely removing these effects, the data become questionable for those types of analyses.

11. Notes

11.1 Limitations of the Data

See Section 10.2.5.

11.2 Known Problems with the Data

Caution should be used when using a band reflectance in the near-infrared calculated with a gaseous transmittance much under 0.9; i.e., use caution in the oxygen band (~760 nm) and the water vapor absorption band (~820 nm) -- where absorption effects can be under/overestimated, respectively. It is suggested that a neighboring band not affected by gaseous absorption be used, which seems to characterize surface absorption effects well through the near-infrared.

Data collected over sparse canopies and with extreme solar geometry (i.e., early morning/late afternoon observations) will contain substantial amounts of shadow, which may complicate the retrieval of surface vegetation parameters.

In addition, isolated atmospheric events (such as forest fires or scattered cloudiness) reduce the certainty in the atmospheric correction. The use of surface-measured atmospheric variables contributes to error in the data set in those cases.

11.3 Usage Guidance

See Sections 10.2.5, 11.1, and 11.2.

11.4 Other Relevant Information

None given.

12. Application of the Data Set

Research questions that may be examined with this data include:

- Retrieval of leaf area index (LAI) from spectral vegetation index.
- Scaling of spectral response in boreal regions (in combination with other BOREAS data sets).

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

The software used in the atmospheric correction of this data set was 6S, Version 3.2 (Vermote et al., 1997).

14.2 Software Access

This software is public domain and available via anonymous ftp at kratmos.gsfc.nasa.gov.

15. Data Access

The RSS-03 reflectance data are available from the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC).

15.1 Contact Information

For BOREAS data and documentation please contact:

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

15.2 Data Center Identification

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

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

None.

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

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17.2 Journal Articles and Study Reports

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Vermote, E., D. Tanre, and J. Morcrette. 1997. Second simulation of the satellite signal in the solar spectrum, 6S: an overview. IEEE Trans. Geosci. Remote Sens., vol. 35, no. 3, pp. 675.

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

None.

19. List of Acronyms

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6S      - Second Simulation of the Satellite Signal in the Solar Spectrum
AGL     - Above Ground Level
ASCII   - American Standard Code for Information Interchange
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
BSQ     - Band Sequential
CCD     - Charge-Coupled Device
CD-ROM  - Compact Disk-Read-Only Memory
DAAC    - Distributed Active Archive Center
DN      - Digital Number
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
FOV     - Field of View
GIS     - Geographic Information System
GSFC    - Goddard Space Flight Center
HTML    - Hyper-Text Markup Language
IFC     - Intensive Field Campaign
IFOV    - Instantaneous Field of View
LAI     - Leaf Area Index
MMR     - Modular Multiband Radiometer
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NSA     - Northern Study Area
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ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
RSS     - Remote Sensing Science
SE-590  - Spectron Engineering spectroradiometer
SSA     - Southern Study Area
SWIR    - Short-Wave Infrared
TM      - Thematic Mapper
URL     - Uniform Resource Locator
UTM     - Universal Transverse Mercator
VIS/NIR - Visible/Near-Infrared
WFF     - Wallops Flight Facility
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Walthall, C. and S. Loechel, "Biophysical Significance of Spectral Vegetation Indices in the Boreal Forest." 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.

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13. ABSTRACT *(Maximum 200 words)*

The BOREAS RSS-3 team collected multiple remotely sensed data sets from the NASA UH-1 helicopter. This data set includes helicopter-based radiometric measurements of forested sites acquired during BOREAS made with an SE-590 processed to reflectance factors. The data used in this analysis were collected in 1994 during the three BOREAS IFCs at numerous tower and auxiliary sites in both the NSA and the SSA. The 15-degree FOV of the SE-590 yielded a ground resolution of approximately 79 m at the 300-m nominal altitude. The data are provided in tabular ASCII files.

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