BOREAS FOLLOW-ON DSP-08 POLDER ATMOSPHERICALLY CORRECTED SURFACE PARAMETERS, SSA

Get Data

## Summary

This data set contains maps of surface reflectance and vegetation parameters derived from imagery collected by the POLDER instrument over BOREAS conifer tower sites in the Southern Study Area (SSA) during the 1994. The POLDER imagery provided in this data set was collected on June 1 and July 21, 1994 from the NASA C-130 aircraft platform.

Note that some of the data files have been compressed using Zip compression. See Section 8.2 for details.

## Data Citation

Cite this data set as follows (citation revised on October 30, 2002):

Roujean, J.-L., and R. Lacaze. 2001. BOREAS Follow-On DSP-08 POLDER Atmospherically Corrected Surface Parameters, SSA. Data set. Available on-line [http://www.daac.ornl.gov] from Oak Ridge National Laboratory Distributed Active Archive Center, Oak Ridge, Tennessee, U.S.A.

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# 1. Data Set Overview

**1.1 Data Set Identification**

BOREAS Follow-On DSP-08 POLDER Atmospherically Corrected Surface Parameters, SSA

**1.2 Data Set Introduction**

The POLarization and Directionality of Earth Reflectances (POLDER) instrument measures Bidirectional Reflectance Distribution Function (BRDF) and Bidirectional Polarization Distribution Function (BPDF) of terrestrial surfaces in several visible and near-infrared spectral bands. POLDER data was collected over several surface types (pine, spruce, fen, and others) in the BOReal Ecosystem-Atmosphere Study (BOREAS) Southern Study Area (SSA) during the Intensive Field Campaigns (IFCs) in 1994. Only data from the SSA conifer tower sites are provided here.

**1.3 Objective/Purpose**

The objective was to provide regional maps of biophysical parameters that are important to the simulation of energy exchanges at the atmospheric boundary layer in Soil-Vegetation-Atmosphere Transfer (SVAT) models. Key variables are albedo, the fractional vegetation cover, and the Leaf Area Index (LAI). The algorithms rely on the use of the coefficients from the BRDF (Bi-directional Reflectance Distribution Function) kernel-driven model of Roujean et al.(1992) which were adjusted against airborne POLDER (POLarization and Directionality of Earth Reflectance) data sets.

**1.4 Summary of Parameters**

Albedo, fractional vegetation cover, LAI.

**1.5 Discussion**

The POLDER instrument measures surface reflectance as a function of wavelength and observation geometry. The algorithms used to derive the parameter images rely on the use of the coefficients from the BRDF kernel-driven model of Roujean et al.(1992) which were adjusted against airborne POLDER data sets.

**1.6 Related Data Sets**

BOREAS RSS-20 POLDER C-130 Measurements of Surface BRDF
BOREAS RSS-11 Ground Network of Sunphotometer Measurements

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## 2. Investigator(s)

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

Dr. Jean-Louis Roujean
Dr. Roselyne Lacaze

**2.2 Title of Investigation**

Estimation of Photosynthetic Capacity using POLDER Polarization

**2.3 Contact Information**

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## 3. Theory of Measurements

POLDER is an optical sensor designed to observe the surface reflectance in visible and near-infrared bands. The main characteristic of the POLDER instrument is that it can observe an area from multiple directions. POLDER has a wide field-of-view (FOV) lens with ± 51° along-track and ± 43° cross-track viewing, and a charge-coupled device (CCD) array detector to collect images.

Two principles of operation should be distinguished during the BOREAS experiment. When POLDER was mounted on the National Aeronautics and Space Administration's (NASA) Wallops Flight Facility (WFF) helicopter platform, the purpose was to collect data over the target at a low altitude, typically 300 m. One image acquired directly over a homogeneous surface provides the BRDF of the experimental site. From the NASA Ames Research Center (ARC) C-130 aircraft, at a nominal altitude 5500 m, the surface cannot be considered homogeneous. The POLDER instrument's capacity to observe an area from various view angles allows for measurement of the complete BRDF with successive images acquired along different flight axes over the experimental site.

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## 4. Equipment

### 4.1 Sensor/Instrument Description

#### 4.1.1 Collection Environment

It is mandatory to operate POLDER in totally clear sky conditions, so that the distribution of irradiance does not change from one measurement to another, and so that calculation of reflectance in absolute units from radiance is possible.

#### 4.1.2 Source/Platform

During IFC-1 and IFC-2, the POLDER instrument was installed alternatively on the NASA ARC C-130 aircraft or the NASA WFF helicopter. The POLDER instrument was deployed on the C-130 only in the SSA. The data described in this document were collected from the C-130 platform.

#### 4.1.3 Source/Platform Mission Objectives

The POLDER mission objective was to collect multiangle and multispectral bidirectional reflectance data over flux tower and auxiliary sites to study the boreal forest canopy.

#### 4.1.4 Key Variables

POLDER measures multispectral radiance in the visible and near infrared domain as a function of solar and view geometry.

#### 4.1.5 Principles of Operation

The POLDER optical system consists of a telecentric lens, a filter wheel, and a CCD array as a detector. The light is almost vertically incident on the filter wheel after passing the telecentric lens. The CCD array (288 x 384 elements) can collect 2-D images. The filter wheel contains 10 slots for spectral filters and polarizers. The first channel is reserved for dark current measurement, while the others allow measurements in five spectral bands (443, 550, 670, 864, and 910 nm). Two spectral bands (443 and 864 nm) are associated with three polarized filters oriented by steps of 60°. A 10-channel image, corresponding to the 10 positions of the filter wheel, is collected within 3 seconds, and this acquisition is repeated every 10 seconds.

The POLDER optical system was installed in the forward bay of the C-130. Aircraft position and attitude parameters provided by the onboard navigation system were recorded by the POLDER electronics subsystem for data post-processing. Typical flight altitude was 5500 m. Different flight lines were flown at each site to collect images in the principal, perpendicular, and 45° solar planes.

#### 4.1.6 Sensor/Instrument Measurement Geometry

The long axis of the CCD array was set parallel to the aircraft longitudinal axis. An inclinometer was used to record the initial bias between the optical axis and true nadir.

#### 4.1.7 Manufacturer of Sensor/Instrument

The instrument was designed and manufactured by:

Laboratoire d'Optique Atmosphérique (LOA)
59655 Villeneuve d'Ascq Cedex
Lille, France

### 4.2 Calibration

Radiometric calibration data were acquired at LOA by J.-Y. Balois before and after the BOREAS experiment (11-May-1994, 24-Oct-1994) using a calibrated integration sphere. The whole exit port of the integration sphere is used to derive the equalization coefficients. For absolute calibration, the exit port is reduced by a diaphragm to illuminate only a small circular area in the center of the CCD array. Readings of 15 x 15 pixel windows are corrected for dark current and averaged to obtain the absolute calibration coefficients.

Other calibration experiments were made during the BOREAS experiment using a 30-inch (0.76-m) diameter portable hemisphere that is owned and operated by NASA's Goddard Space Flight Center (GSFC). This portable hemisphere was made available to Remote Sensing Science (RSS)-20 by Brian Markham and John Schaffer. The calibration of POLDER was performed at the Prince Albert airport when POLDER was installed in C-130 aircraft on 27-May-1994 and 21-Jul-1994.

There is a good agreement between the LOA calibration and the first in situ calibration. The second in situ calibration shows discrepancies greater than 10% for all channels. The reasons for such discrepancies are still unknown.

#### 4.2.1 Specifications

The general specifications of the POLDER calibration accuracy were 5% absolute accuracy, 3% interband relative calibration accuracy, and 2% multitemporal relative calibration accuracy.

##### 4.2.1.1 Tolerance

A general rise in sensitivity was noted between the two calibration experiments made at LOA (11-May-1994, 24-Oct-1994); 8% in the blue (443 nm), 3.5% in the green (550 nm) and in the red (670 nm), 5.5% for the 864-nm channel, and 5% for the 910-nm channel. For subsequent processing, mean coefficients obtained at LOA are used.

#### 4.2.2 Frequency of Calibration

The instrument is generally calibrated once before an experimental campaign and once after the campaign. Calibration was performed at LOA on 11-May-1994 and 24-Oct-1994. Onsite calibration was performed on 27-May-1994 and 21-Jul-1994.

#### 4.2.3 Other Calibration Information

For details see the relevant sections of other POLDER documents referenced in section 1.6.

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## 5. Data Acquisition Methods

During BOREAS, a typical airborne POLDER flight consisted of five flight lines in the principal plane and one perpendicular to it. In some cases, as a function of the site and of the day, one or two more flight lines were achieved in the 45° solar plane. The nominal flight altitude was 5500 m, which gives a ground resolution of about 35m.

The description of the POLDER instrument, the data acquisition, and the atmospheric corrections applied to the images are described in the documentation file of the data set "BOREAS RSS-20 POLDER C-130 Measurements of Surface BRDF" available as part of the BOREAS archive (see section 15).

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## 6. Observations

### 6.1 Data Notes

None.

### 6.2 Field Notes

None.

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# 7. Data Description

## 7.1 Spatial Characteristics

### 7.1.1 Spatial Coverage

The POLDER study areas for this data set are centered on the Old Jack Pine (OJP) and Old Black Spruce (OBS) sites of the SSA. The image centered on the OJP site is about 130 $km^2$, i.e. is 10.5 km from south to north and 12.25 km from east to west. It includes the Young Jack Pine (YJP) site and a large disturbed area, either cut or burned. Dominant species are pine stands and pine mixed with spruce and deciduous trees. The image centered on the OBS site is smaller, about 85 $km^2$, 10.5 km from south to north and 8.05 km from east to west. The dominant specie is spruce, with pure stands or mixed with pines and aspen. A large part of the area is occupied by muskeg. The two images include small lakes.

The following are North American Datum of 1983 (NAD83) coordinates for tower sites within this data set:

| Site | BORIS Grid ID | West Longitude | North Latitude | UTM Easting | UTM Northing | UTM Zone |
|---|---|---|---|---|---|---|
| SSA Old Black Spruce (OBS) | G8I4T | 105.11779 | 53.98718 | 492306.1 | 5981879 | 13 |
| SSA Old Jack Pine (OJP) | G2L3T | 104.69203 | 53.91634 | 520257.0 | 5974035 | 13 |
| SSA Young Jack Pine (YJP) | F8L6T | 104.64527 | 53.87581 | 523350.7 | 5969540 | 13 |

### 7.1.2 Spatial Coverage Map

Not available.

### 7.1.3 Spatial Resolution

The pixel size for POLDER images from the C-130, at an altitude of 5500m, is 35m.

### 7.1.4 Projection

The atmospherically clear images were projected on a UTM (Universal Transverse Mercator) grid and geolocated by referencing to a land cover map derived from LANDSAT/TM imagery. Using anchor points, a warping transformation has been performed by applying a second-degree polynomial least-squares method. The accuracy assessment on the geo-location is assessed to be better than the pixel resolution.

### 7.1.5 Grid Description

Not applicable.

## 7.2 Temporal Characteristics

### 7.2.1 Temporal Coverage

| Sites | Day of Year | Sun Angle |
|---|---|---|
| SSAñOJP | June 1 1994 | 50.05° |
| SSAñOJP | July 21 1994 | 33.51° |
| SSAñOBS | July 21 1994 | 35.69° |

### 7.2.3 Temporal Resolution

See Section 7.2.1.

## 7.3 Data Characteristics

### 7.3.1 Parameter/Variable

The parameters contained in the data files are:

| Parameter Name |
|---|
| Albedo |
| Fractional Vegetation Cover |
| LAI |

### 7.3.2 Variable Description/Definition

The descriptions of the parameters contained in the data files are:

| Parameter Name | Description |
|---|---|
| Albedo | Hemispherical reflectance, or directional albedo is defined as the integration of the bi-directional reflectance over the upper viewing hemisphere. |
| Fractional Vegetation Cover | Percentage of ground covered by vegetation. |
| LAI | Leaf Area Index, the total one-sided leaf area per unit ground surface area. |

### 7.3.3 Unit of Measurement

The measurement units for the parameters contained in the data files are:

| Parameter Name | Units |
|---|---|
| Albedo | Values in the albedo files need to be divided by 1000 to get physical values in the range [0, 1]. |
| Fractional Vegetation Cover | Values in the fraction of vegetation files need to be divided by 1000 to get physical values in the range [0, 1]. |
| LAI | Values in the LAI files need to be divided by 100 to get physical values in the range [0, 6]. |

### 7.3.4 Data Source

The source of the original data was the POLDER instrument onboard the NASA C-130 aircraft.

### 7.3.5 Data Range

The data range for the parameters contained in the data files are:

| Parameter Name | Data Range |
|---|---|
| Albedo | [0, 1] |
| Fractional Vegetation Cover | [0, 1] |
| LAI | [0, 6] |

Missing values were set to -99.

**7.4 Sample Data Record**

Not applicable to image data.

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## 8. Data Organization

**8.1 Data Granularity**

There is one parameter image per date and site.

**8.2 Data Format(s)**

The following list gives image file names and sizes:

| Image File Name | Pixels/Line | # of Lines | Bits/Pixel |
|---|---|---|---|
| Directional Albedo | | | |
| 94-06-01_ssa-ojp_albedo670.img | 350 | 300 | 16 |
| 94-06-01_ssa-ojp_albedo864.img | 350 | 300 | 16 |
| 94-07-21_ssa-obs_albedo670.img | 230 | 300 | 16 |
| 94-07-21_ssa-obs_albedo864.img | 230 | 300 | 16 |
| 94-07-21_ssa-ojp_albedo670.img | 350 | 300 | 16 |
| 94-07-21_ssa-ojp_albedo864.img | 350 | 300 | 16 |
| Fraction of Vegetation | | | |
| 94-06-01_ssa-ojp_fract-veg.img | 350 | 300 | 16 |
| 94-07-21_ssa-obs_fract-veg.img | 200 | 300 | 16 |
| 94-07-21_ssa-ojp_fract-veg.img | 350 | 300 | 16 |
| LAI | | | |
| 94-06-01_ssa-ojp_lai.img | 350 | 300 | 16 |
| 94-07-21_ssa-obs_lai.img | 200 | 300 | 16 |
| 94-07-21_ssa-ojp_lai.img | 350 | 300 | 16 |

The image files have been compressed with the MS Windows-standard Zip compression scheme. These files were compressed using Aladdin's DropZip on a Macintosh. DropZip uses the Lempel-Ziv algorithm (Welch, 1994), also used in Zip and PKZIP programs. The compressed files may be uncompressed using PKZIP (with the -expand option) on MS Windows and UNIX, or with StuffIt Expander on the Mac OS. You can get newer versions from the PKZIP Web site at http://www.pkware.com/download-software/ [Internet Link].

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## 9. Data Manipulations

**9.1 Formulae**

See Section 9.1.1.

**9.1.1 Derivation Techniques and Algorithms**

METHOD FOR THE RETRIEVAL OF SURFACE PARAMETERS

The atmospherically corrected POLDER images were processed using the model of Roujean et al. (1992) which describes the bi-directional reflectance as:

$\rho(\theta_s, \theta_v, \phi) = k_0 + k_1 * f_1(\theta_s, \theta_v, \phi) + k_2 * f_2(\theta_s, \theta_v, \phi)$ (1)

The angular functions $f_1$ and $f_2$, respectively, describe the geometric effects and the volume scattering. The coefficients $k_{i=0,1,2}$ are retrieved from the inversion of the model using POLDER data.

#### 9.1.1.1 Albedo product

The hemispherical reflectance, or directional albedo, a, is defined as the integration of the bi-directional reflectance over the upper viewing hemisphere. It is expressed as:

$a(\theta_s) = k_0 + k_1 * I_1(\theta_s) + k_2 * I_2(\theta_s)$ (2)

with:

$I_1(\theta_s) = - 0.7733 - 1.1033 * (\theta_s) + 2.4895 * (\theta_s)^2 - 1.7621 * (\theta_s)^3$
(3a)

$I_2(\theta_s) = - 0.0160 + 0.0806 * (\theta_s) - 0.1476 * (\theta_s)^2 + 0.1784 * (\theta_s)^3$
(3b)

The functions $I_1(\theta_s)$ and $I_2(\theta_s)$ approximate the numerical integration of the kernels $f_1(\theta_s)$ and $f_2(\theta_s)$, respectively, over the upper viewing hemisphere (Lacaze, 1999). The directional albedo is calculated for the average sun angle of the POLDER flight. Those are:

| Sites | Day of Year | Sun Angle |
|---|---|---|
| SSA-OJP | June 1 1994 | 50.05° |
| SSA-OJP | July 21 1994 | 33.51° |
| SSA-OBS | July 21 1994 | 35.69° |

#### 9.1.1.2 Fractional vegetation cover $\sigma_f$

The conifer forest canopies form a highly discontinuous landscape that can be described by tree density and crown characteristics (shape, dimension). Actually, the crown properties as well as the Sun position influence the radiation regime within the canopy. Therefore, two cases must be distinguished:

1. At large zenith angles, only top crown layers are illuminated, or seen by the sensor, and therefore the forest canopy can be assimilated in first approximation by a turbid medium composed of a homogeneous horizontal crown layer. In this case, the gap fraction within-crown has to be considered and volume scattering is the dominant phenomenon
2. At a near-nadir sun angle, the solar beam, or sensor field of view, can travel deeply into the canopy and hence the forest rather resembles a heterogeneous horizontal medium. In this case, the gap fraction between-crown has to be considered. Shading effects are the dominant phenomena in this case.

In order to improve the description of the forest canopy, we take advantage of the BRDF sampling of the POLDER instrument to select appropriate angular data sets and the model most adapted to each radiation regime:

A) $\rho(\theta_s, \theta_v, \phi) = k_0 + k_2 * f_2(\theta_s, \theta_v, \phi)$ is applied to the observations acquired with a view angle larger than 35°. (SSA-OJP, June 1)

B) $\rho(\theta_s, \theta_v, \phi) = k_0 + k_1 * f_1(\theta_s, \theta_v, \phi)$ is applied to the observations acquired with a view angle smaller than 35°. (SSA-OJP, July 21 and SSA-OBS, July 21)

To calculate the fractional vegetation cover $\sigma_f$, we need to minimize the effects of soil reflectance. We use a relationship based on the difference vegetation index (DVI) built from the spectral coefficients $k_0$:

$$DVI = (k_0)_{NIR} - (k_0)_{VIS} \quad (4)$$

and $\sigma_f = 5.39 * DVI - 0.38$ for $DVI <= 0.2$ (5a)
$\sigma_f = 1.00 * DVI + 0.50$ for $DVI >= 0.2$ (5b)

These relationships were used to map the biophysical parameters from space-borne POLDER data (Lacaze and Roujean, 2001).

#### 9.1.1.3 Leaf Area Index (LAI)

The LAI is derived from the fractional vegetation cover as follows:

$$LAI_e = \ln(1-\sigma_f) / bG(\theta_s=0) \quad (6a)$$

$$LAI = LAI_e / \Omega \quad (6b)$$

where $b$ is a function of the leaf albedo (b=0.95), $G(\theta_s)$ is the leaf projection factor, here G=0.5, and LAIe is the effective LAI which assumes a random distribution of the foliage (Chen, 1996). $\Omega$ is the clumping index (Nilson, 1971) which quantifies the foliage aggregation. An adjustment between the retrieved $LAI_e$ and ground measurements of LAI (Chen et al., 1997) served to yield an estimate of the clumping index for primary and auxiliary sites. A simple relationship was established between clumping index and DVI:

$$\Omega = -0.923 + 9.126 * DVI \quad (7)$$

It has been applied at the regional scale over forested areas according to a threshold value determined empirically by:

$$0.13 <= DVI <= 0.20$$

## 9.2 Data Processing Sequence

### 9.2.1 Processing Steps

See section 9.1.1.

### 9.2.2 Processing Changes

None.

### 9.3 Calculations

#### 9.3.1 Special Corrections/Adjustments

See section 9.1.1.

#### 9.3.2 Calculated Variables

All parameters were calculated. See section 9.1.1.

### 9.4 Graphs and Plots

None.

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## 10. Errors

### 10.1 Sources of Error

None given.

### 10.2 Quality Assessment

#### 10.2.1 Data Validation by Source

The POLDER data have been tested against the four-scale BRDF reflectance model (Leblanc et al., 1997) as well as against the PARABOLA data and the DART 3-D BRDF model (Gastellu-Etchegorry et al., 1997).

#### 10.2.2 Confidence Level/Accuracy Judgment

The uncertainty associated with POLDER spectral reflectances, taking into account only error in the absolute calibration coefficient, is approximately less than 0.005 for the visible channels and 0.01 for the near-infrared channel.

#### 10.2.3 Measurement Error for Parameters

```
Albedo                         0.03 (absolute units)
Fractional vegetation cover    0.05 (absolute units)
LAI                            0.2 for LAI < 1 (absolute units)
                               20% otherwise   (relative units)
```

#### 10.2.4 Additional Quality Assessments

None.

#### 10.2.5 Data Verification by Data Center

BORIS staff have viewed the POLDER imagery and worked with the DSP08 team on the format and structure of the image files.

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# 11. Notes

**11.1 Limitations of the Data**
None.

**11.2 Known Problems with the Data**
None.

**11.3 Usage Guidance**
Not applicable.

**11.4 Other Relevant Information**
None.

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# 12. Application of the Data Set

This data set can be used for running climate or ecological models.

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# 13. Future Modifications and Plans

None.

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# 14. Software

**14.1 Software Description**
Zip uses the Lempel-Ziv algorithm (Welch, 1994) used in the zip and PKZIP commands.

**14.2 Software Access**
Zip is available from many Web sites across the Internet. You can get newer versions from the PKZIP Web site at http://www.pkware.com/download-software/ [Internet Link]. Versions of the decompression software for MS Windows, Mac OS, and several varieties of UNIX systems are included in this archive.

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# 15. Data Access

**15.1 Contact for Data Center/Data Access Information**
These BOREAS data are available from the Earth Observing System Data and Information System (EOS-DIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC). The BOREAS contact at ORNL is:

ORNL DAAC User Services
Oak Ridge National Laboratory

(865) 241-3952
ornldaac@ornl.gov
ornl@eos.nasa.gov

**15.2 Procedures for Obtaining Data**

BOREAS data may be obtained through the ORNL DAAC World Wide Web site at http://www.daac.ornl.gov/ [Internet Link] or users may place requests for data by telephone or electronic mail.

**15.3 Output Products and Availability**

Requested data can be provided electronically on the ORNL DAAC's anonymous FTP site or on various media including, CD-ROMs, 8-MM tapes, or diskettes.

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## 16. Output Products and Availability

**16.1 Tape Products**

None.

**16.2 Film Products**

None.

**16.3 Other Products**

None.

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## 17. References

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

None.

**17.2 Journal Articles and Study Reports**

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**17.3 Archive/DBMS Usage Documentation**

None.

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## 18. Glossary of Terms

None.

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# 19. List of Acronyms

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ASCII   - American Standard Code for Information Interchange
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
BPDF    - Bidirectional Polarization Distribution Function
BRDF    - Bidirectional Reflectance Distribution Function
CCD     - Change Coupled Device
CD-ROM  - Compact Disk-Read-Only Memory
DAAC    - Distributed Active Archive Center
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
FOV     - Field of View
GIS     - Geographic Information System
GSFC    - Goddard Space Flight Center
HTML    - HyperText Markup Language
IFC     - Intensive Field Campaign
LAI     - Leaf Area Index
LOA     - Laboratoire d'Optique Atmospherique
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NSA     - Northern Study Area
OBS     - Old Black Spruce
OJP     - Old Jack Pine
ORNL    - Oak Ridge National Laboratory
POLDER  - POLarization and Directionality of Earth's Reflectances
RSS     - Remote Sensing Science
SSA     - Southern Study Area
URL     - Uniform Resource Locator
UTM     - Universal Transverse Mercator
YJP     - Young Jack Pine
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