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

Forrest G. Hall and Shelaine Curd, Editors

Volume 156

BOREAS TE-9 NSA Photosynthetic Capacity and Foliage Nitrogen Data

Q. Dang, H. Margolis, and M. Coyea

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

October 2000

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BOREAS TE-9 NSA Photosynthetic Capacity and Foliage Nitrogen Data

Qinglai Dang, Lakehead University, Thunder Bay, Canada
Hank Margolis and Marie Coyea, Université Laval,
Sainte-Foy, Quebec, Canada

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

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BOREAS TE-9 NSA Photosynthetic Capacity and Foliage Nitrogen Data

Qinglai Dang, Hank Margolis, Marie Coyea

Summary

The BOREAS TE-9 team collected several data sets related to chemical and photosynthetic properties of leaves in boreal forest tree species. This data set describes the spatial and temporal relationship between foliage nitrogen concentration and photosynthetic capacity in the canopies of black spruce, jack pine, and aspen located within the NSA. The data were collected from June to September 1994 and are useful for modeling the vertical distribution of carbon fixation for different forest types in the boreal forest. The data are available in tabular ASCII files.

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1. Data Set Overview

1.1 Data Set Identification

BOREAS TE-09 NSA Photosynthetic Capacity and Foliage Nitrogen Data

1.2 Data Set Introduction

This data set describes the relationship between foliage nitrogen concentration and photosynthetic capacity in the canopies of the BOReal Ecosystem Atmosphere Study (BOREAS) Northern Study Area (NSA)-Old Black Spruce (OBS), NSA-Upland Black Spruce (UBS), NSA-Old Jack Pine (OJP), NSA-Young Jack Pine (YJP), and NSA-Old Aspen (OA).

The canopy profiles of nitrogen concentration and photosynthetic capacity were examined as part of an effort to characterize the spatial and temporal variations in photosynthetic capacity and nitrogen allocation in the boreal forest. This information will be useful for modeling the vertical distribution of carbon fixation for different forest types in the boreal forest. Samples were taken from five forest types in the NSA: NSA-OBS, NSA-UBS, NSA-OJP, NSA-YJP, and NSA-OA during each of the three Intensive Field Campaigns (IFCs) in 1994.

Measurements were taken under controlled environmental conditions in the laboratory. An open gas exchange system in differential mode was used for measuring the photosynthetic capacity.

1.3 Objective/Purpose

This data set was collected and prepared to provide the profile of photosynthetic capacity and nitrogen concentration in the forest canopy of NSA-OBS (Picea mariana Mill.), NSA-UBS, NSA-OJP (Pinus banksiana Lamb.), NSA-YJP, and NSA-OA (Populus tremuloides Michx.). This information will also be useful for modeling the vertical distribution of carbon fixation for different forest types in the boreal forest.

1.4 Summary of Parameters

Light-saturated net photosynthesis, nitrogen concentration.

1.5 Discussion

The canopy profiles of nitrogen concentration and photosynthetic capacity were examined as part of an effort to characterize the spatial and temporal variations in photosynthetic capacity and nitrogen allocation in the boreal forest. This information will be useful for modeling the vertical distribution of carbon fixation for different forest types in the boreal forest. Samples were taken from five forest types in the NSA: NSA-OBS, NSA-UBS, NSA-OJP, NSA-YJP, and NSA-OA during each of the three IFCs in 1994.

Measurements were taken under controlled environmental conditions in the laboratory. An open gas exchange system in differential mode was used for measuring the photosynthetic capacity.

1.6 Related Data Sets

BOREAS TE-09 Photosynthetic Response Data

2. Investigator(s)

2.1 Investigator(s) Name and Title

Dr. Hank Margolis, Associate Professor

2.2 Title of Investigation

Relationship Between Measures of Absorbed and Reflected Radiation and the Photosynthetic Capacity of Boreal Forest Canopies and Understories

2.3 Contact Information

Contact 1:
Dr. Hank Margolis
Universite Laval
Faculte de foresterie et de geomatique
Pavillon Abitibi-Price
Sainte-Foy, Quebec
Canada G1K 7P4
(418) 656-7120
Hank.margolis @sbf.ulaval.ca

Contact 2:
Dr. Qinglai Dang
Lakehead University
Faculty of Forestry
955 Oliver Road, Thunder Bay
Canada P7B 5E1
(807) 343-8507
(807) 343-8116 (fax)
Qinglai.Dang@flash.lakeheadu.ca

Contact 3:
Shelaine Curd
Raytheon ITSS
Code 923
NASA GSFC
Greenbelt, MD 20771
(301) 286-2447
(301) 286-0239 (fax)
shelaine.curd@gsfc.nasa.gov

3. Theory of Measurements

During the process of photosynthesis, CO_2 is assimilated by the green leaves while H_2O is released into the atmosphere. The amount of water released and the amount of CO_2 absorbed are determined by comparing the concentrations of water vapor and CO_2 in the air moving into the leaf cuvette and those in the air moving out of the cuvette at a certain flow rate. The concentration of CO_2 and water vapor in both incoming and outgoing air streams is measured using an infrared gas analyzer (IRGA).

The total nitrogen concentration of foliage was determined by the Kjeldahl method. This consists of two main steps: (1) The nitrogen in the sample is converted to NH_4+ by digestion with concentrated H_2SO_4 containing substances that promote this conversion. (2) The NH_4+ is determined from the amount of NH_3 liberated by distillation of the digest with alkali. This is a common procedure for total nitrogen determination for plant materials.

4. Equipment

4.1 Sensor/Instrument Description

4.1.1 Collection Environment

The vertical profile of the canopy was divided into three layers: top, middle, and bottom. For NSA-OBS, NSA-UBS, and NSA-OJP, all three layers were of the same species. For NSA-YJP, the bottom layer was the understory black spruce seedlings, while the top and middle layers were jack pine. For NSA-OA, the bottom layer was alder, while the top and middle layers were aspen. Branch samples were harvested from each layer and were immediately recut under water. The samples were then transported back to the laboratory for gas exchange measurements. The cut surface of the branch was submerged in water during transport and in the laboratory.

Samples were cut in the dark. The samples that were about to be measured, however, were exposed to saturated light for 2 hours prior to measurement to induce stomatal opening and photosynthetic activity. To keep a continual supply of water to the branch, the cut surface was kept in contact with water during the entire period. The light source was two 1,000-watt high-pressure sodium lamps. Different levels of light were achieved by using different neutral density filters. The environmental conditions inside the leaf cuvette were as follows: temperature 20 +/- 0.5 °C; vapor pressure deficit 0.7 +/- 0.2 kPa; CO_2 360 +/- 20 ppm.

Photosynthesis and related parameters all are expressed on a hemisurface area basis. The shape factors for the leaf area calculation were 4 and 4.59, respectively, for black spruce and jack pine.

4.1.2 Source/Platform

Branch samples were taken using a shotgun and were recut under water. Photosynthesis was measured in the laboratory under a controlled environment.

4.1.3 Source/Platform Mission Objectives

The mission objectives were to obtain the canopy profile of photosynthetic capacity and nitrogen concentration and to examine interspecific and interseasonal differences in these canopy profiles.

4.1.4 Key Variables

Rate of light-saturated net photosynthesis, foliar nitrogen concentration.

4.1.5 Principles of Operation

A LI-COR-6262 IRGA, thermocouples, balance, Decagon AgVision root and leaf analysis system, and LI-COR quantum Photosynthetically Active Radiation (PAR) sensor were used in the data collection process. Eight samples were measured from each canopy level. Two samples were measured at a time, and measurements were alternated between different canopy levels.

4.1.6 Sensor/Instrument Measurement Geometry

All samples were taken from the upper third of the forest canopy. Efforts were made to keep the amount of foliage relatively consistent from sample to sample. The leaf chamber for the measurement is about 1,300 in.

4.1.7 Manufacturer of Sensor/Instrument

LI-6200 portable gas exchange system
LI-COR
P.O. Box 4425,
4421 Superior St.
Lincoln, NE 68504
(800) 447-3576

Leaf area measurement system/optical image analysis system (AgVision, monochrome system, root and leaf analysis)
Decagon Devices, Inc.
P.O. Box 835
Pullman, WA 99163
(800) 755-2751

4.2 Calibration

The gas analyzer was calibrated against standard gas that was calibrated against the prime CO_2 standard in the NSA lab in Thompson. Calibration was done at the beginning of each field campaign.

4.2.1 Specifications

The weighing balance was accurate to within 0.0001 g. The leaf area system was accurate to within 1%. The gas exchange system was accurate to 1 ppm CO_2.

The shape factor used for black spruce was 4, in accordance with the BOREAS Experiment Plan, Appendix K, Version 3.0. Based on observations of two cross-sections of two needles per fascicle for five fascicles for six jack pine trees from Thompson, Manitoba, an average shape factor of 4.59 (+/- 0.07) was calculated.

4.2.1.1 Tolerance

No tolerance level was set for these measurements.

4.2.2 Frequency of Calibration

LI-COR 6262 IRGA was calibrated at the beginning of each IFC.

4.2.3 Other Calibration Information

None.

5. Data Acquisition Methods

The vertical profile of the canopy was divided into three layers: top, middle, and bottom. For NSA-OBS, NSA-UBS, and NSA-OJP, all three layers were of the same species. For NSA-YJP, the bottom layer was the understory black spruce seedlings, while the top and middle layers were jack pine. For NSA-OA, the bottom layer was alder, while the top and middle layers were aspen. Branch samples were harvested from each layer and were immediately recut under water. The samples were then transported back to the laboratory for gas exchange measurements. The cut surface of the branch was submerged in water during transport and in the laboratory.

Samples were cut in the dark. The samples that were about to be measured, however, were exposed to saturated light for 2 hours prior to measurement to induce stomatal opening and photosynthetic activity. To keep a continual supply of water to the branch, the cut surface was in contact with water during the entire period. The light source was two 1,000-watt high-pressure sodium lamps. Different levels of light were achieved by using different neutral density filters. The environmental conditions inside the leaf cuvette were as follows: temperature 20 +/- 0.5 °C; vapor pressure deficit 0.7 +/- 0.2 kPa; CO_2 360 +/- 20 ppm.

Photosynthesis and related parameters all are expressed on a hemisurface area basis. The shape factors for the leaf area calculation were 4 and 4.59, respectively, for black spruce and jack pine.

6. Observations

6.1 Data Notes

None.

6.2 Field Notes

Samples were taken between 6:00 and 7:00 a.m. from one site per day over 5 days. See pages 2-23 and 2-24 in the BOREAS Experiment Plan, Version 3.0, for a description of site conditions.

7. Data Description

7.1 Spatial Characteristics

7.1.1 Spatial Coverage

At each site, branch samples were taken from four different trees that were at least 10 m apart from one another. The North American Datum of 1983 (NAD83) coordinates of each site are:

- NSA-YJP flux tower site: Lat/Long: 55.89575°N, 98.28706°W; UTM Zone 14, N: 6194706.9, E:544583.9
- NSA-OJP flux tower site: Lat/Long: 55.842°N, 98.62396°W; UTM Zone 14, N: 6198176.3, E: 523496.2
- NSA-OA canopy access tower site (auxiliary site number T2Q6A, BOREAS Experiment Plan, Version 3): Lat/Long: 55.88691°N, 98.67479°W; UTM Zone 14, N: 6193540.7, E: 520342;
- NSA-OBS flux tower site: Lat/Long: 55.88007°N, 98.48139°W; UTM Zone 14, N: 6192853.4, E: 532444.5
- NSA-UBS canopy access tower site (auxiliary site number T6R5S, BOREAS Experiment Plan, Version 3): Lat/Long: 55.90802°N, 98.51865°W; UTM Zone 14, N: 6195947, E: 530092

7.1.2 Spatial Coverage Map

Not available.

7.1.3 Spatial Resolution

The data represent point source measurements made near the designated sites.

7.1.4 Projection

Not applicable.

7.1.5 Grid Description

Not applicable.

7.2 Temporal Characteristics

7.2.1 Temporal Coverage

The data were collected during the period of 02-June to 04-September-1994. Samples were taken between 6:00 and 7:00 a.m. Measurements in the lab normally took 8 to 14 hours. An independent data set was taken during each of the three IFCs in 1994.

7.2.2 Temporal Coverage Map

Site	Sample Dates (1994)
NSA-OBS	09-Jun, 21-Jul, 04-Sep
NSA-UBS	06-Jun, 22-Jul, 01-Sep
NSA-OJP	02-Jun, 19-Jul, 31-Aug
NSA-YJP	05-Jun, 23-Jul, 02-Sep
NSA-OA	07-Jun, 21-Jul, 03-Sep

7.2.3 Temporal Resolution

Each of the sites was visited three times during 1994.

7.3 Data Characteristics

7.3.1 Parameter/Variable

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

Column Name
SITE_NAME
SUB_SITE
START_DATE
END_DATE
SPECIES
PHOTOSYNTHETIC_RATE
NITROGEN_CONC
NITROGEN_DENSITY
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:

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 BOREA S, 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.
START_DATE	The date on which the collection of the reference data commenced.
END_DATE	The date on which the collection of the referenced data was terminated.
SPECIES	Botanical (Latin) name of the species (Genus species).
PHOTOSYNTHETIC_RATE	Measured Net Photosynthesis
NITROGEN_CONC	The nitrogen concentration of the foliage dry mass sample.
NITROGEN_DENSITY	Nitrogen per unit hemisurface area.
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.

7.3.3 Unit of Measurement

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

Column Name	Units
SITE_NAME	[none]
SUB_SITE	[none]
START_DATE	[DD-MON-YY]
END_DATE	[DD-MON-YY]
SPECIES	[none]
PHOTOSYNTHETIC_RATE	[micromoles][meter^-2][second^-1]
NITROGEN_CONC	[milligrams][gram^-1]
NITROGEN_DENSITY	[grams][meter^-2]
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:

Column Name	Data Source
SITE_NAME	BORIS Designation
SUB_SITE	BORIS Designation
START_DATE	BORIS Designation
END_DATE	BORIS Designation
SPECIES	Human Observer
PHOTOSYNTHETIC_RATE	Laboratory Equipment
NITROGEN_CONC	Laboratory Equipment
NITROGEN_DENSITY	Laboratory Equipment
CRTFCN_CODE	BORIS Designation
REVISION_DATE	BORIS Designation

7.3.5 Data Range

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

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	NSA-YJP-FLXTR	None	None	None	None
SUB_SITE	9TE09-NPH01	9TE09-NPH01	None	None	None	None
START_DATE	24-MAY-94	30-AUG-94	None	None	None	None
END_DATE	16-JUN-94	19-SEP-94	None	None	None	None
SPECIES	N/A	N/A	None	None	None	None
PHOTOSYNTHETIC_RATE	.562	15.213	None	None	None	None
NITROGEN_CONC	4.06	46.35	None	None	None	None
NITROGEN_DENSITY	.6	6.5	None	None	None	None
CRTFCN_CODE	CPI	CPI	None	None	None	None
REVISION_DATE	19-SEP-96	19-SEP-96	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:

```
SITE_NAME,SUB_SITE,START_DATE,END_DATE,SPECIES,PHOTOSYNTHETIC_RATE,NITROGEN_CONC,
NITROGEN_DENSITY,CRTFCN_CODE,REVISION_DATE
'NSA-9OA-9TETR','9TE09-NPH01',24-MAY-94,16-JUN-94,'Populus tremuloides',13.178,
30.62,1.6,'CPI',19-SEP-96
'NSA-9OA-9TETR','9TE09-NPH01',24-MAY-94,16-JUN-94,'Populus tremuloides',10.9,
30.89,1.4,'CPI',19-SEP-96
```

8. Data Organization

8.1 Data Granularity

The smallest unit of orderable data is data collected on one day at one 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

Photosynthetic capacity was calculated according to von Caemmerer and Farquhar (1981), Planta 153: 376-387.

9.2 Data Processing Sequence

9.2.1 Processing Steps

Data were recorded automatically by a computer and also printed on a printer. Subsequent calculations of different parameters were performed using MS Excel for Windows 5.0.

BOREAS Information System (BORIS) staff processed the data by:

- Reviewing the initial data files and loading them online for BOREAS team access.
- Designing relational data base tables to inventory and store the data.
- Loading the data into the relational data base tables.
- Working with the Hydrology (HYD)-06 team to document the data set.
- Extracting the standardized data into logical files.

9.2.2 Processing Changes
None.

9.3 Calculations
Photosynthetic capacity was calculated according to von Caemmerer and Farquhar (1981), Planta 153: 376-387.

9.3.1 Special Corrections/Adjustments
None.

9.3.2 Calculated Variables
Photosynthetic capacity was calculated according to von Caemmerer and Farquhar (1981) Planta 153: 376-387.

9.4 Graphs and Plots
Photosynthetic capacity versus N.

10. Errors

10.1 Sources of Error
None.

10.2 Quality Assessment
Data are preliminary. Please contact Hank Margolis or Qinglai Dang if the data are used for publication. (See Section 2.3 contact information.)

10.2.1 Data Validation by Source
A base measurement (i.e., when the cuvette contains no samples) was taken both before and after each set of measurements. Other measurements were adjusted by the base values, if necessary.

10.2.2 Confidence Level/Accuracy Judgment
No statistical confidence level is available, but BORIS staff feels that these data are reliable.

10.2.3 Measurement Error for Parameters
None.

10.2.4 Additional Quality Assessments
Calculated results were plotted and the patterns were examined and compared with the literature. Outliers (determined visually) were eliminated from the data set.

10.2.5 Data Verification by Data Center
Data were examined for general consistency and clarity.

11. Notes

11.1 Limitations of the Data
None.

11.2 Known Problems with the Data
None.

11.3 Usage Guidance

None.

11.4 Other Relevant Information

None.

12. Application of the Data Set

This data set was collected and prepared to provide the profile of photosynthetic capacity and nitrogen concentration in black spruce, jack pine, and aspen stands. This information will also be useful to modeling the vertical distribution of carbon fixation for different forest types in the boreal forest.

13. Future Modifications and Plans

None.

14. Software

14.1 Software Description

Calculations were performed using MS Excel for Windows 5.0.

14.2 Software Access

Contact Microsoft Corp.

15. Data Access

The photosynthetic capacity and foliage nitrogen 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/.

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

LI-COR 6262 Infrared gas analyzer manual.

17.2 Journal Articles and Study Reports

Bremner, J.M. and C.S. Mulvaney. 1982. Nitrogen - Total. pp. 595-623. In: Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties. Second edition. A.L. Page, R.H. Miller, and D.R. Keeney, editors. American Society of Agronomy Inc. and the Soil Science Society of America Inc., Madison, WI.

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17.3 Archive/DBMS Usage Documentation

None.

18. Glossary of Terms

- A - Photosynthetic capacity (µmol/m^2/s)
- N% - percent nitrogen concentration (%)
- N g/m^2 - nitrogen per unit hemisurface area (g/m^2)
- N mg/g - nitrogen per dry mass of foliage (mg/g)

19. List of Acronyms

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ASCII   - American Standard Code for Information Interchange
BOREAS  - BOReal Ecosystem-Atmosphere Study
BORIS   - BOREAS Information System
CD-ROM  - Compact Disk-Read-Only Memory
CGR     - Certified by Group
CPI     - Checked by Principal Investigator
CPI-??? - CPI but questionable
DAAC    - Distributed Active Archive Center
EOS     - Earth Observing System
EOSDIS  - EOS Data and Information System
GIS     - Geographic Information System
GSFC    - Goddard Space Flight Center
HTML    - Hyper-Text Markup Language
HYD     - Hydrology
IRGA    - Infrared Gas Analyzer
NAD83   - North American Datum of 1983
NASA    - National Aeronautics and Space Administration
NSA     - Northern Study Area
OA      - Old Aspen
OBS     - Old Black Spruce
OJP     - Old Jack Pine
ORNL    - Oak Ridge National Laboratory
PANP    - Prince Albert National Park
PAR     - Photosynthetically Active Radiation
SSA     - Southern Study Area
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TE      - Terrestrial Ecology
UBS     - Upland Black Spruce
URL     - Uniform Resource Locator
UTM     - Universal Transverse Mercator
YJP     - Young Jack Pine
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Qinglai Dang, Hank Margolis, and Marie Coyea
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Q. Dang: Lakehead University, Thunder Bay, Canada; H. Margolis and M. Coyea: Université Laval, Sainte-Foy, Quebec, Canada; S. Curd: Raytheon ITSS, NASA Goddard Space Flight Center, Greenbelt, Maryland

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The BOREAS TE-9 team collected several data sets related to chemical and photosynthetic properties of leaves in boreal forest tree species. This data set describes the spatial and temporal relationship between foliage nitrogen concentration and photosynthetic capacity in the canopies of black spruce, jack pine, and aspen located within the NSA. The data were collected from June to September 1994 and are useful for modeling the vertical distribution of carbon fixation for different forest types in the boreal forest. The data are available in tabular ASCII files.

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