BOREAS Operations 1994

Final Version 2.3 (September 13, 1996)

Executive Summary

The design of the BOREAS-94 field experiment is described in the BOREAS Experiment plan (EXPLAN-94); preliminary results and a summary of field operations and weather conditions may be found in Sellers et al. (1995).

This document describes what was actually achieved in BOREAS-94. The reports from individual investigators, minutes from evening planning meetings, aircraft logs, etc. have all been analyzed to produce a condensed history of the measurements taken in the field and the experimental conditions experienced during the field year. This document is primarily intended to serve as a desk-top guide for scientists and staff in the project which will allow quick scanning across investigations prior to delving into the detailed data sets held in BORIS.

1.0 Introduction to BOREAS

The Boreal Ecosystems Atmosphere Study (BOREAS) is a large scale, international investigation focused on improving our understanding of the exchanges of radiative energy, sensible heat, water, CO_2 and trace gases between the boreal forest and the lower atmosphere. A primary objective of BOREAS is to collect the data needed to improve computer simulation models of the important processes controlling these exchanges so that scientists can anticipate the effects of global change, principally altered temperature and precipitation patterns, on the biome.

The scientific issues at stake are as follows:

I. **Sensitivity of the boreal forest biome to changes in the physical climate system.** A number of simulation studies have been carried out to assess the climatic impact of increasing atmospheric CO_2, see the reviews of Schlesinger and Mitchell (1987), Harrington (1987) and Houghton et al. (1990). Many of these studies indicate that the greatest warming engendered by increasing CO_2 will occur at higher (45°N-65°N) latitudes with the most marked effects within the continental interiors; for example, the doubled-CO_2 experiment of Mitchell (1983) produced differences of 3K to 10K in the mean winter surface temperature for much of the land surface area of this zone. Other studies have indicated that there may be significant warming and drying in the summer months in the same region. Studies by Davis and Botkin (1985) and Solomon and Webb (1985) suggest that this warming and drying could modify the composition and functioning of the boreal forest.

II. **The carbon cycle and biogeochemistry in the boreal forest**. The study of Tans et al. (1990) was the first to present evidence for the existence of a large terrestrial sink for fossil fuel carbon in the mid latitudes of the Northern Hemisphere. More recently, work by Denning et al. (1995) and Ciais et al. (1995), has reinforced this conclusion. The exact mechanisms involved and the spatial contributions to this sink are as yet unknown, but the implication is that carbon is being stored in either living tissue or in the soil. However, any sustained increase in surface temperature, combined with changes in soil moisture, could result in changes in the cycling of nutrients in the soils with associated releases of CO_2, CH_4 and other trace gases from the surface. If this occurs on a large enough spatial scale, the oxidative capacity of the lower atmosphere could be significantly altered. Additionally, changes in the temperature and moisture regime could alter the biomes' exposure and response to discontinuous disturbance, i.e. fire frequency, which could substantially affect the carbon cycle within the biome. As yet, we do not know enough about the processes which control the carbon cycle to be able to predict or even to simulate the carbon source/sink dynamics within the region.

III. **Biophysical feedbacks on the physical climate system**. Research work has indicated (See I. above) that changes in the ecological functioning of the biome could be brought about by changes in the physical climate system. It is anticipated that these may be accompanied by alterations in the biophysical characteristics of the surface; namely albedo, surface roughness and the biophysical control of evapotranspiration (surface and internal resistance). Any changes in these may have feedback effects on the near-surface climatology (temperature, humidity, precipitation and cloudiness fields), see Sato et al. (1989) and Bonan et al. (1992, 1995).

These scientific issues provided the motivation for the design and execution of a cooperative field experiment involving elements of land surface climatology, biogeochemistry and terrestrial ecology with remote sensing playing a strong integrating role. A coordinated multidisciplinary approach to the design of BOREAS was adopted from the outset to ensure the maximum benefit from each discipline's participation.

1.1 Objectives

The overall goal of BOREAS is to improve our understanding of the interactions between the boreal forest biome and the atmosphere in order to clarify their roles in global change.

The immediate experimental phase of BOREAS is planned to run over two to three years, 1993-1996. Obviously, this is too short a period for us to directly measure the ongoing effects of global change but it will allow us to observe important processes under a wide range of conditions so that we can develop and test key process models. The experimental strategy is specifically directed toward this: measurements will be taken throughout the annual cycle and at a variety of 'representative' sites to capture the range of significant climatic, edaphic (soil) and ecophysiological conditions to be found within the biome. Initially, these measurements will be used to improve our models and apply them over large areas to see how well we can describe the present situation. If this can be done convincingly over one or two annual cycles, then we will have more confidence in applying them as predictive tools to address the scientific issues listed above. In addition, the knowledge gained should enable us to design better, more cost-effective long-term monitoring programs to track future changes in the biome. The governing objectives of BOREAS can therefore be stated as follows:

(I) **Improve the process models which describe the exchanges of radiative energy, water, heat, carbon and trace constituents between the boreal forest and the atmosphere**.

Our approach here is to measure the fluxes of energy (radiation, heat) and mass (water, CO_2 and important trace gases) over a wide range of spatial scales together with observations of the ecological, biogeochemical, and atmospheric conditions controlling them. These data will be used to develop and thoroughly test process models before we apply them to the 'global change' issues described above.

The initial focus will be on validation and improvement of local-scale energy balance, mass balance and biophysical process models that operate at relatively short time scales (seconds to seasons) and which are amenable to measurement within a two year field program. The results of this effort will also be useful for the study of ecosystem level dynamics and land surface/climate interactions at regional and local scales over longer time periods (years to decades).

The field observations which support this model development include measurements of water, CO_2 and trace gas fluxes at the plot or leaf scale (chambers, porometers), the stand scale (tower mounted devices) and the mesoscale (airborne eddy correlation). These measurements will be coordinated with a series of ecological, meteorological and edaphic observations which will link these fluxes to appropriate state variables.

(II) **Develop methods for applying the process models over large spatial scales using remote sensing and other integrative modeling techniques**.

The process studies described in (I) above have been coordinated with remote sensing investigations using satellite, airborne and surface-based instruments which focus on methods for quantifying the critical state variables. These remote sensing studies, combined with mesoscale meteorological studies, will allow us to scale-up and apply the process models at regional and ultimately global scales. Some large-scale validation techniques were incorporated in the experiment design to test our scale-integration methods directly, including airborne eddy correlation and meteorological observation and modeling.

1.2 Experiment Design

The principal objectives of BOREAS defined in (I) and (II) above relate to two different spatial scales that must be reconciled within the experiment design. The primary focus of objective I is best addressed by local scale (a few centimeters to a few kilometers) process studies which involve detailed coordinated in-situ observations; e.g., leaf and soil plot scale, CO_2 and water flux measurements and tower-mounted eddy correlation. These local-scale studies must be connected to the larger-scale measurement and analysis tools associated with objective II which is directed toward defining regional-scale (10 to 1000 kilometers) fluxes and states. In BOREAS, as in previous field experiments such as FIFE (Sellers et al.; 1992) and HAPEX-Sahel (Goutorbe et al.; 1994), the science team adopted a nested multiscale measurement strategy to integrate observations and process models over a defined range of spatial scales. At the regional scale, satellite remote sensing, meteorological observations and modeling, and airborne flux measurements provide a large-scale picture of the important processes governing the exchanges of energy, water and carbon between the atmosphere and the land surface. Embedded within the region, data collected from the tower flux sites and process/auxiliary sites are used for point validation while studies carried out at intermediate scales (study area and modeling sub-area scales, see below) will be used to test different integration approaches.

The overall goals of the project emphasize the need to study the biome's biophysical, chemical and ecological functioning under different conditions. The governing climatological variables controlling these in the biome are temperature (associated with length of growing season, radiation budget, etc.) and moisture availability (associated with precipitation, snow hydrology and surface hydrological processes). Essentially, the northern ecotone (transitional boundary) of the forest is delineated by temperature (growing degree days) while the southern boundary is determined by moisture stress and fire frequency in central and western Canada, and by ecological competition with temperate deciduous forest to the east of the Great Lakes. Also, in most of Central Canada, agriculture has pushed up to the southern boundary of the forest. Most global change scenarios predict warming and drying in the mid-continent. A minimum of two intensive study areas is therefore desirable as these allow the observation of processes associated with the controlling factors (temperature in the north, moisture in the south) which are most likely to undergo significant change within the biome as a whole. Two study areas were selected in 1990 with final tower flux sites specified within them in 1992. The northern study area (NSA) is located close to Thompson, Manitoba while the southern study area, (SSA) 600 km away to the southwest but almost directly 'downhill' in terms of temperature and precipitation isolines is located near Prince Albert, Saskatchewan, just north of the large agricultural region that lies to the south of the forest.

Each study area covers a domain big enough to allow the acquisition of useful airborne flux measurements and satellite observations but small enough to conserve a reasonable density of surface instrumentation. Almost all of the land surface climatology, nutrient cycling and tropospheric chemistry process studies (i.e. flux towers and other flux measurement efforts) and most of the remote sensing validation work is being conducted within these areas. The distance between the two study areas is large enough to resolve the ecological gradient but small enough to permit the ferrying of research aircraft and specialized equipment. The scale domains are described further in section 1.3.

BOREAS started with a monitoring program in 1993 which will extend at least through 1996. This consists of satellite data acquisition, surface meteorological and radiation measurements from ten automatic meteorological stations (AMS) distributed throughout the region, and continuous flux/concentration measurements from two towers, one in each study area. This program has been punctuated by a series of field campaigns in which the bulk of the BOREAS scientists and specialized equipment were committed to the field to carry out coordinated studies.

In 1992, 85 science teams were selected out of over 240 proposals to take part in BOREAS. These were organized into six disciplinary groups for easier organization doing the field phase. The objectives of these six science groups are summarized below.

Airborne Fluxes and Meteorology (AFM): Four aircraft were used to measure turbulent fluxes; a sounding radar (profiler) and a Doppler cloud radar were also deployed. Ten mesometeorological stations and a dense array of upper air radiosounding stations operated over the region during 1994. The Global Telecommunications System was used to transmit data from this network to operational meteorological centers for assimilation. Several investigators, including some with strong links to these centers, are using mesoscale and global scale atmospheric models in their studies of surface-atmosphere interactions.

Hydrology (HYD): The HYD group is principally focused on the measurement of snow hydrology components to support remote sensing algorithm development, and has also worked on catchment hydrological processes in the SSA and NSA using precipitation gage networks, stream gages and a rain radar (SSA only). One team operated a program of almost continuous soil moisture measurements at the TF sites during the 1994 growing season.

Remote Sensing Science (RSS): The RSS group is developing linkages between optical and microwave remote sensing and boreal zone biophysical parameters at scales that include leaf, canopy and regional levels using field, aircraft and satellite-borne sensors and a range of radiative transfer models.

Staff Science (Staff): The science teams are supported by a staff of scientists and support contractors from the National Aeronautics and Space Administration (NASA); Atmospheric Environment Services (AES), Canada; the Canadian Center for Remote Sensing (CCRS), the School of Forestry, University of Wisconsin and the Canadian Forest Service. The BOREAS staff oversee the components of the project that require significant logistical effort, extended and/or routine monitoring work, or work that requires the particular expertise and resources of one of the participating agencies.

Staff Science (cont.)
In particular, the staff dealt with the organization of the field logistics (tower construction, tower supplies, etc.) and the day-to-day management of field operations. The staff monitoring program includes:

Automatic Meteorological Station Network
Upper Air Network
Hydrology, snow and soil moisture
Auxiliary site work
Biometry and allometry
Radiometric calibration
Standard gasses and gas calibration
Thermal radiance intercomparison
Global and Positioning System (GPS) facilities

The NASA staff are also responsible for implementing the BOREAS Information System (BORIS) which will serve as a data organization, distribution and archiving center for the project. All in all, some 300 people were working within or above the study areas during the growing season of 1994.

Terrestrial Ecology (TE): Over twenty teams are examining the biophysical controls on carbon, nutrient, water and energy fluxes for the major ecosystems in the boreal landscape and will develop models and algorithms to scale chamber measurements to stand, landscape, and regional scales. An important focus for the TE group is the measurement of components of the carbon cycle. A number of towers were installed in the study areas to facilitate access to the vegetation canopy for chamber measurements and other in-situ work.

Tower Fluxes (TF): Ten TF towers operated almost continuously during the growing season of 1994, measuring radiation, heat, water, CO_2 and in some cases CH_4 and other trace gas fluxes. Two of the sites, one in the NSA and one in the SSA have operated more-or-less continuously from the fall of 1993 onwards.

Trace Gas Biogeochemistry (TGB): Ten TGB teams use chamber measurements and other techniques to characterize the flux of trace gases between the soil and the atmosphere, including CO_2, CH_4 and non-methane hydrocarbons (NMHC's). The TGB group is also trying to quantify the long-term accumulation of carbon in boreal soils.

1.3 Study Area Descriptions and Logistics

Essentially, the northern ecotone of the forest is delineated by temperature (growing degree days) while the southern boundary is determined by moisture stress and fire frequency in central and western Canada, and by ecological competition with temperate deciduous forest to the east of the Great Lakes. Most global change scenarios predict warming and drying in the mid-continent. A minimum of two intensive study areas is therefore desirable as this would allow the observation of processes associated with the controlling factors (temperature in the north, moisture in the south) which are most likely to undergo significant change within the biome as a whole.

Each study area covers a domain big enough to allow the acquisition of useful airborne flux measurements and satellite observations but small enough to permit reasonable coverage with surface instruments. Almost all of the land surface climatology, nutrient cycling and tropospheric chemistry process studies (i.e. flux towers and other flux measurement efforts) and most of the remote sensing validation work was conducted within these areas. Ecological survey and remote sensing studies may also require some sampling within the whole domain along and normal to the growing degree day isolines (roughly corresponding to the productivity gradient) with particular concentration within and around the main sites. The definition and allocation of the auxiliary/process study sites was directed at defining the variability of surface states and processes and associated remote sensing signatures within and between the main sites. The distance between the two study areas is roughly 800 km: this is large enough to resolve the ecological gradient but small enough to permit the ferrying of research aircraft and specialized equipment between sites.

The scale domains are defined as follows:

Region: An area of roughly 1000 km by 1000 km covering a large portion of Saskatchewan and Manitoba. This is the domain of meteorological and satellite data acquisition and large-scale modeling. This is the domain of meteorological and satellite data acquisition and large-scale modeling.

Study Areas: These two areas are embedded within the region and are the focus of satellite and airborne remote sensing studies, airborne flux measurement and mesoscale modeling. The Southern Study Area (SSA) (11,170 km^2) is located north of Prince Albert, Saskatchewan, and the Northern Study Area (NSA) (8,000 km^2) lies west of Thompson, Manitoba.

Transect: This is the area connecting and including the NSA and SSA, running from Thompson, Manitoba to Prince Albert National Park (PANP), Saskatchewan. It is approximately 800 km long. It is mainly flown by aircraft, but there are some ground instruments positioned at meteorological sites along the way.

Modeling Sub-Areas: These are the test areas for modeling activities and gridded data products; They have the highest priority for airborne remote sensing studies and low-level airborne flux measurements. These sub-areas are located within the study areas.

Tower Flux (TF) Sites: These are sites within the study areas where flux measurement towers (TF sites) operate. The TF sites are located in the center of areas of around 1 km^2 of relatively homogenous vegetation cover, and are expected to measure fluxes representative of these vegetation types. Ten TF sites operated during the field campaigns. These primary sites were also the focus of many of the measurements made in BOREAS.

In the NSA there are the following flux towers:

- Beaver Pond (NSA-BP) — Flux tower on a small lake
- Fen (NSA-Fen) — Flux tower in a swampy wetland area
- Old Black Spruce (NSA-OBS) — Flux tower in old growth black spruce (wet soil)
- Old Jack Pine (NSA-OJP) — Flux tower in an area of old Jack Pine (dry soil)
- Young Jack Pine (NSA-YJP) — Flux Tower in an area of young Jack Pine (dry soil)

The SSA has the following flux towers:

- Fen (SSA-Fen) — Flux tower in a swampy wetland area
- Old Aspen (SSA-OA) — Flux tower in an area of old growth aspen trees
- Old Black Spruce (SSA-OBS) — Flux tower in old growth black spruce (wet soil)
- Old Jack Pine (SSA-OJP) — Flux Tower in an area of old Jack Pine (dry soil)
- Young Aspen (SSA-YA) — Flux tower in an area of young aspen trees
- Young Jack Pine (SSA-YJP) — Flux Tower in an area of young Jack Pine (dry soil)

Besides the flux tower sites there are sites with canopy access towers. The NSA sites are:

- Upland Black Spruce (NSA-UBS) — Canopy access tower in a small stand of spruce
- Old Aspen (NSA-OA) — Canopy access tower in a large stand of old Aspen trees

The SSA has a canopy access tower site at:

- Mixed Growth TE Site (SSA-Mix) — TE canopy tower in a mixed forest

Auxiliary and Process Study Sites: Approximately 80 auxiliary and process study sites, some located within the TF sites, most of the others elsewhere within the study areas, were used for investigator studies or correlative targets for remote sensing investigations. A few of these sites were foci for carbon cycle studies which incorporated measurements of leaf physiology, litterfall and soil CO_2 flux. The majority of the sites serve as remote sensing targets and were visited by teams during the field year (1994) who collected a common set of biometric measurements: leaf area index, crown closure, stem area density, etc. These data will be used to improve our ability to interpret satellite and airborne remote sensing data into biophysical and ecological parameters. These sites represent mostly pure types of vegetation coverage, providing a range of stand characteristics to extend the observations of the primary sites. The auxiliary sites were assigned names based on location in the BOREAS operational grid; the first four characters describe the location in the grid and the final character describes the cover type: T for tower site, A for aspen, M for mixed, P for pine, S for spruce, C for clearing. The operational grid locations are based on letters locating a 10 km by 10 km grid and numbers to locate a 1 km by 1 km grid within that 10 km by 10 km cell. The grid coordinates are expressed in the order northern grid, eastern grid. A list of auxiliary sites is provided in table 1.3.1.1.

Table 1.3.1.1 BOREAS Auxiliary Sites

Site Name	Location (SSA)	Ground Cover
B9B7A	SSA AIM-13	Aspen
D9G4A	SSA AMH-16	Aspen
D9I1M	SSA-Mix (TE Tower)	Mix
G9I4S	SSA BDL-20	Black Spruce
I2I8P	SSA JIH-7	Jack Pine
G6K8S	SSA BMH-9	Black Spruce
G9L0P	SSA JMH-10	Jack Pine
A2P	Nisbet	
E7B7C	SSA HYD-5 Tower, Clearing (Flux Tower)	Snow
A1A	Batoche	
E7C3A	SSA AMM-12	Aspen
E6C5W	SSA HYD-5 Tower, Lake (Flux Tower)	Ice
H3D1M	SSA Auxiliary Site	Mix
H2D1M	SSA Auxiliary Site	Mix
H2D1S	SSA Auxiliary Site	Black Spruce
H1E4S	SSA Auxiliary Site	Black Spruce
D6H4A	SSA Near Snowcastle	Aspen
D0H6S	SSA BMM-1	Black Spruce
G4I3M	SSA MW-1	Mix
G2I4S	SSA BIH-B	Black Spruce
F5I6P	SSA JIH-4	Jack Pine
F7J0P	SSA JMH-5	Jack Pine
F7J1P	SSA JMH-A2	Jack Pine
G7K8P	SSA JMM-8A	Jack Pine
G4K8P	SSA JMM-5	Jack Pine
G1K9P	SSA JMM-6	Jack Pine
D6L9A	SSA ADH-2	Aspen
G2L7S	SSA B?L	Black Spruce
G8L6P	SSA JDM-8	Jack Pine
F1N0M	SSA Jail Site	Mix

Site Name	Location (NSA)	Ground Cover
T9Q8P	NSA JIL-1	Jack Pine
T6R5S	NSA-TEBS (BIH-9) (TE Tower)	Black Spruce
U6W5S	NSA BIL-21	Black Spruce
W0Y5A	NSA AIM-20	Aspen
T8S9P	NSA JDH-3	Jack Pine
T8T1P	NSA JDM-1	Jack Pine
T7T3S	NSA BML-21	Black Spruce
T6T6S	NSA BIL-2	Black Spruce
P7V1A	NSA AMH-1	Aspen
T4U5A	NSA AIM-1	Aspen
Q1V2M	NSA MW-2	Mix
Q3V2A	NSA Auxiliary Site	Aspen
Q3V3P	NSA P-JM-1	Jack Pine
T4U8S	NSA BIM-1	Black Spruce
T3U9S	NSA BIM-12	Black Spruce
T4U9S	NSA BIH-1	Black Spruce
R8V8A	NSA T-AM-1	Aspen
S8W0S	NSA Auxiliary Site	Black Spruce
T0W1S	NSA Auxiliary Site	Black Spruce
U5W5S	NSA Auxiliary Site	Black Spruce
V5X7A	NSA AIH-30	Aspen

1.4 Duration and Timing of Field Campaigns

The organization of BOREAS-94 was to concentrate efforts during specific field campaign periods. Most aircraft flights occurred during the field campaigns. BOREAS-94 began with a winter focused field campaign (FFC-W) which consisted mostly of HYD and RSS groups studying winter processes. FFC-W was followed by a thaw campaign (FFC-T) aimed at studying the forest during this period. The ground teams kept up a full schedule of activities from beginning of IFC-1 through and in some cases beyond the end of IFC-3. Most of the tower flux sites were operating during this entire period along with associated soil moisture, ecological, and trace gas studies. Throughout the field campaigns, a program of science meetings allowed the scientists to share their findings and continuously influence the execution of the project. Towards the end of IFC-3, a series of 'golden days' (one set per field campaign per study area) were identified by the BOREAS staff and participating scientists. These periods are to be the initial foci for data set preparation and submission as they include good time-series of ground team data combined with a high density of successful airborne remote sensing and flux measurement missions.

The dates of the field campaigns and golden days are:

IFC	Duration	SSA Golden Days	NSA Golden Days
FFC-W	February 2-18, 1994	February 5-9	February 5-9
FFC-T	April 12-May 2, 1994	April 17, 19	April 17, 20
IFC-1	May 24-June 16, 1994	June 5-9	June 5-12
IFC-2	July 19-August 10, 1994	July 21-25	August 3-8,
IFC-3	August 30-September 19, 1994	September 10-17	September 5-10, 17

1.5 Satellites and Aircraft

1.5.1 Aircraft Mission Plans

Each aircraft mission in BOREAS was assigned a four letter identifier which includes information on:

First Letter: The type of mission (remote sensing or flux measurement)
Second Letter: Aircraft type/identification
Third Letter: Specific mission objective
Fourth Letter: Mission target area

The table below provides a quick reference for decoding BOREAS aircraft mission identifiers. For example, 'RC-MN' translates to:

R: Remote sensing aircraft
C: C-130
M: Mapping mission
N: NSA

First Letter Mission Type	Second Letter Aircraft Type	Third Letter Mission Objective	Fourth Letter Location
R: Remote Sensing	A: Aerocommander C: C-130 D: DC-8 E: ER-2 F: DC-3 H: Helicopter P: Chieftain T: Twin Otter V: CV-580	B: Radar or microwave baseline D: Like B, predawn I: Like B, 25 degree incidence M: Mapping R: Regional S: Snow survey T: Tower or aux site (optical) U: Special snow survey (ER-2) W: Soil moisture survey	N: NSA S: SSA T: Transect
F: Flux Measurement	L: LongEZ K: Kingair E: Electra T: Twin Otter	C: Candle Lake Run F: flights of two G: Grids/stacks H: Stacks/tees L: Regional/mini transect P: Budget box pattern R: Regional transect T: TF site specific run Z: Low-level routes	N: NSA S: SSA T: Transect

BOREAS Aircraft

Aircraft Type	BOREAS ID	Tail Number	Science Team	Equipment	Primary target/ Role	Home Institution
Remote Sensing Aircraft (R-prefix on BOREAS Identifier)						
ER-2	RE	NASA-706	RSS-18	Airborne Visible Infrared Imaging Spectrometer (AVIRIS)	Vegetation properties	NASA/Ames Research Center
			HYD-2	MODIS Airborne Simulator (MAS) in FFC-W.	Snow	
C-130	RC	NASA-707	RSS-2	Advanced Solid State Array Spectroradiometer (ASAS)	Vegetation properties.	NASA/Ames Research Center
			Staff	Thematic Mapper Simulator (TMS), MODIS Airborne Simulator (MAS), Airborne Tracking Sun photometer (ATSP)	Surface and atmospheric radiative transfer (SART)	
			RSS-20	Polarization and Directionality of the Earths Radiation (POLDER)	Vegetation properties.	
Piper Chieftain	RP	C-GCJX	RSS-19	Compact Airborne Spectrographic Imager (CASI).	Vegetation properties, SART	York Univ. /Institute Space & Terrest. Sci.
Helicopter (UH-1)	RH	NASA-415	RSS-3,13, 20	SE-590, Barnes Multiband Modular Radiometer, C-band Scatterometer, ATSP, POLDER.	Vegetation and surface properties	NASA/Wallops Flight Facility
DC-8	RD	NASA-717	RSS-15,16, 17	Airborne Synthetic Aperture Radar (AIRSAR); P, L, C-band; fully polarimetric.	Vegetation & soil properties, Soil Moisture	NASA/Ames Research Center
CV-580	RV	C-GRSC	TE-16	Airborne Synthetic Aperture Radar (CCRS-SAR); X and C band, polarimetric.	Vegetation & soil properties, Soil Moisture	Canada Centre for Remote Sensing (CCRS)
Twin Otter (DH-6)	RT	C-FPOK	HYD-2	Microwave radiometers; 18, 37, 92 GHz; H and V.	Snow	National Research Council, Canada
Aero-commander	RA	N-51RF	HYD-6	Gamma ray equipment.	Snow and soil moisture	NOAA, National Weather Service
Flux Measurement Aircraft (F-prefix on BOREAS identifier)						
Electra	FE	N308D	AFM-3	Flux; H, LE, CO2, LIDAR, Limited atmospheric chemistry.	Local and regional flux, chemistry	National Center for Atmospheric Research, CO
Kingair	FK	N2UW	AFM-2	Flux; H, LE, CO2	Local and regional (5-600 km) flux	University of Wyoming
Twin Otter (DH6)	FT	C-FPOK	AFM-4	Flux; H, LE, CO2, O3	Local and regional flux	National Research Council, Canada
LongEZ	FL	N3R	AFM-1	Flux; H, LE, CO2	Local scale (5-60 km) flux	NOAA, Oak Ridge, TN

Aircraft Participation in BOREAS

Aircraft Type	Equipment	Field Campaign Participation					
	Remote Sensing Aircraft	IFC-93	FFC-W	FFC-T	IFC-1	IFC-2	IFC-3
ER-2	Airborne visible infrared Imaging spectrometer (AVIRIS)		■	■	■	■	■
	MODIS Airborne Simulator (MAS)		■				
C-130	Advanced Solid State Array Spectroradiometer (ASAS)			■	■	■	■
	Thematic Mapper simulator (TMS),			■	■	■	■
	MODIS Airborne Simulator (MAS),			■	■	■	■
	Airborne Tracking Sun photometer (ATSP)			■	■	■	■
	Polarization and Directionality of the Earth's Radiation (POLDER)			■	■	■	■
Piper Chieftain	Compact Airborne Spectrographic Imager (CASI).		■	■	■	■	■
Helicopter (UH-1)	Spectron Electronics-590, Barnes Multiband Modular Radiometer, C-band Scatterometer, ATSP, POLDER.				■	■	■
DC-8	Airborne Synthetic Aperture Radar (AIRSAR); P, L, C-band; fully polarimetric.	■		■	■	■	■
CV-580	Airborne Synthetic Aperture Radar (CCRS-SAR); X and C band, polarimetric.			■		■	■
Twin Otter (DH-6)	Microwave radiometers; 18, 37 and 92 GHz; H and V.		■				
Aero-commander	Gamma ray equipment.		■			■	■
	Flux Measurement Aircraft						
Electra	Flux; H, LE, CO2, LIDAR Limited atmospheric chemistry.				■	■	■
Kingair	Flux; H, LE, CO2				■	■	■
Twin Otter (DH-6)	Flux; H, LE, CO2, O3	May 93			■	■	■
LongEZ	Flux; H, LE, CO2	■			■	■	■

Mission Summaries for BOREAS Aircraft

Remote Sensing Aircraft

Aircraft	Mission Identifier	Duration (hours)	Mission Summary
C-130	RC-SN	3.5	NSA TF sites during FFC-T(snow)/ASAS
	RC-SS	3.5	SSA TF sites during FFC-T(snow)/ASAS
	RC-TN	3.5	NSA TF sites (IFCs)/ASAS, MAS, (IFC-2), POLDER, TMS
	RC-TS	4.5	SSA TF sites (IFCs)/ASAS, MAS, (IFC-2), POLDER, TMS
	RC-MN	2.0	NSA Mapping; TMS, POLDER, MAS, (IFC-2)
	RC-MS	3.0	SSA Mapping; TMS, POLDER, MAS, (IFC-2)
	RC-RT	2.0	Transect between SSA & NSA aligned with AFM Regional transect; TMS, MAS, (IFC-2)
DC-8	RD-MS	3.0	AIRSAR SSA Modeling Grid Mosaic
	RD-MN	2 .0	AIRSAR NSA Modeling Grid Mosaic
	RD-RT	1 .0	AIRSAR SSA to NSA AFM Transect
	RD-BS	1.7	AIRSAR SSA Baseline
	RD-BN	1 .0	AIRSAR NSA Baseline with 43° angle
	RD-IS	1.0	AIRSAR SSA Baseline with 25° angle
	RD-DS	1.7	AIRSAR SSA Baseline pre-dawn
CV-580	RV-BS	3.0	SAR over SSA
	RV-RT	3.0	SAR SSA to NSA AFM transect
	RV-BN	2.0	SAR over NSA
DH-6	RT-SN	3.0	Snow microwave, NSA (FFC-W)
(Twin Otter)	RT-SS	3.0	Snow microwave, SSA (FFC-W)
	RT-ST	3.0	Snow microwave, transect (FFC-W)
ER-2	RE-MS	6.0	Mapping of SSA, AVIRIS
	RE-MN	8.0	Mapping of NSA, transect, AVIRIS
	RE-US	6.0	Snow Survey, SSA, MAS (FFC-W)
	RE-SS	6.0	Snow lines, SSA, AVIRIS (FFC-T)
	RE-SN	6.0	Snow lines, NSA, AVIRIS (FFC-T)
Chieftain	RP-TS	2.0	Mapping of SSA TF and aux sites
	RP-TN	2.0	Mapping of NSA TF and aux sites
	RP-SS	2.0	Snow lines SSA
	RP-SN	2.0	Snow lines NSA
	RP-RT	3.5	Regional transect, line segments
DC-3	RF-TS	5.0	Mapping of SSA TF sites
	RF-TN	3.0	Mapping of NSA TF sites
Helicopter	RH-TS	2.3	TF, aux site optical mission, SSA
	RH-BS	2.3	Microwave scatterometer mission, SSA
	RH-TN	2.3	TF, aux site optical mission, NSA
	RH-BN	2.3	Scatterometer mission, NSA
Aerocommander	RA-SS	4.0	Gamma snow survey, SSA
	RT- ST	4.0	Gamma snow survey, transect
	RA-SN	4.0	Gamma snow survey, NSA
	RA-WS	4.0	Gamma soil moisture survey, SSA
	RA-WT	4.0	Gamma soil moisture survey, transect

Mission Summaries for BOREAS Aircraft (times are approximate)

Flux Aircraft

Aircraft	Mission Identifier	Duration (hours)	Mission Summary
LongEZ	FL-CS	2.0	Candle Lake runs (SSA)
	FL-TS	1.0-1.5	Site specific (TF site) (SSA)
	FL-LS	3.0	Mini, meso transect (SSA)
	FL-GS	3.0	Grids and stacks (SSA)
	FL-FS	0.5-1	Flights of two (SSA)
	FL-ZS	0.3	Low level routes (SSA)
DH-6	FT-CS	2.0	Candle Lake runs
(Twin Otter)	FT-TS,N	1.0-1.5	Site specific (TF site)
	FT-LS,N	1.5-2.5	Mini, meso transect (SSA, NSA)
	FT-GS,N	2.5-3.0	Grids and stacks (SSA, NSA)
	FT-PS,N	2.5-3.0	Budget box pattern(SSA, NSA)
	FT-HS,N	2.5-3.0	Stacks and Tees (SSA, NSA)
	FT-FS,N	0.5-1.0	Flights of two (SSA, NSA)
	FT-ZS	0.2	Low level routes (SSA)
King Air	FK-CS	1.5	Candle Lake runs
	FK-LS,N	1.0-2.0	Mini, meso transect (SSA, NSA)
	FK-GS,N	1.0-2.0	Grids and stacks (SSA, NSA)
	FK-PS,N	2.0-3.0	Budget box pattern(SSA, NSA)
	FK-HS,N	2.0-3.0	Stacks and Tees (SSA, NSA)
	FK-FS,N	2.0-3.0	Flights of two (SSA, NSA)
	FK-ZS	0.2	Low level routes (SSA)
Electra	FE-CS	1.5	Candle Lake runs
	FE-RT	6.0	Regional transect
	FE-LS,N	1.0-2.0	Mini, meso transect (SSA, NSA)
	FE-FS,N	0.5-1.0	Flights of two (SSA, NSA)

Satellite Instrument Information

Satellite	Instrument/Band	Bandpass (50% RSR)(μm)	Spatial Resolution	Repeat/Time
ERS-1	C-band (23° incidence)	NA	30 m (high)	Monthly
	VV polarization		100 m (low)	Weekly
GOES	Visible		1 km	48 per day
	Infrared		4 km	48 per day
	Water vapor		8 km	24 per day
Landsat-5	MSS/1	0.497 - 0.607	78 m	1 per 10 days
	MSS/2	0.603 - 0.615	78 m	
	MSS/3	0.704 - 0.814	78 m	
	MSS/4	0.809 - 1.036	78 m	
	TM/1	0.451 - 0.521	30 m	
	TM/2	0.526 - 0.615	30 m	
	TM/3	0.622 - 0.699	30 m	
	TM/4	0.771 - 0.905	30 m	
	TM/5	1.564 - 1.790	30 m	
	TM/6	10.45 - 12.46	120 m	
	TM/7	2.083 - 2.351	30 m	
NOAA-12	AVHRR/1	0.570 - 0.699	1.1 km	2 per day
	AVHRR/2	0.714 - 0.983	1.1 km	
	AVHRR/3	3.525 - 3.931	1.1 km	
	AVHRR/4	10.33 - 11.25	1.1 km	
	AVHRR/5	11.39 - 12.34	1.1 km	
NOAA-14	AVHRR/1	0.570 - 0.699	1.1 km	2 per day
	AVHRR/2	0.714 - 0.983	1.1 km	
	AVHRR/3	3.525 - 3.931	1.1 km	
	AVHRR/4	10.33 - 11.25	1.1 km	
	AVHRR/5	11.39 - 12.34	1.1 km	
SPOT-2	HRV/1	0.506 - 0.591	20 m	1 per 3 to 5 days
	HRV/2	0.627 - 0.670	20 m	
	HRV/3	0.792 - 0.884	20 m	
	HRV/PAN	0.525 - 0.706	10 m	
SPOT-3	HRV/1	0.506 - 0.591	20 m	1 per 3 to 5 days
	HRV/2	0.627 - 0.670	20 m	
	HRV/3	0.792 - 0.884	20 m	
	HRV/PAN	0.525 - 0.706	10 m	

NSA Satellite and Aircraft Coverage

Site	OBS					OJP					YJP					Fen					BP				
FFC/IFC	**W**	**T**	**1**	**2**	**3**	**W**	**T**	**1**	**2**	**3**	**W**	**T**	**1**	**2**	**3**	**W**	**T**	**1**	**2**	**3**	**W**	**T**	**1**	**2**	**3**
Platform/Sensor																									
AVHRR		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X
ERS	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
GOES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Landsat	▓		▓			▓		▓			▓		▓			▓		▓			▓				
SIR-C/XSAR		█			█		█			█		█			█		█			█		█			█
SPOT		▓	█		▓		▓	█		▓		▓	█		▓		▓	█		▓		▓	█		█
ER2 - AOCI				X					X					X					X					X	
- AVIRIS		█	█	█	█		█	█	█	█		█	█	█	▓		█	█	█	█					
- Daedalus TMS																									
- Photography		X	X	X			X	X	X			X	X	X			X	X	X			X	X	X	
C130 - ASAS		█		█	░		█		█	█		█			█		█			█					█
- MAS				X					X					X					X					X	
- NS001 TMS		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X
- Polder																									
- TIMS																									
- Photography		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X
Chieftain - CASI	█	█	█	█	█	█	█	█	█	█	█	█	█	█	█		█	█	█	█			▓	▓	▓
CV580 - SAR		X	X				X	X				X	X				X	X				X	X		
DC8 - AirSAR		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X
- Photography		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X
Helicopter - MMR			X	X	X			X	X	X			X	X	X			X	X	X			X	X	X
- Polder			X	X	X			X	X	X			X	X	X			X	X	X			X	X	X
- SE590			X	X	X			X	X	X			X	X	X			X	X	X			X	X	X
- Photography																									

	Key
X	Data available, no quality check
█	Multiple good looks
▓	One good look
░	Hazy or cloudy looks only

SSA Satellite and Aircraft Coverage

Site	OA					YA					OBS					OJP					YJP					Fen				
FFC/IFC	**W**	**T**	**1**	**2**	**3**	**W**	**T**	**1**	**2**	**3**	**W**	**T**	**1**	**2**	**3**	**W**	**T**	**1**	**2**	**3**	**W**	**T**	**1**	**2**	**3**	**W**	**T**	**1**	**2**	**3**
Platform/Sensor																														
AVHRR		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X
ERS	■	■	■	■	■			■	■	■	■	■	■	■	■			■	■	■			■	■	■			■	■	■
GOES	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Landsat	▒				▒	▒				■	░				■	▒	▒	▒	░	■	▒	▒	▒	░	■	▒	▒	▒	░	■
SIR-C/XSAR		■			■		■			■		■			■		■			■		■			■		■			■
SPOT		▒	▒	▒	▒		░	▒				░	▒	▒	■		▒	■	▒	■		▒	■	▒	■		▒	■	▒	■
ER2 - AOCI				X					X					X					X					X					X	
- AVIRIS		■		■			■		▒	▒		■		▒	■		■		▒	■		■		▒	■		▒		▒	
- Daedalus TMS																														
- Photography		X		X	X		X		X	X		X		X	X		X		X	X		X		X	X		X		X	X
C130 - ASAS		■	■	░	■				■			■	■	░	■		■	■	■	▒			■	▒	░			■	■	■
- MAS				X					X					X					X					X					X	
- NS001 TMS		X	X	X	X				X			X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X
- Polder			X	X				X	X				X	X				X	X				X	X				X	X	
- TIMS																														
- Photography		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X
Chieftain - CASI	■	■	■	■	■		X	X	X	X	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
CV580 - SAR				X					X					X					X					X					X	
DC8 - AirSAR		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X
- Photography		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X		X	X	X	X
Helicopter - MMR			X	X	X			X	X	X			X	X	X			X	X	X			X	X	X			X	X	X
- Polder					X					X					X					X					X					X
- SE590			X	X	X			X	X	X			X	X	X			X	X	X			X	X	X			X	X	X
- Photography																														

	Key
X	Data available, no quality check
■	Multiple good looks
▒	One good look
░	Hazy or cloudy looks only

2.0 Experiment Execution

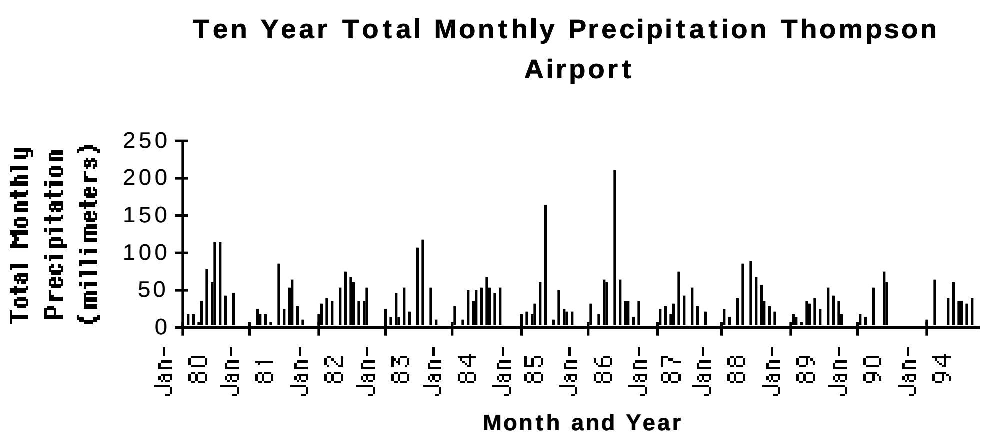
This section describes the long term and short term environmental conditions at the study areas and provides information on the activities of aircraft and investigators during the field campaigns.

2.1 Environmental Conditions

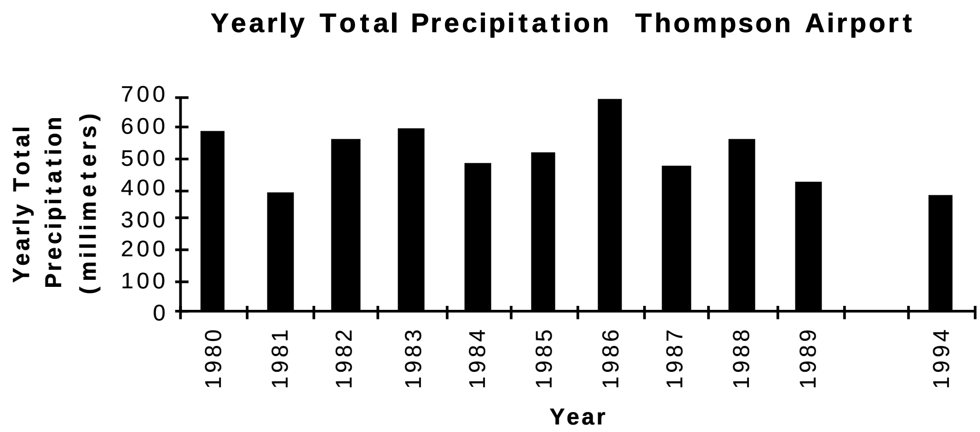
2.1.1 Climatology

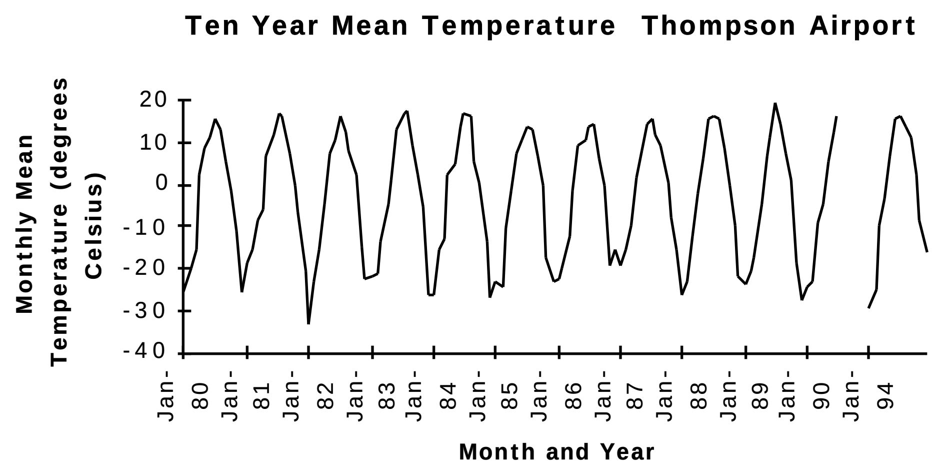
Climatologically, 1994 was not a normal year for the BOREAS region. 1994 set a new record for the longest frost-free period at Prince Albert National Park; the last spring frost was recorded on 9 May and the first full frost occurred on 7 October giving a frost-free period of 150 days, which may be compared to the previous record of 125 frost-free days in 1988. At the same time, the NSA experienced one of the driest years on record. The following plots show conditions over a ten year period to provide a context for what was experienced in BOREAS. The data plotted here come from AES automated stations with the 1994 SRC station data added.

Conditions Over a Ten-Year Period For Thompson Airport (NSA)

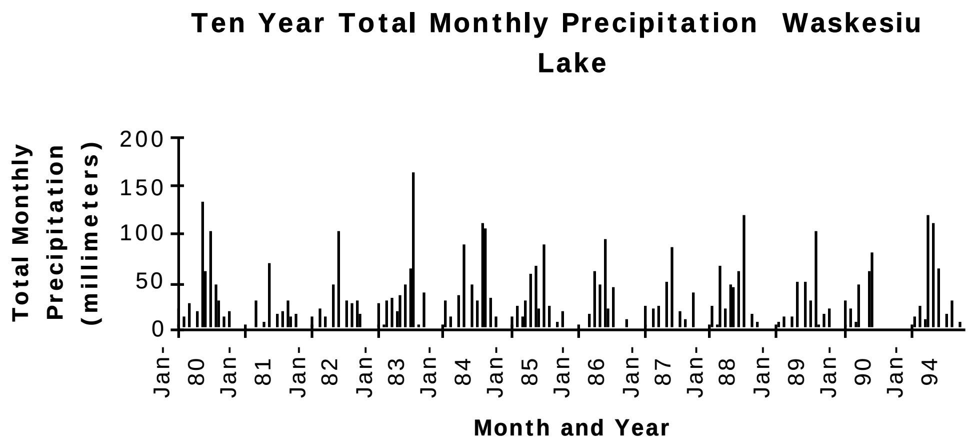


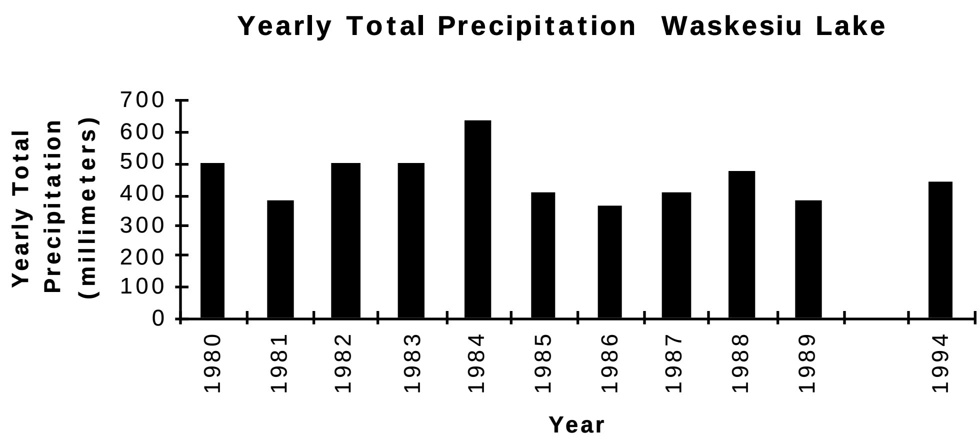
Conditions Over a Ten-Year Period For Thompson Airport (NSA) (cont.)

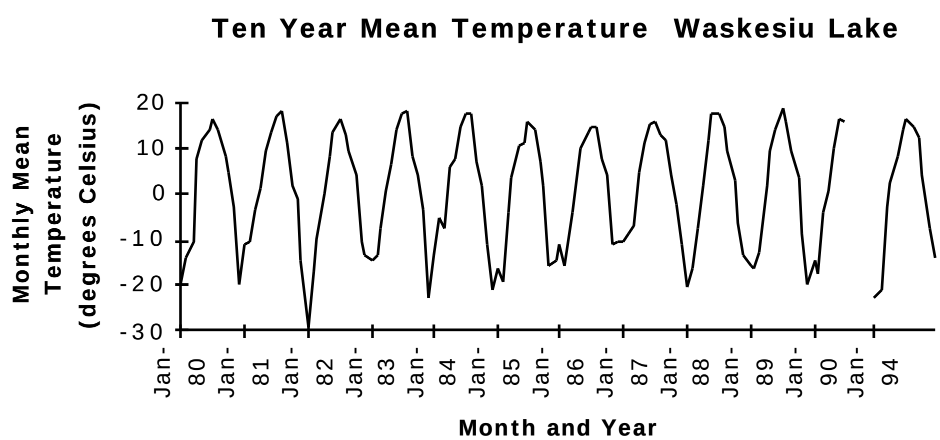




Conditions Over a Ten-Year Period for Waskesiu Lake (SSA)



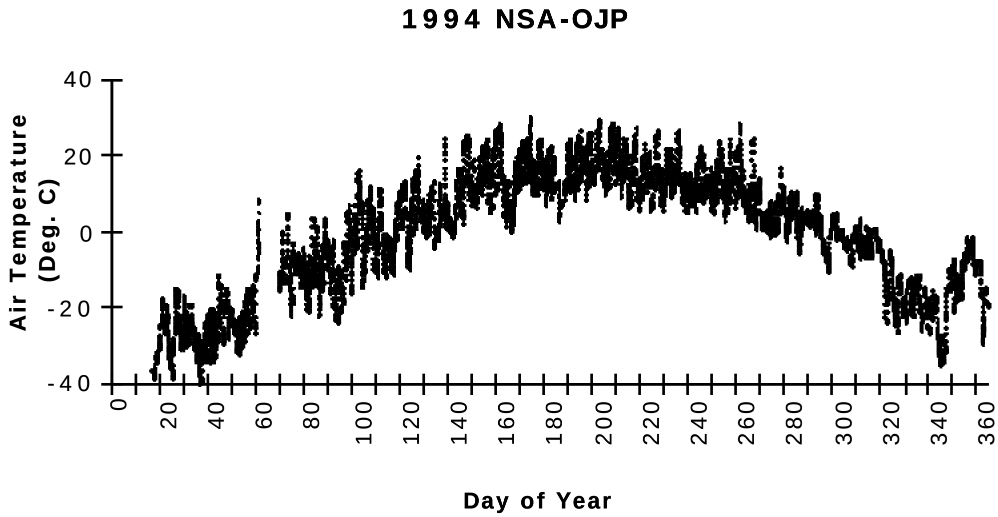


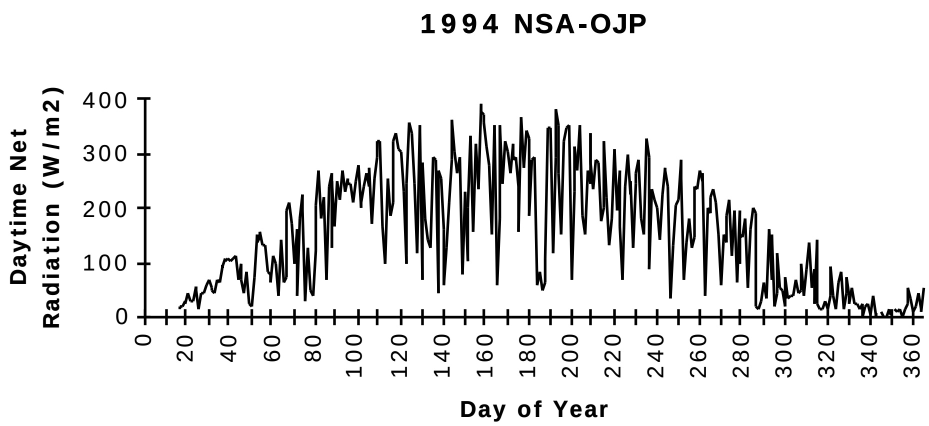


2.1.2 Meteorology

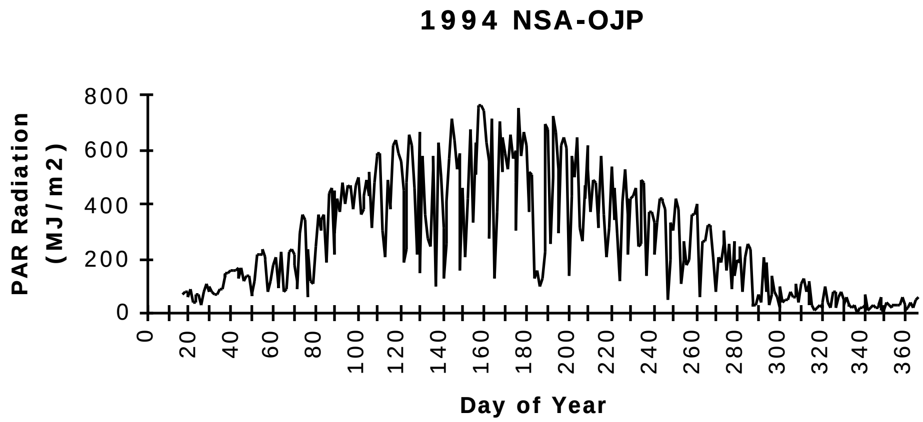
The following figures show the meteorological conditions at the SRC meteorological stations for 1994 at the BOREAS study areas.

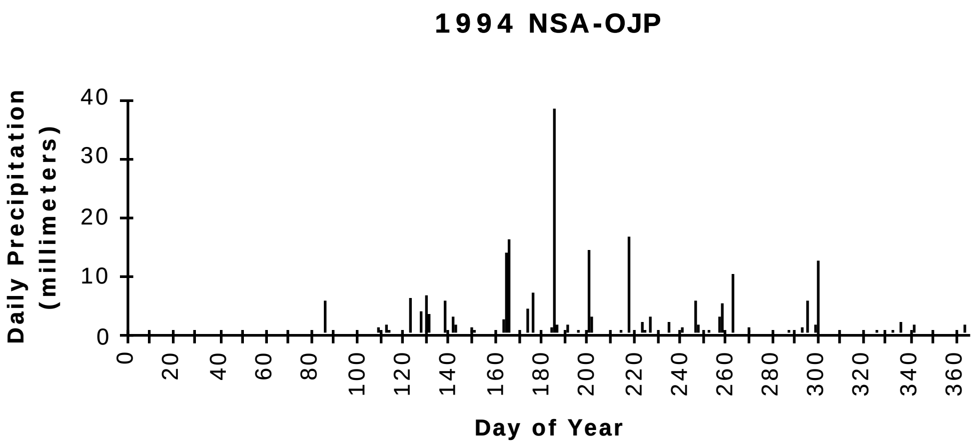
Conditions in 1994 at NSA Old Jack Pine

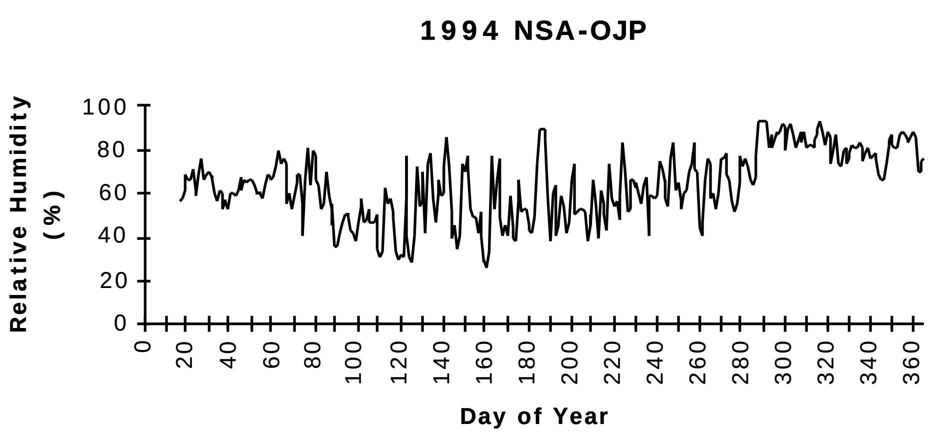




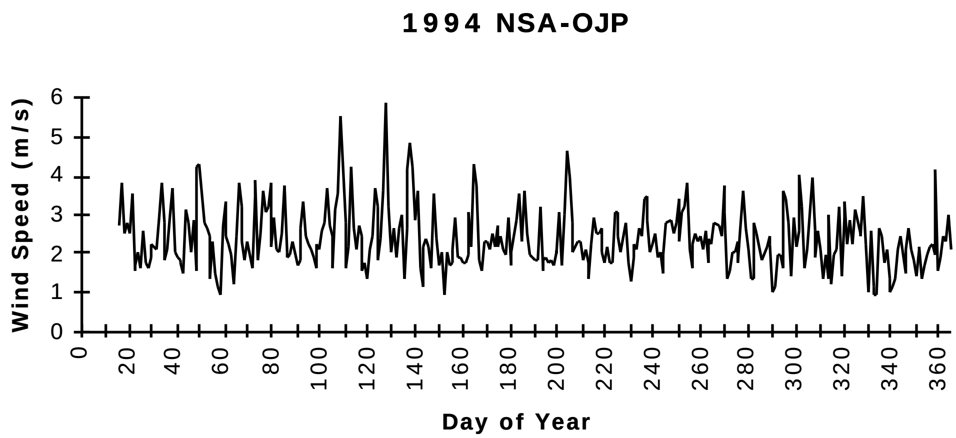
Conditions in 1994 at NSA Old Jack Pine (cont.)

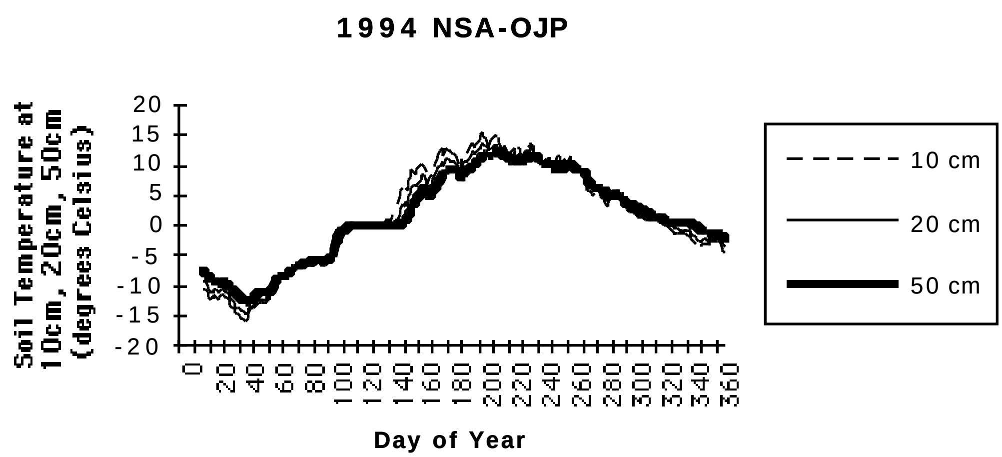




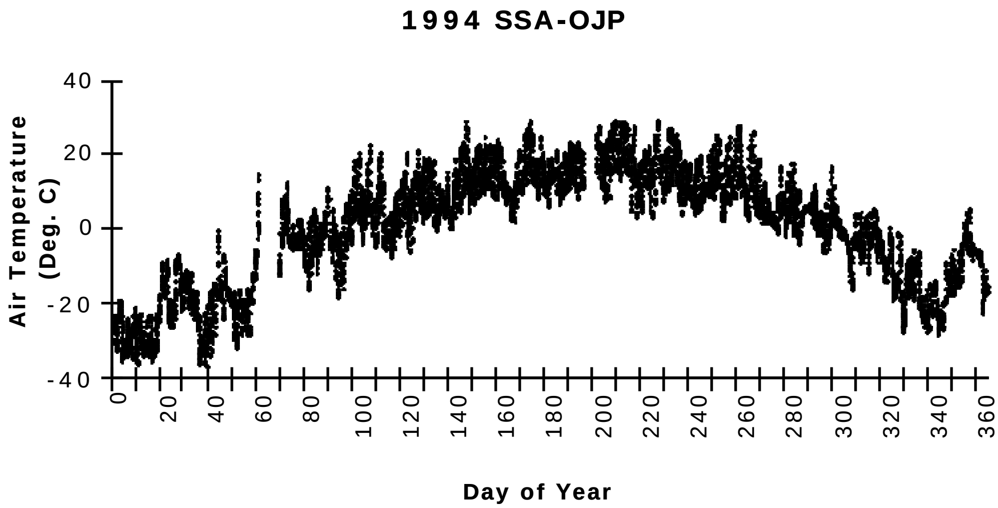


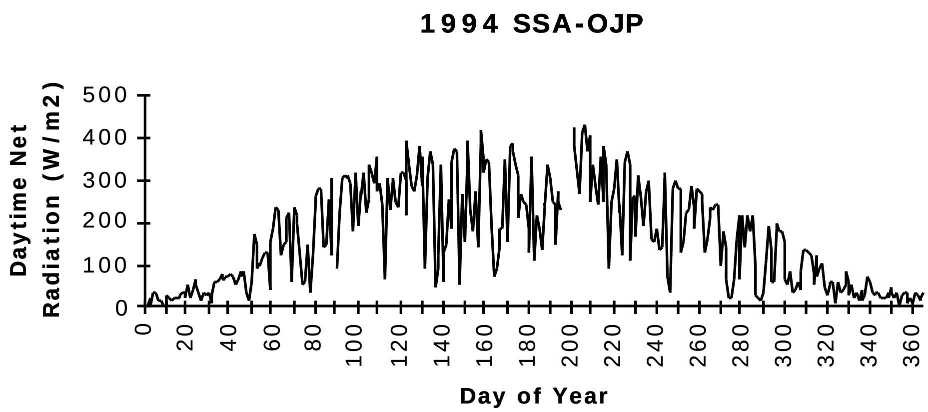
Conditions in 1994 at NSA Old Jack Pine (cont.)

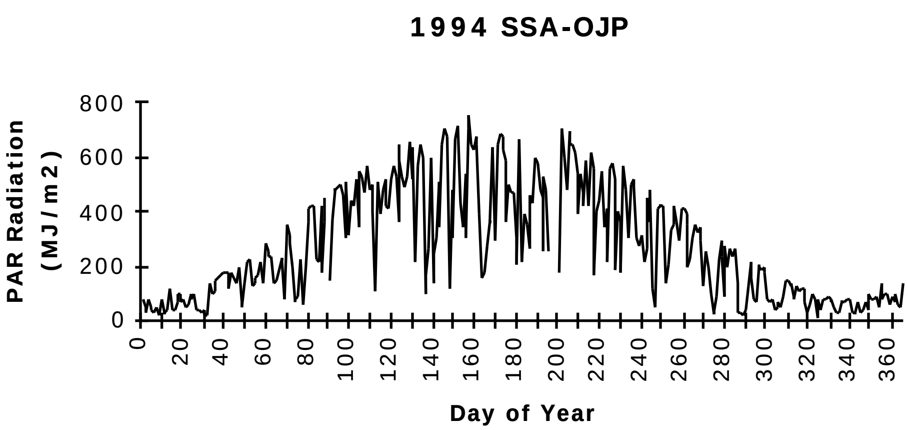




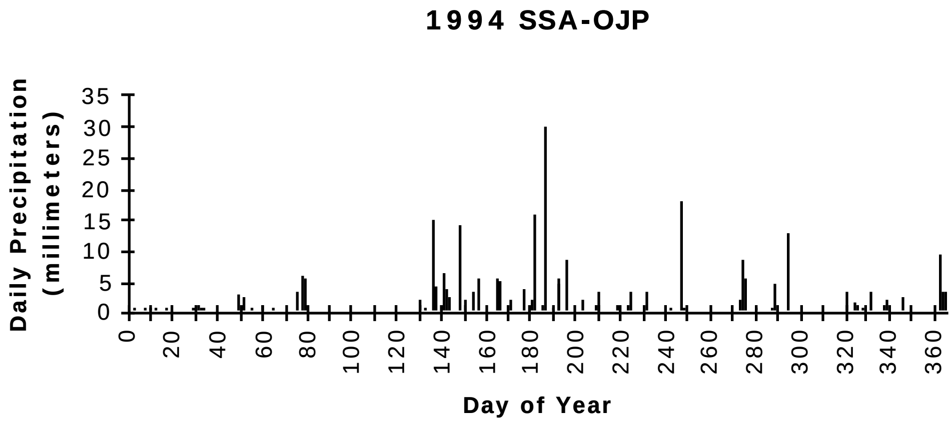
Conditions in 1994 at SSA Old Jack Pine

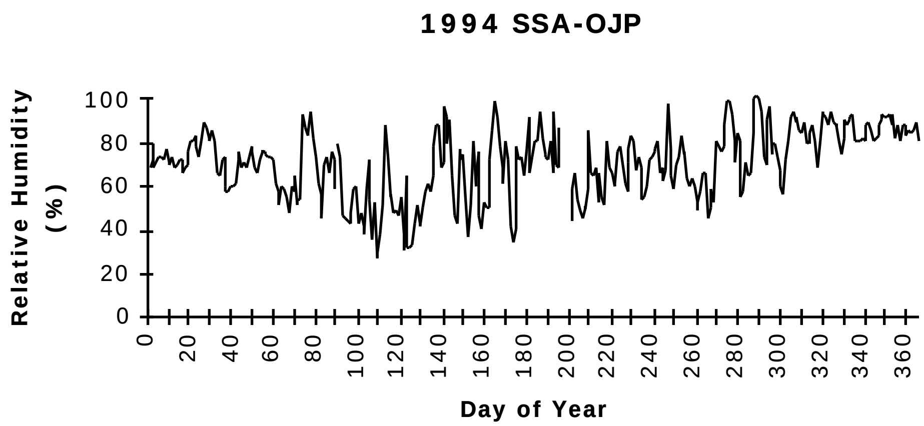


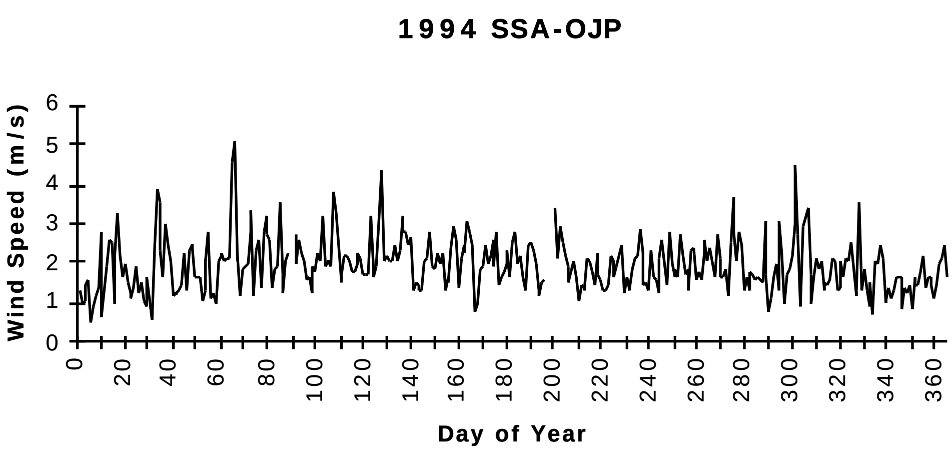




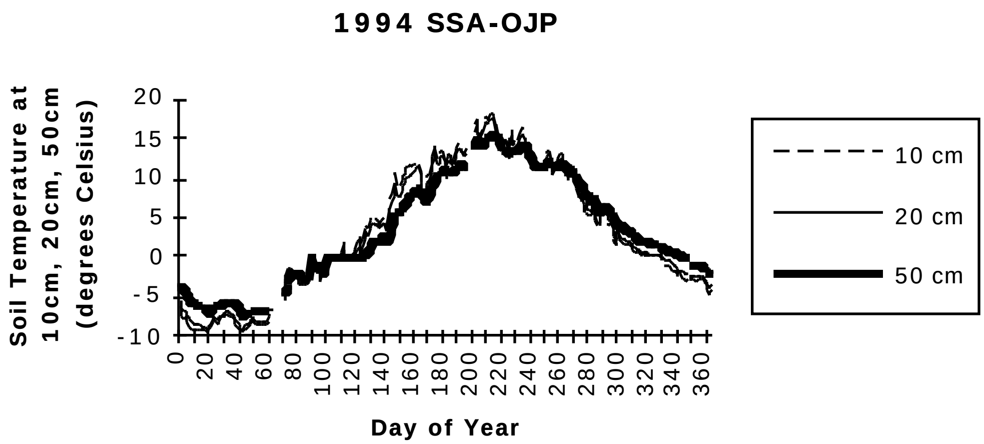
Conditions in 1994 at SSA Old Jack Pine (cont.)





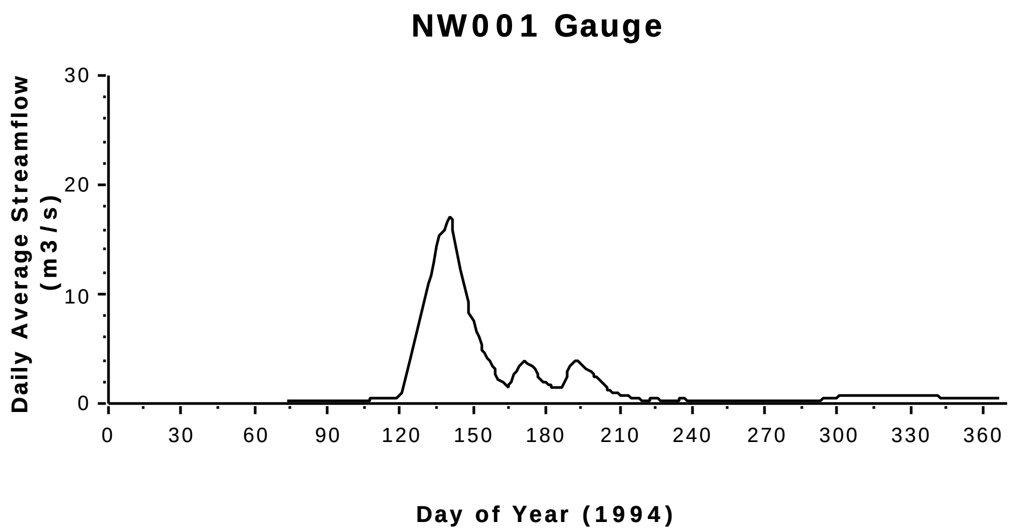


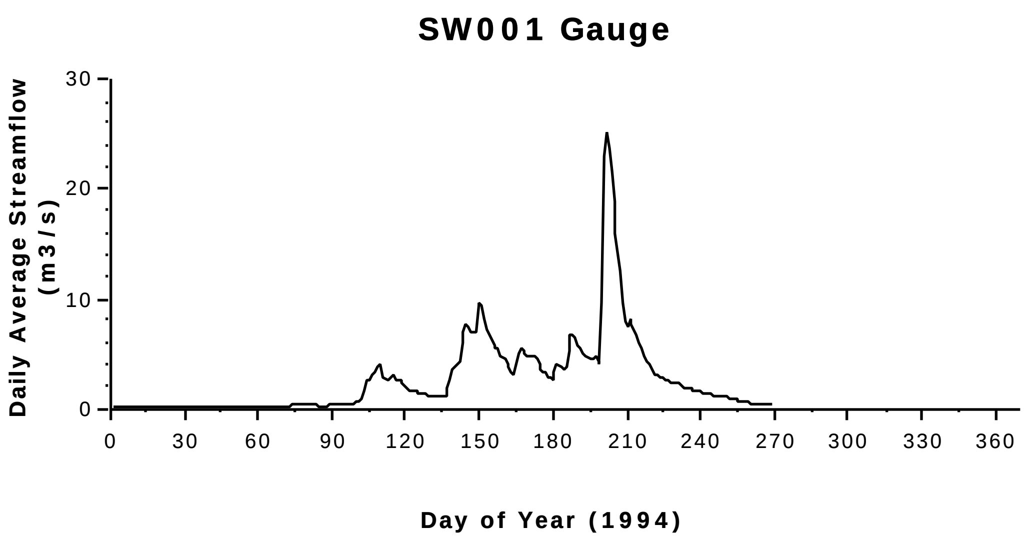
Conditions in 1994 at SSA Old Jack Pine (cont.)



2.1.3 Hydrology

In BOREAS stream gauges were installed to provide a reasonable estimate of the total surface and subsurface runoff from the White Gull Creek and Sapochi River watersheds during the study period. The NW001 gauge was on a tributary to the Sapochi River in the NSA and the SW001 gauge was on White Gull Creek in the SSA. The stream gauge at SW001 was chosen by HYD-9 Canada before the BOREAS project. During the project, the Environment Canada Water Survey operated the NW001 gauge.





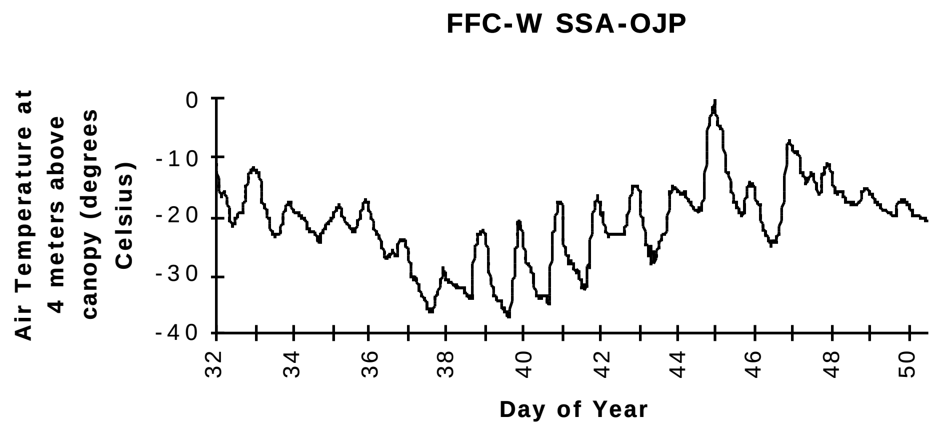
2.2 Overview of Conditions and Data Acquisition During Field Campaigns

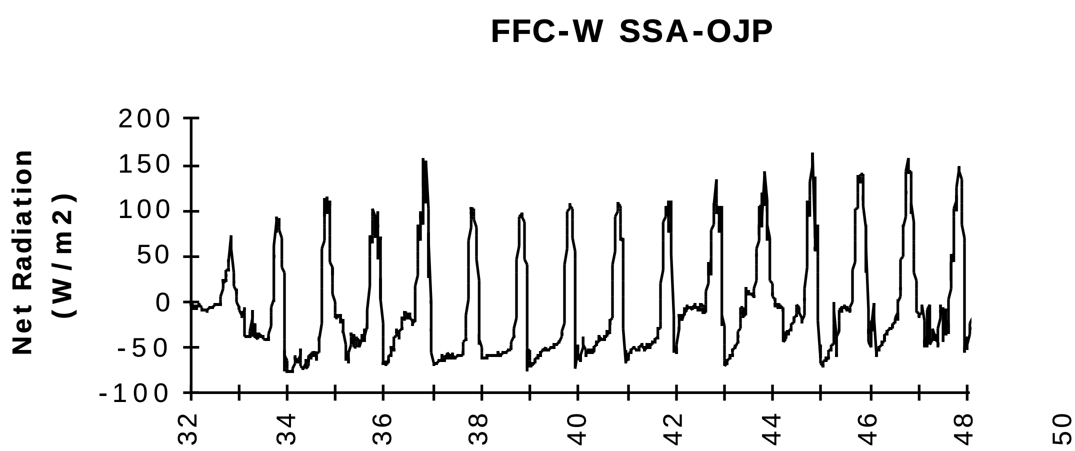
This section provides a overview of the meteorological conditions and the aircraft and ground operations during each field campaign.

2.2.1 Focused Field Campaign – Winter 1994 (FFC-W)

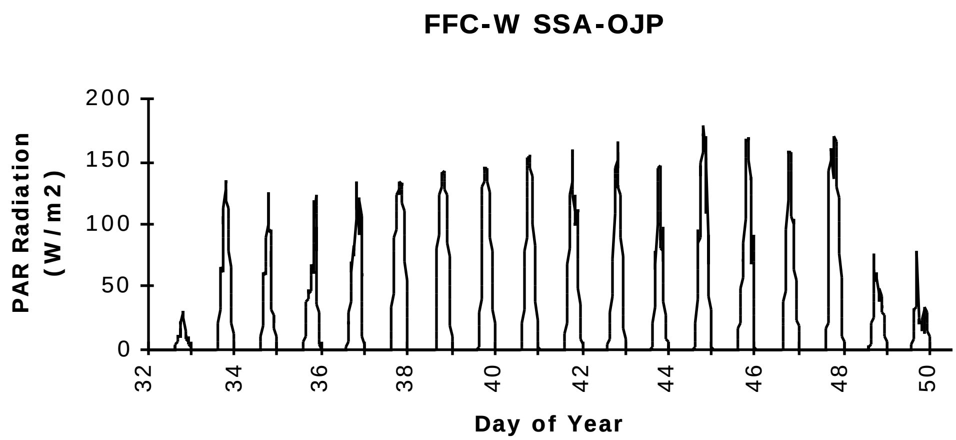
The focused field campaign for winter processes (FFC-W) was carried out during the period 2-18 February, 1994. In spite of brutal weather conditions (-45˚C), the field teams, drawn principally from the HYD and RSS groups, managed to sample snow transects arranged under the remote sensing aircraft flight lines.

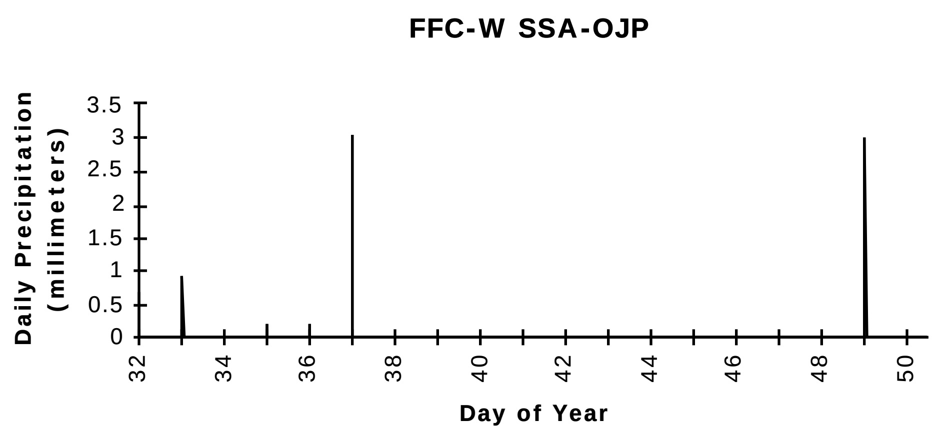
2.2.1.1 Meteorological Data from SRC towers during FFC-W

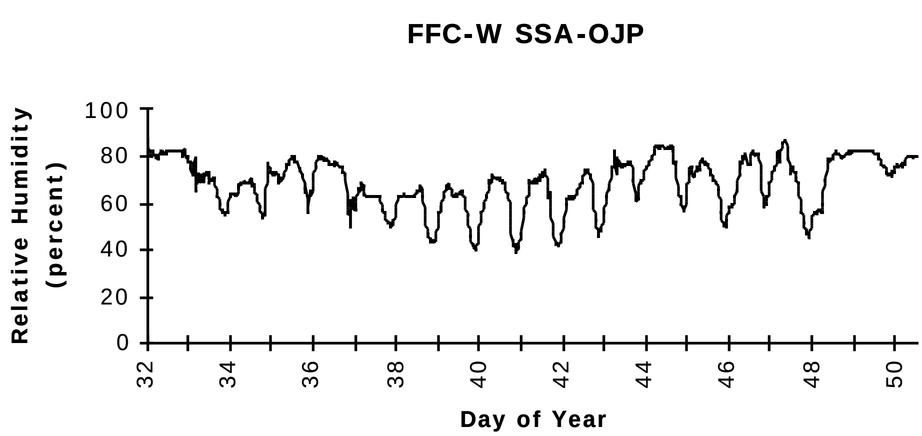




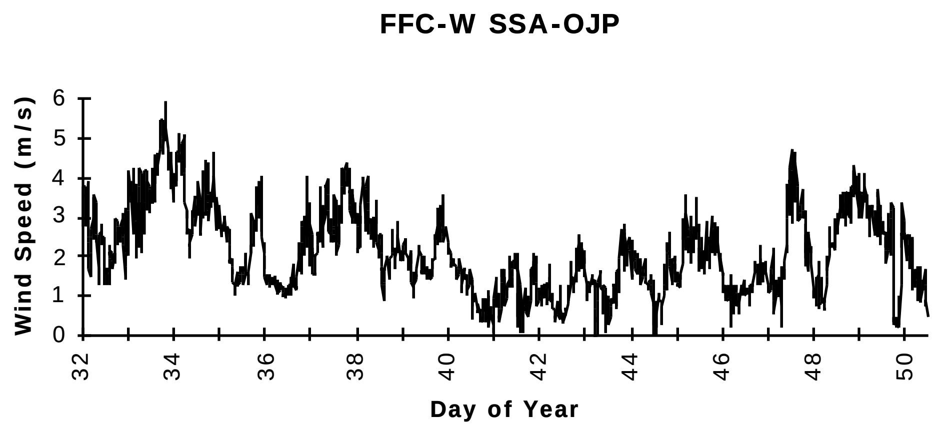
2.2.1.1 Meteorological Data - FFC-W (cont.)

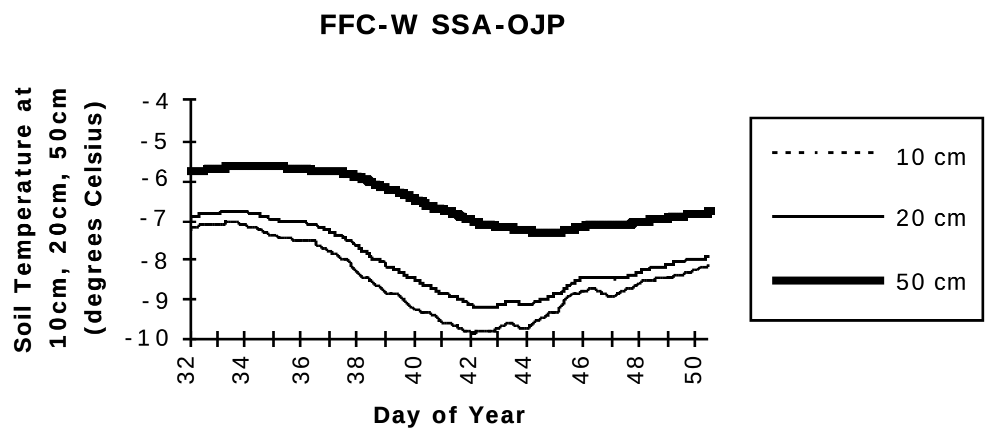




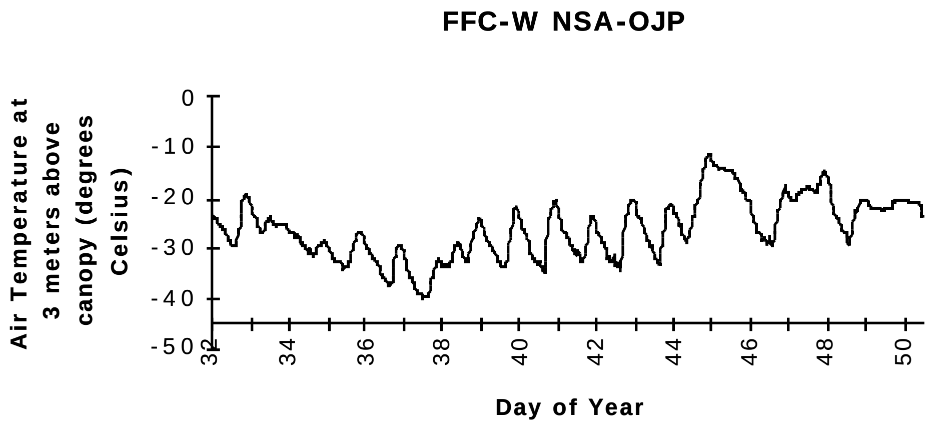


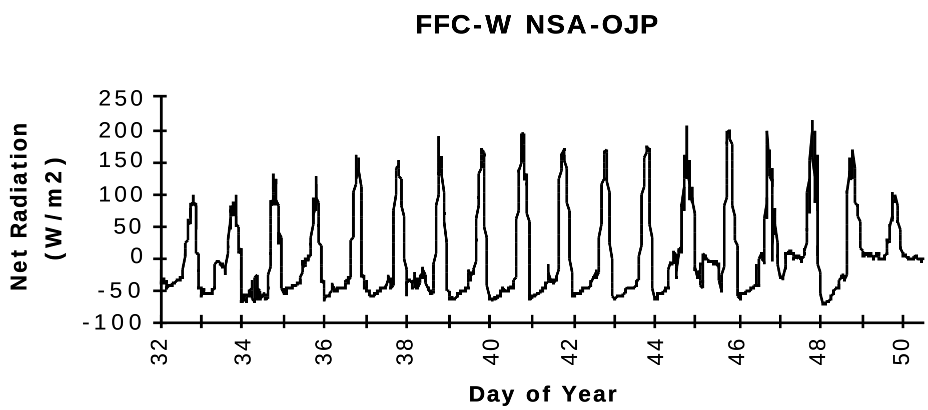
2.2.1.1 Meteorological Data - FFC-W (cont.)

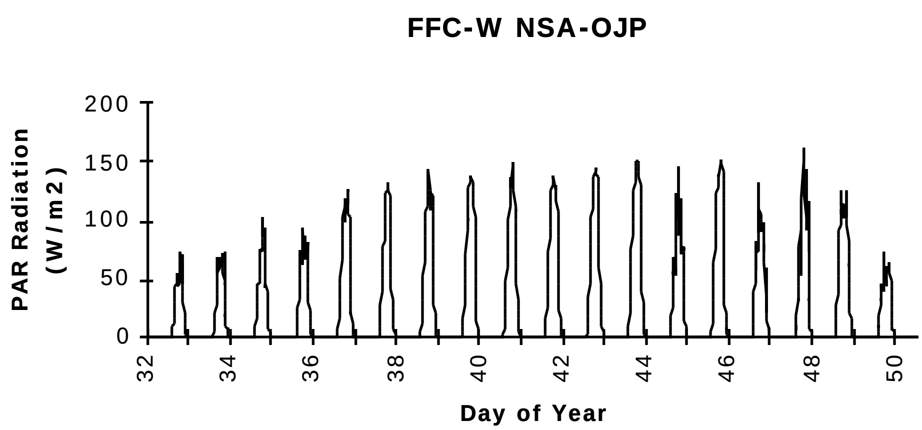




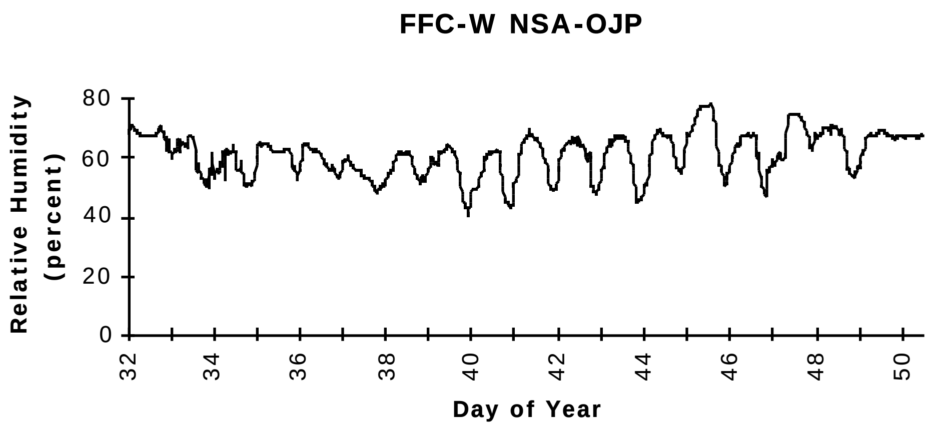
2.2.1.1 Meteorological Data - FFC-W (cont.)

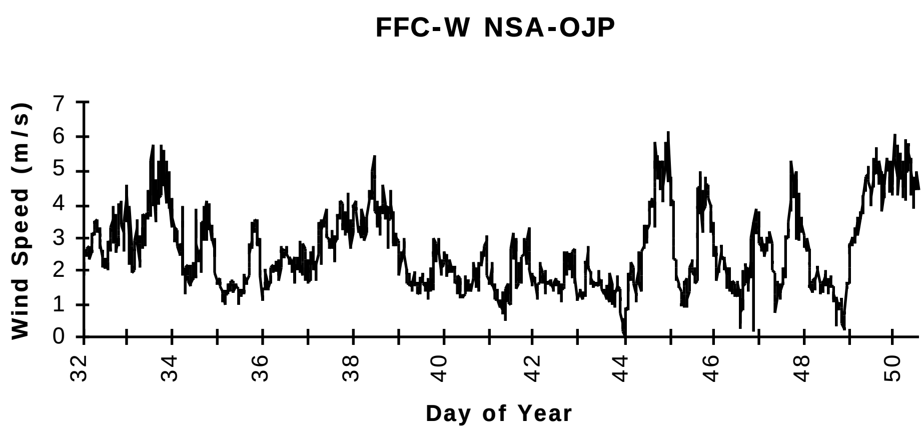


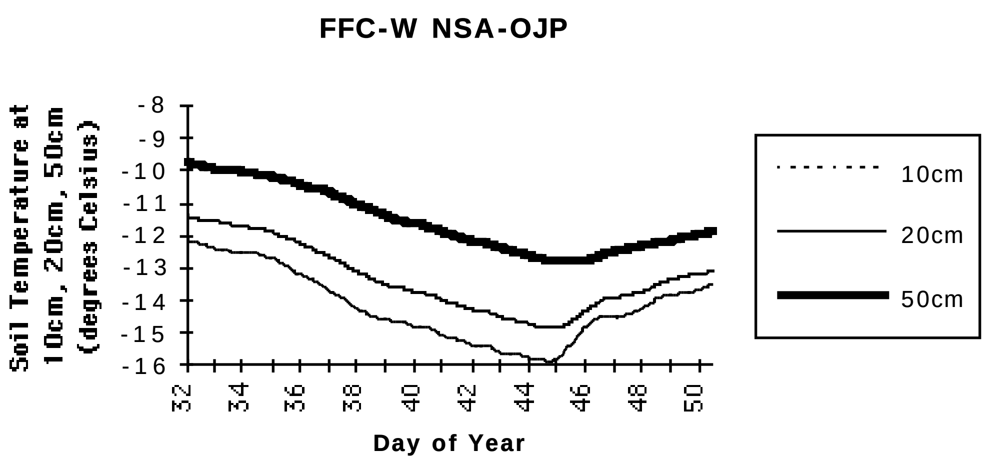




2.2.1.1 Meteorological Data - FFC-W (cont.)







2.2.1.2 FFC-W Aircraft Operations

	2/2	2/3	2/4	2/5	2/6	2/7	2/8	2/9	2/10	2/11	2/12	2/13	2/14
GOLDEN NSA													
DAYS SSA													
ER-2							SS						
(RE)													
C-130													
(RC)													
Chieftain					SS-TS	SS-TS	TS-RT	TS-SS	TN-SN	TN-SN			
(RP)						- RT							
Helicopter													
(RH)													
DC-8													
(RD)													
CV-580													
(RV)													
Twin Otter		SS			SS,SS,	SS,SS	SS,ST,	SN,ST,	SS	SS		SS	
(RT)					SS		ST	ST					
Aerocommand					SS,SS	SS,SS	SS	RT-SN,					
(RA)								SN					
Electra													
(FE)													
King Air													
(FK)													
Twin Otter													
(FT)													
Long EZ													
(FL)													
LANDSAT									NSA				
					SSA								
SPOT													

RT: Regional transect
SN: Snow survey, NSA
SS: Snow survey, SSA
ST: Snow survey, Transect
TN: TF site specific run, NSA
TS: TF site specific run, SSA

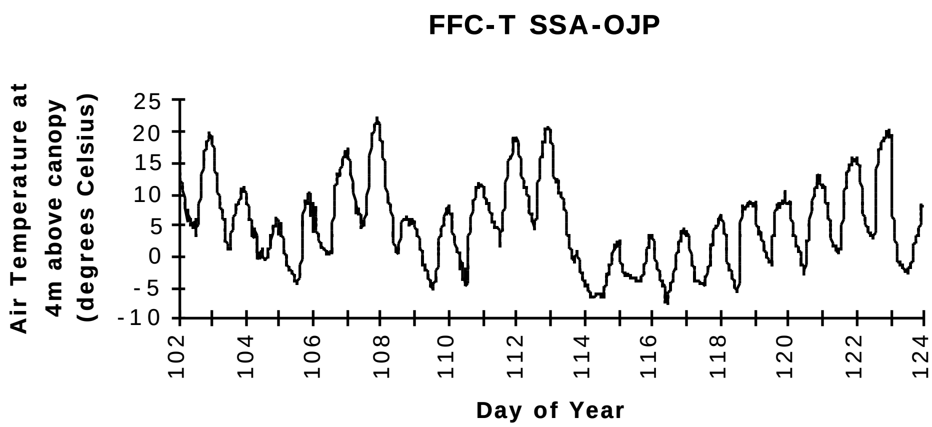
2.2.1.3 FFC-W Ground Operations

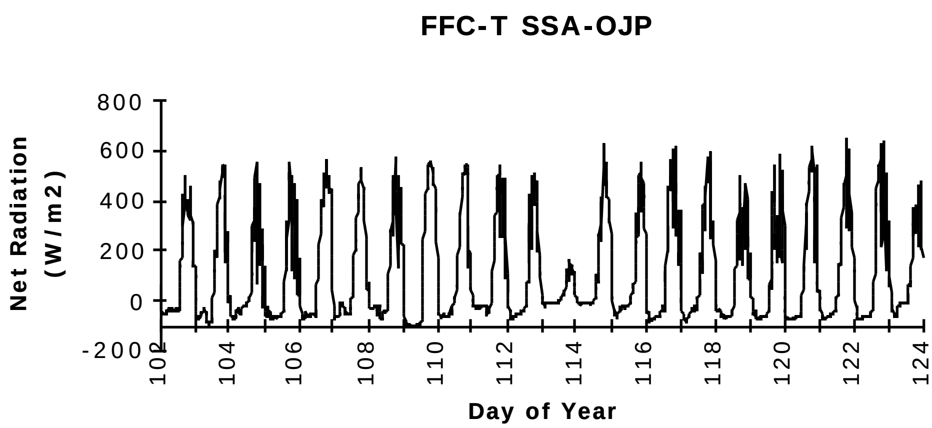
Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AFM – NSA																							
SSA																							
TF – NSA			*																				
SSA	*	*																					
TE – NSA																							
SSA																							
TGB – NSA																							
SSA																							
HYD – NSA		*	*	*	*																		
SSA			*	*	*																		
RSS – NSA																			*				
SSA													*						*				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

2.2.2 Focused Field Campaign – Thaw 1994 (FFC-T)

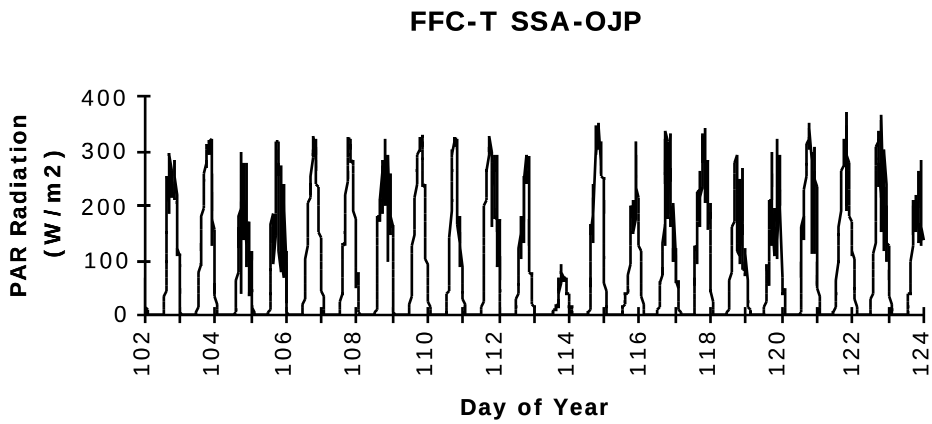
The FFC-T (Focused Field Campaign-Thaw) was targeted at studying the forest during the thaw. FFC-T ran for three weeks in April 1994 and involved many of the same ground teams as in FFC-W but the two radar-equipped aircraft, the DC-8 and the CV-580, were added to the optical remote sensing aircraft (C-130, ER-2 and Chieftain) for the campaign. After a long period of cloudy skies, a large high pressure air mass moved over the SSA for a day and then slid northeast to the NSA to give near-perfect conditions there the next day. Almost all the successful airborne optical remote sensing flights for FFC-T were flown over both study areas in two sets of coordinated missions on these two days, 19 and 20 April 1994.

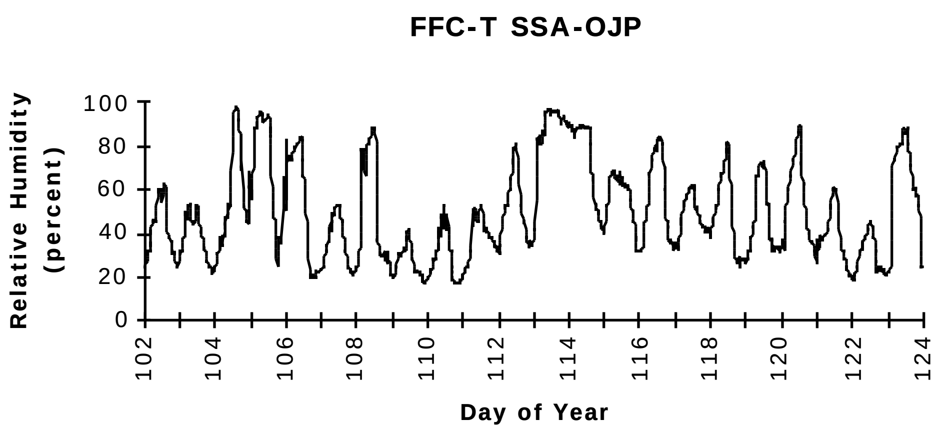
2.2.2.1 Meteorological Data from SRC towers during FFC-T

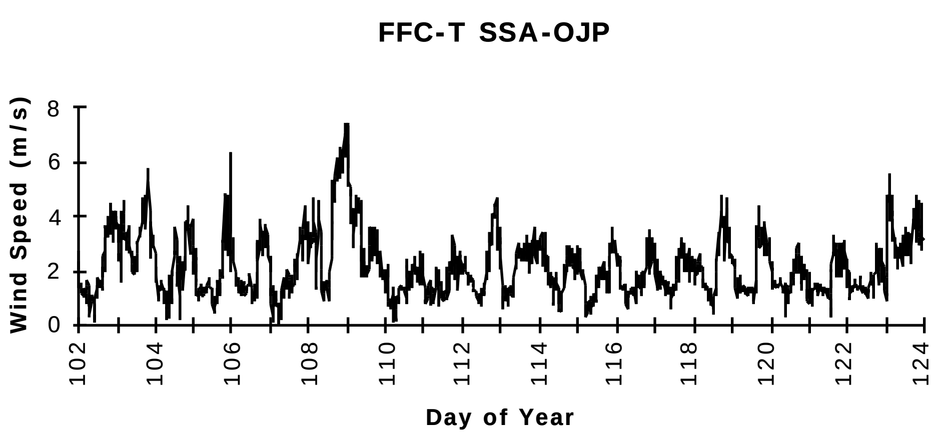




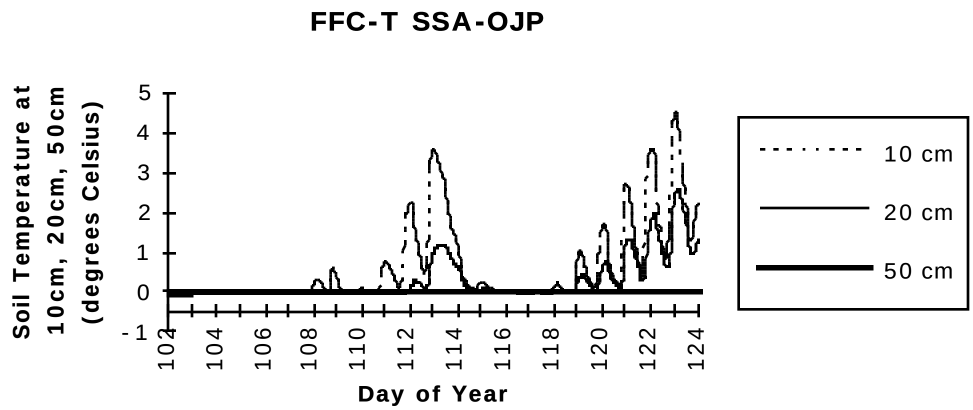
2.2.2.1 Meteorological Data – FFC-T (cont.)

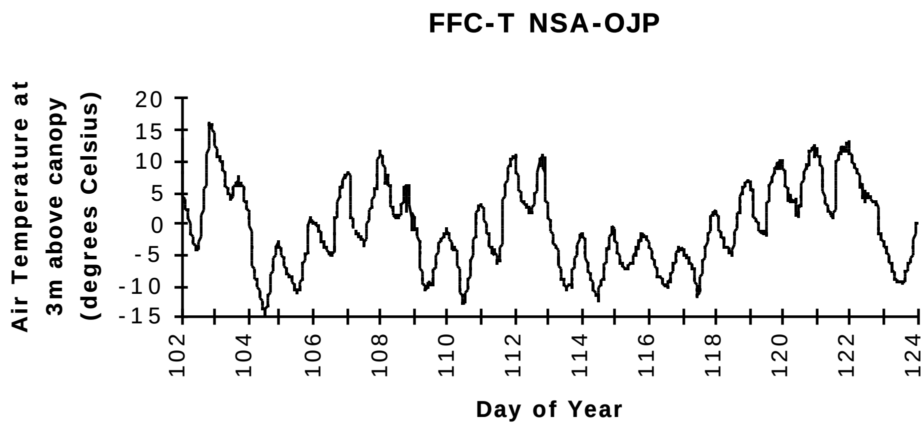


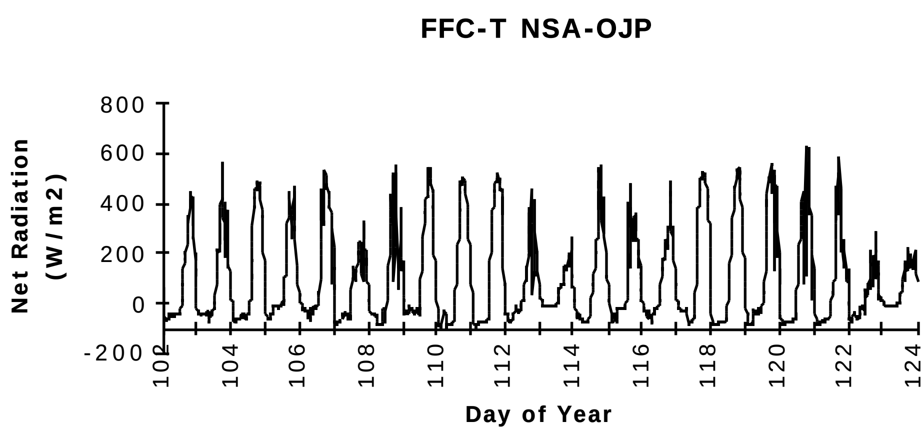




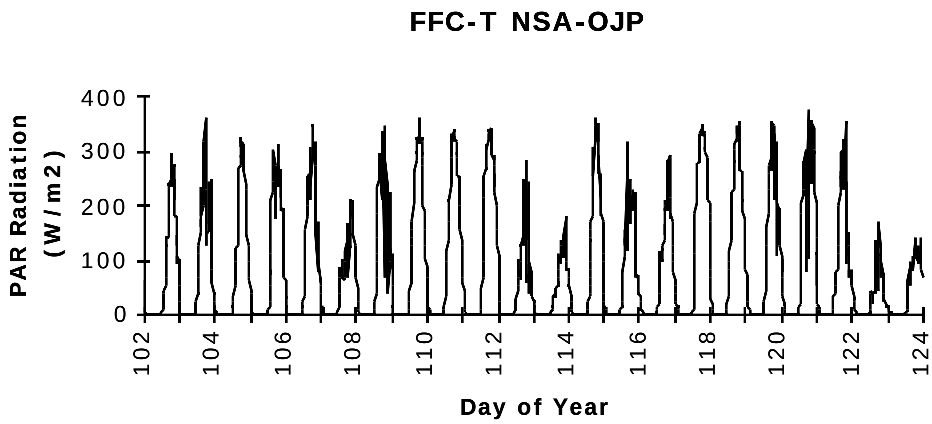
2.2.2.1 Meteorological Data – FFC-T (cont.)

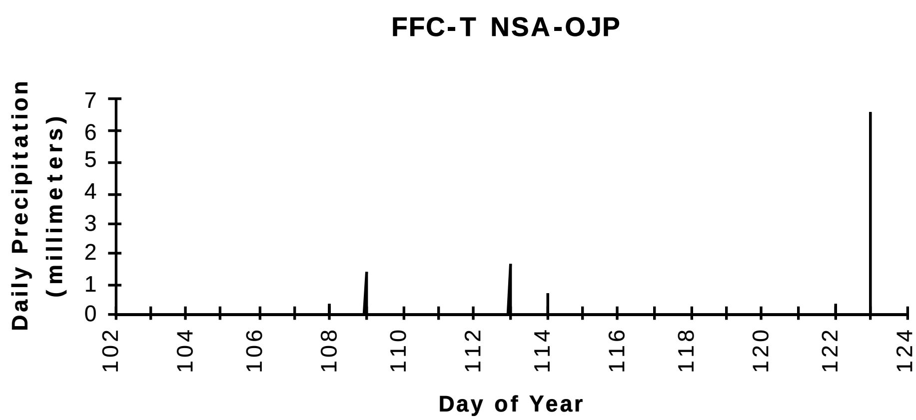


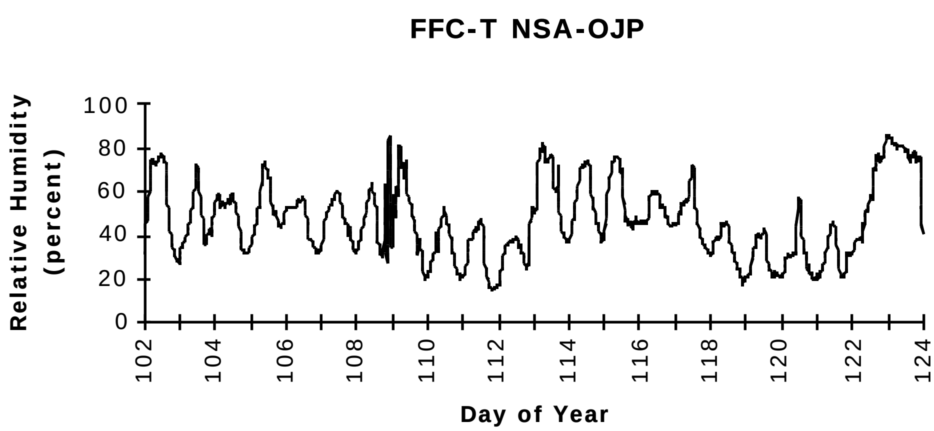




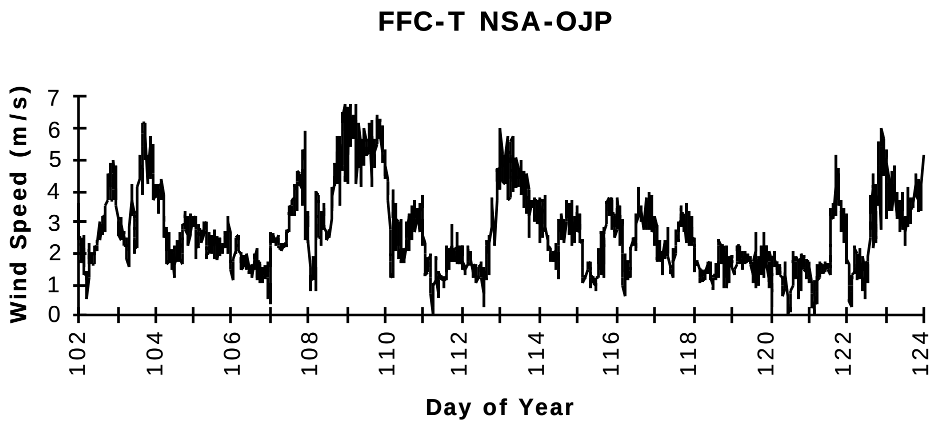
2.2.2.1 Meteorological Data – FFC-T (cont.)

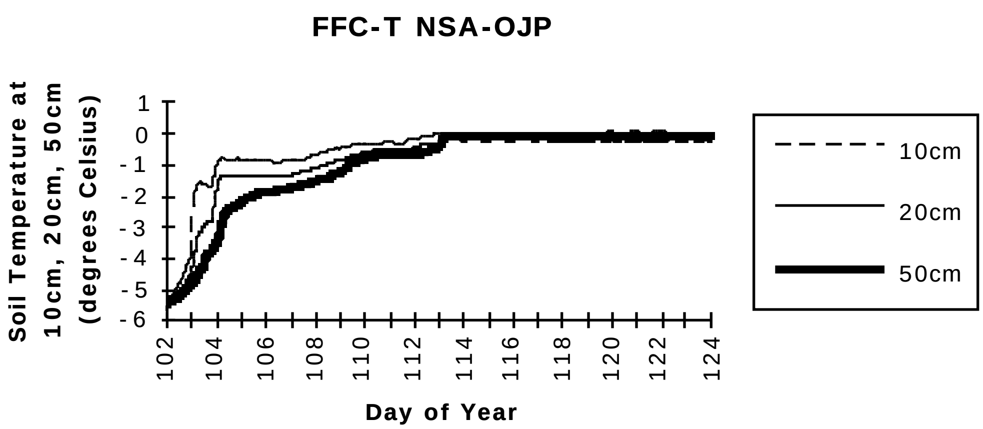






2.2.2.1 Meteorological Data – FFC-T (cont.)





2.2.2.2 FFC-T Aircraft Operations

	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2
GOLDEN DAYS NSA																					
GOLDEN DAYS SSA																					
ER-2 (RE)								MS	MN								MN				
																	-RT				
C-130 (RC)					TS			TS-MS	TN-MN												
								RT	RT												
Chieftain (RP)					TS,	TS		TS	TN	TN											
					TS			-RT	-RT												
Helicopter (RH)																					
DC-8 (RD)						BN-BS			BN-RT		BS				BS-BN		BN-RT				
						SIR			BS								BS-MS				
CV-580 (RV)						BN			RT-BN												
						SIR -BS															
Twin Otter (RT)																					
Aerocommand. (RA)																					
Electra (FE)																					
King Air (FK)																					
Twin Otter (FT)																					
Long EZ (FL)																					
LANDSAT																					
									SSA ?												
SPOT																	NSA				
						SSA				SSA											
SIR-C	NSA	NSA	NSA																		
	SSA	SSA	SSA	SSA	SSA	SSA	SSA														

BN: Radar or microwave baseline, NSA
BS: Radar or microwave baseline, SSA
MN: Mapping, NSA
MS: Mapping, SSA
RT: Regional transect
SIR: Snow survey (IR)
TN: TF site specific run, NSA
TS: TF site specific run, SSA

2.2.2.3 FFC-T Ground Operations

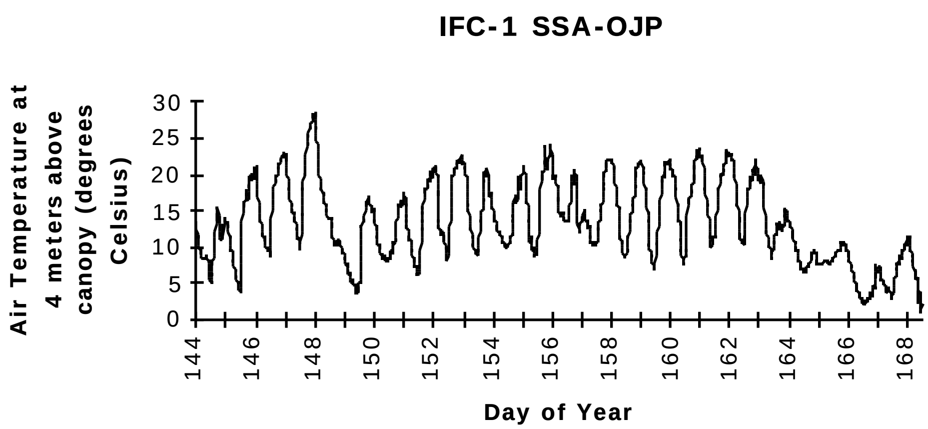
Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AFM – NSA					*		*																
SSA					*	*	*																
TF – NSA			*							*													
SSA	*	*																					
TE – NSA									*														
SSA	*			*			*				*		*										
TGB – NSA					*							*											
SSA								*															
HYD – NSA			*						*														
SSA			*		*				*														
RSS – NSA																	*		*				
SSA	*	*													*	*	*		*				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

2.2.3 Intensive Field Campaign #1 1994 (IFC-1)

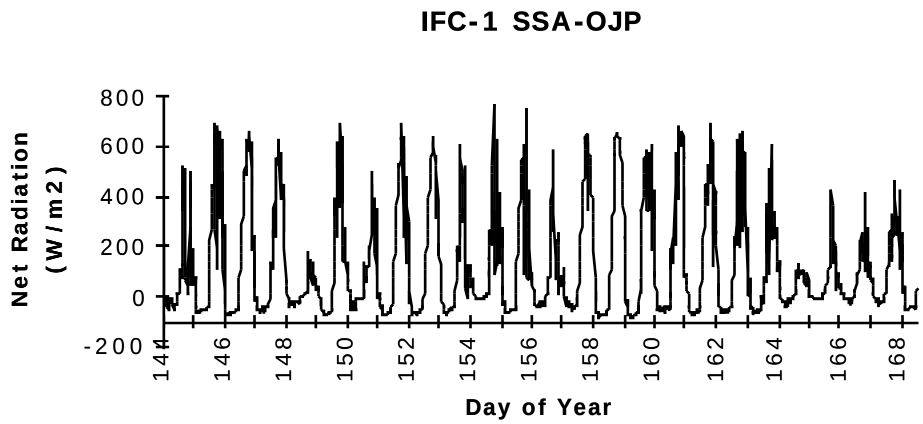
The first full-up Intensive Field Campaign (IFC-1) took place from 24 May through 16 June 1994. At the outset of IFC-1, around 150 scientists were at work on the ground taking a wide range of meteorological, ecological, hydrological and remote sensing measurements.

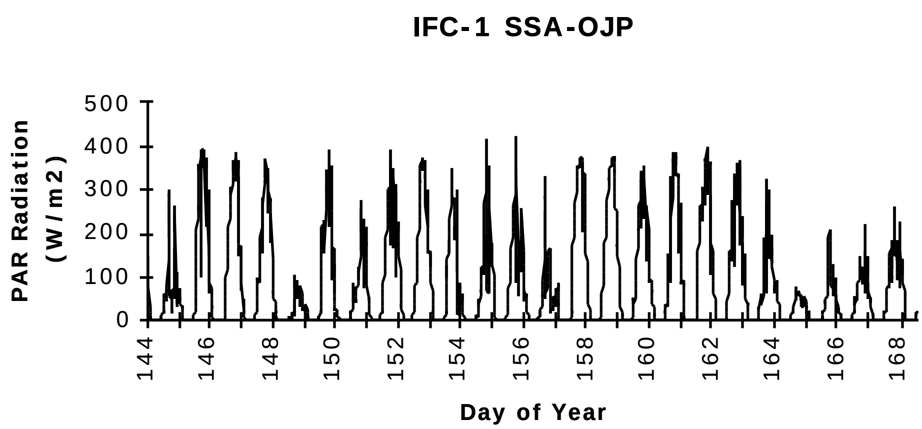
At this point, the research aircraft committed to BOREAS constituted a small air force (see Table 2) which was committed to the SSA for the first half of IFC-1 (24 May through 6 June). Four flux measurement aircraft (U. Wyoming Kingair, NCAR Electra, Canadian NRC Twin Otter, NOAA Long EZ) and three remote sensing aircraft (NASA C130, NASA Helicopter, Canada's Chieftain) were based at Prince Albert airport or in nearby Saskatoon (NCAR Electra). The NASA ER-2 and DC-8 also flew missions over the study areas from Spokane, Washington and NASA/Ames Research Center, respectively. The locally-based aircraft completed their assigned missions by 6 June 1994 after which, five of them; the C-130, helicopter, Chieftain, Kingair and Twin Otter, moved the 400 miles up to the NSA to complete a large number of missions there in two days of clear weather on 6-8 June 1994. A huge forest fire just north of the NSA trailed a smoke plume over the study area for a few days near the end of IFC-1, which closed down remote sensing work but, fortunately, was extinguished before roasting any investigators or equipment.

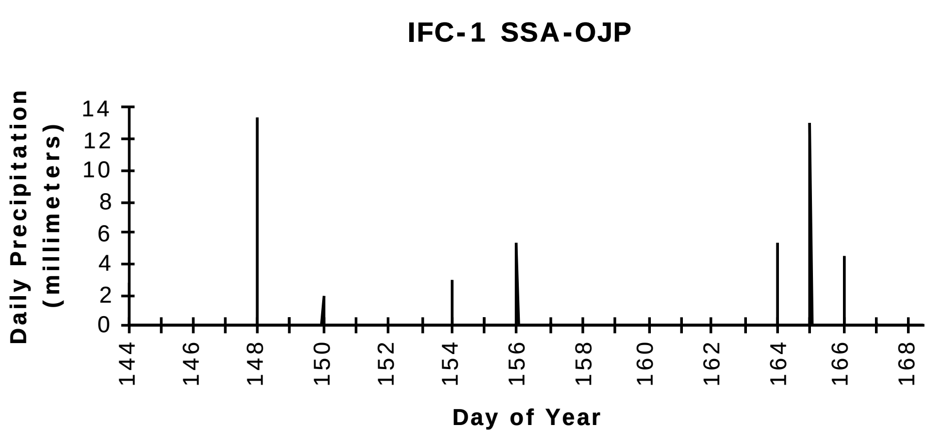
2.2.3.1 Meteorological Data from SRC towers during IFC-1



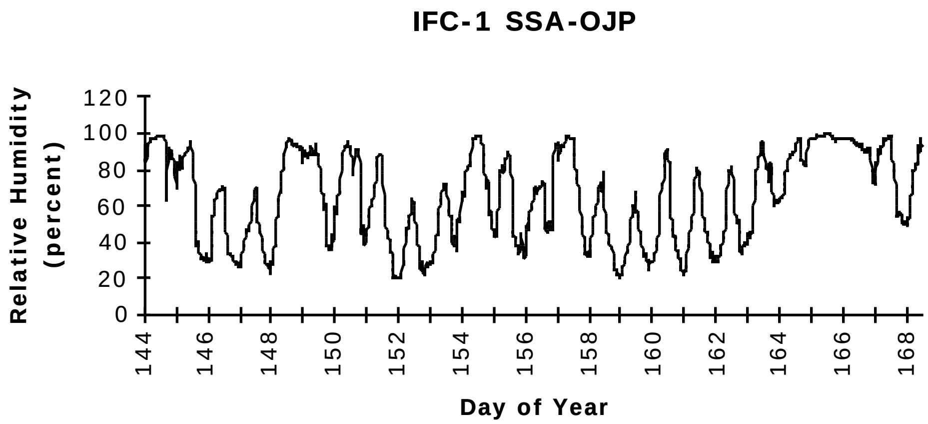
2.2.3.1 Meteorological Data – IFC-1 (cont.)

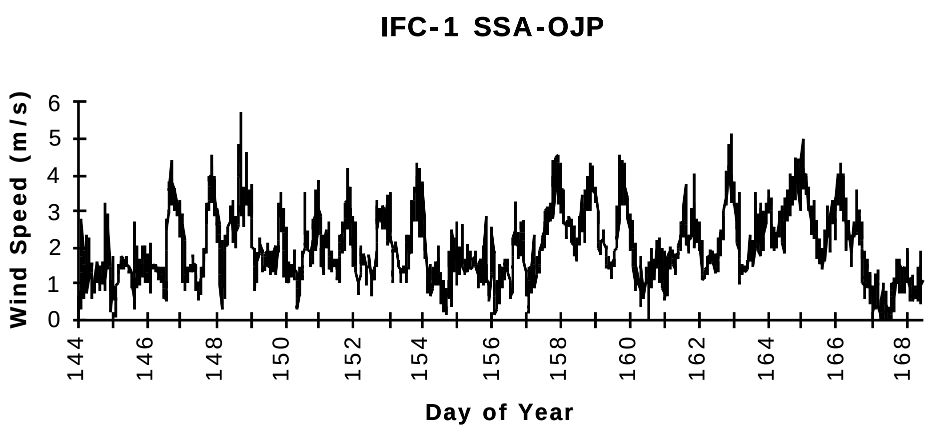


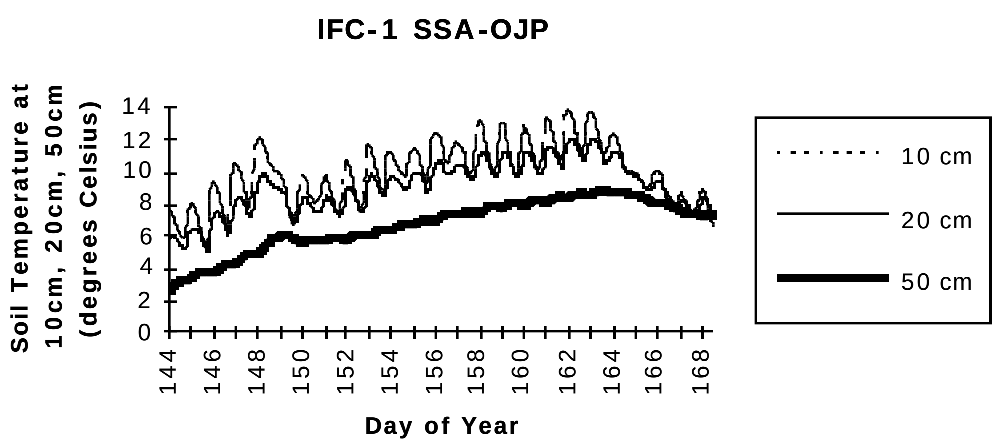




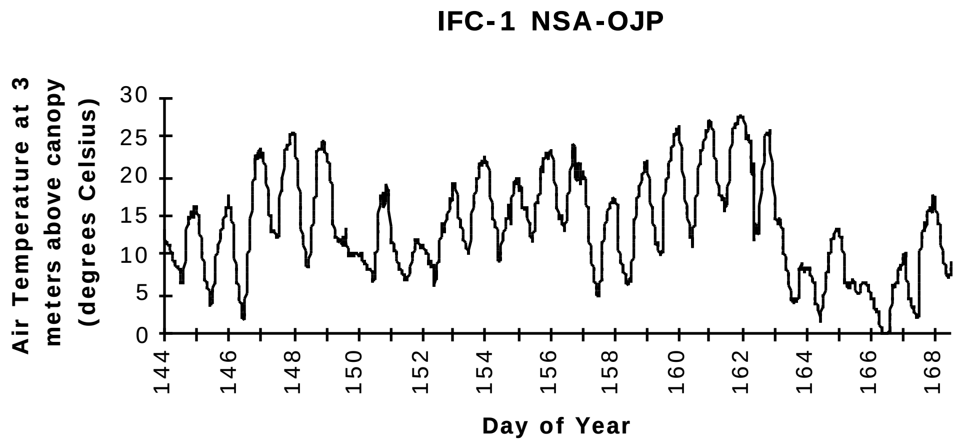
2.2.3.1 Meteorological Data – IFC-1 (cont.)

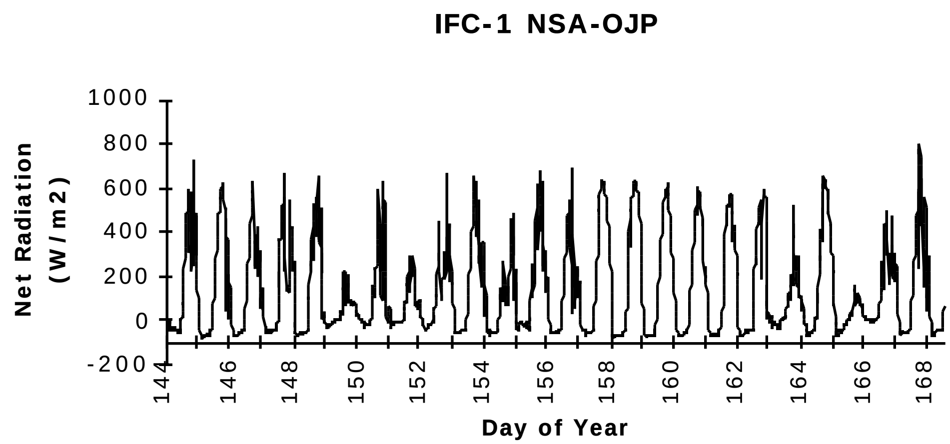


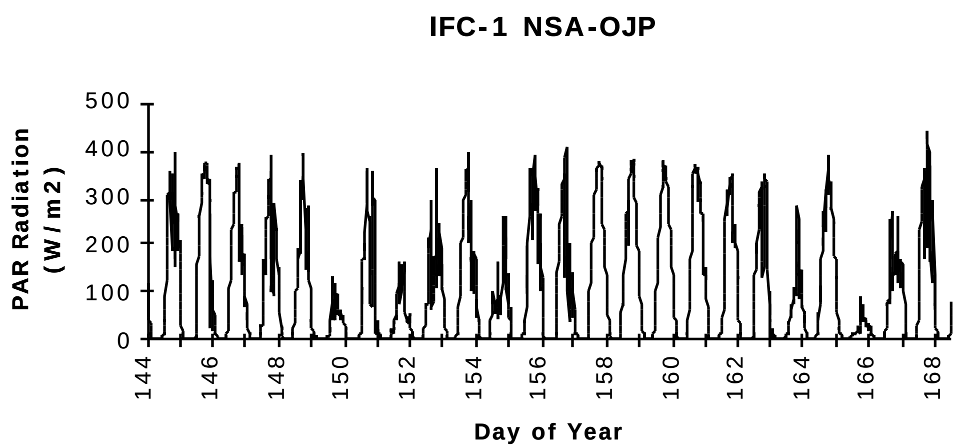




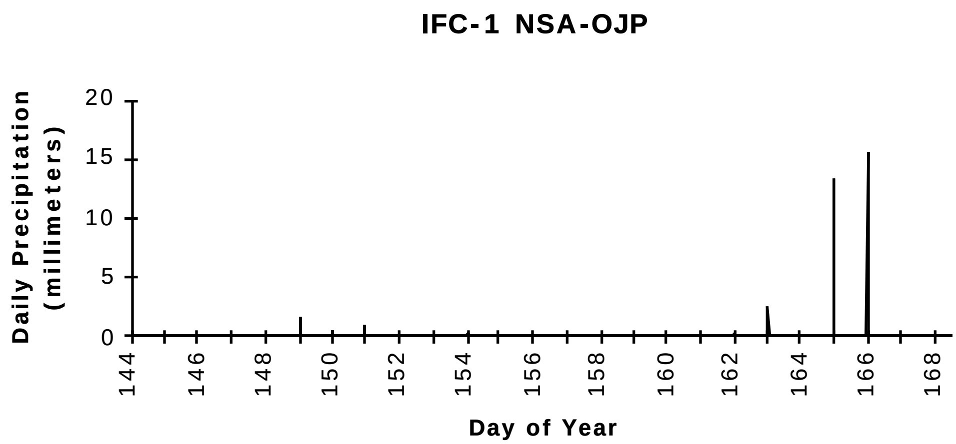
2.2.3.1 Meteorological Data – IFC-1 (cont.)

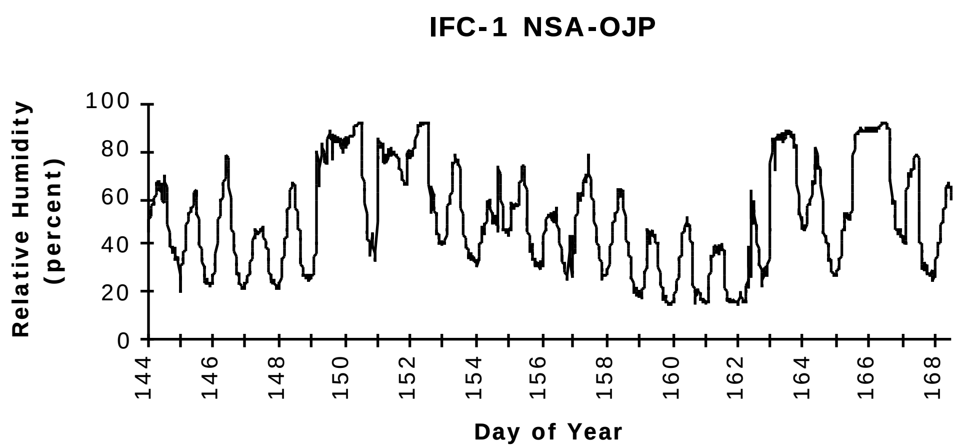


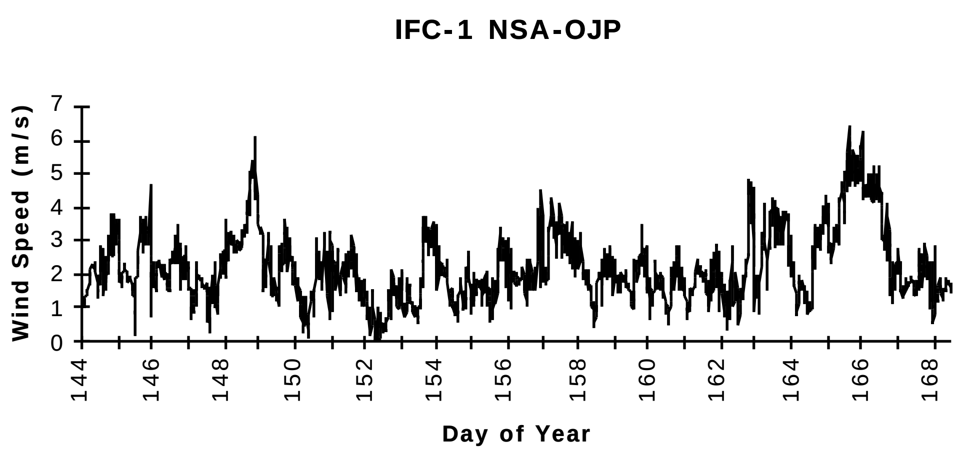




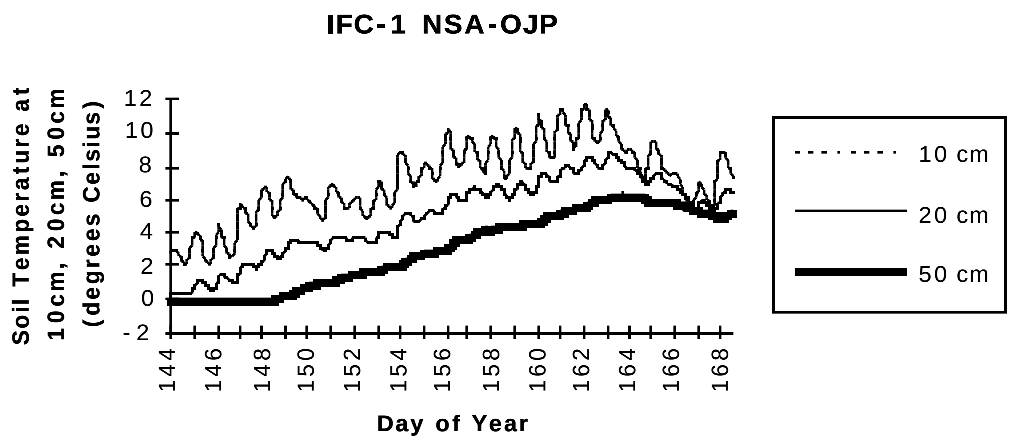
2.2.3.1 Meteorological Data – IFC-1 (cont.)







2.2.3.1 Meteorological Data – IFC-1 (cont.)



2.2.3.2. IFC-1 Aircraft Operations

	5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5
GOLDEN NSA													
DAYS SSA													
ER-2													
(RE)													
C-130			TS					TS	TS			TS	
(RC)													
Chieftain			TS	TS				TS	TS			TS	TS,RT
(RP)													
Helicopter		TS		TS		TEST		TS, TS	TS			TS	
(RH)													
DC-8													
(RD)													
CV-580													
(RV)													
Twin Otter													
(RT)													
Aerocommand													
(RA)													
Electra		CS-RT	CS					CS	RT				
(FE)													
King Air		CS	GS					GS	LS-CS			CS	
(FK)													
Twin Otter	ZS	CS-TS	GS	TS		LS		GS	TS			GS-TS,	
(FT)												TS	
Long EZ	ZS, ZS	ZS-TS	CS,TS	TS		TS		CS	CS-TS,			CS	
(FL)									TS			CS,TS	
LANDSAT													
SPOT	NSA		NSA										

CS: Candle Lake Run, SSA
GS: Grids/stacks, SSA
LS: Regional/mini transect, SSA
RT: Regional transect
TEST: Testing instruments
TS: TF site specific run, SSA
ZS: Low-level routes, SSA

2.2.3.2. IFC-1 Aircraft Operations (cont.)

	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15	6/16
GOLDEN NSA											
DAYS SSA											
ER-2			MN-RT								
(RE)											
C-130	TS,RT	TN-MN	TN								
(RC)											
Chieftain	TN, TN	TN									
(RP)											
Helicopter	TS	TN, TN	TN,TN		TN						
(RH)											
DC-8						BN-RT					
(RD)						-BS					
CV-580											
(RV)											
Twin Otter											
(RT)											
Aerocommand											
(RA)											
Electra	RT	RT		CS	RT		TEST	RT			
(FE)											
King Air	LS	GN	LN		GN	RT					
(FK)											
Twin Otter	CS,RT	TN-GN	GN,GN	TN	GN	TS		GN-TN,			
(FT)								TN			
Long EZ	LS,LS	CS, CS	TS,TS	TEST	TS-LS,	CS-TS	TS, TS				
(FL)					TS						
LANDSAT				NSA							
		SSA									
SPOT	NSA										
	SSA										

BN: Radar or microwave baseline, NSA
BS: Radar or microwave baseline, SSA
CS: Candle Lake Run, SSA
GN: Grids/stacks, NSA
LN: Regional/mini transect, NSA
LS: Regional/mini transect, SSA
MN: Mapping, NSA
RT: Regional transect
TEST: Testing instruments
TN: TF site specific run, NSA
TS: TF site specific run, SSA

2.2.3.3 IFC-1 Ground Operations

Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AFM – NSA		*	*	*	*		*	*															
SSA	*	*	*	*	*	*	*	*															
TF – NSA			*					*		*													
SSA	*	*		*	*				*		*												
TE – NSA		*			*	*			*														*
SSA	*	*		*	*	*	*	*		*		*			*								*
TGB – NSA	*		*	*	*																		
SSA							*	*	*	*													
HYD – NSA	*								*														
SSA	*								*														
RSS – NSA		*	*				*				*								*	*			
SSA	*	*	*				*				*	*						*	*	*			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

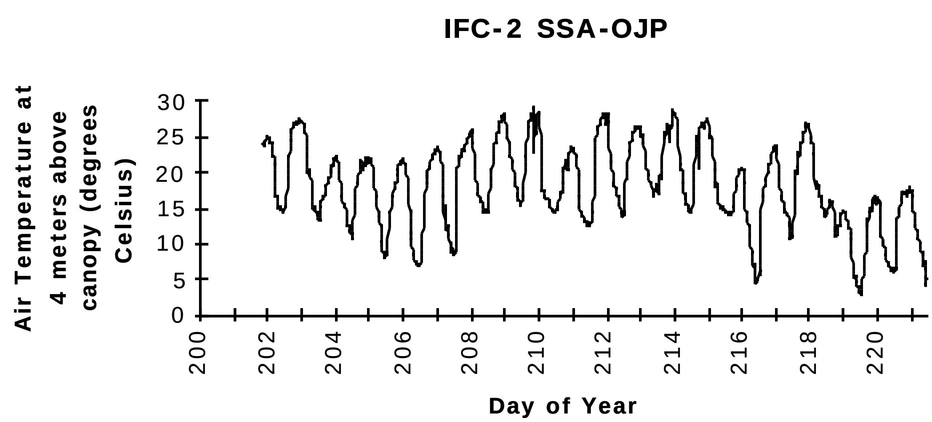
2.2.4 Intensive Field Campaign #2 1994 (IFC-2)

The second intensive field campaign of BOREAS (IFC-2) ran from 19 July 1994 through 10 August 1994. Once again, the initial focus was in the Southern Study Area (SSA) near Prince Albert, Saskatchewan. Most of the research aircraft were based at the local airport and many of the teams working on remote sensing science had set up sites within the nearby forest. On 21 July 1994, two days after the start of IFC-2, a high pressure ridge moved over the SSA and sat there for about 12 hours giving clear sky conditions over the entire 140x60 km area. All ten aircraft that were committed to the experiment at the time flew that day for a record total of sixteen research missions. The resulting data set is truly impressive: in addition to the continuous surface measurements made by twenty-five science teams on the surface, the aircraft collected a wide range of coordinated optical (ER-2, C-130, Chieftain, NASA Helicopter) and microwave (DC-8, CV-580) remote sensing data, and a comprehensive set of low-level surface flux measurements (NCAR Electra, U. Wyoming Kingair, Canadian NRC Twin Otter, NOAA LongEZ).

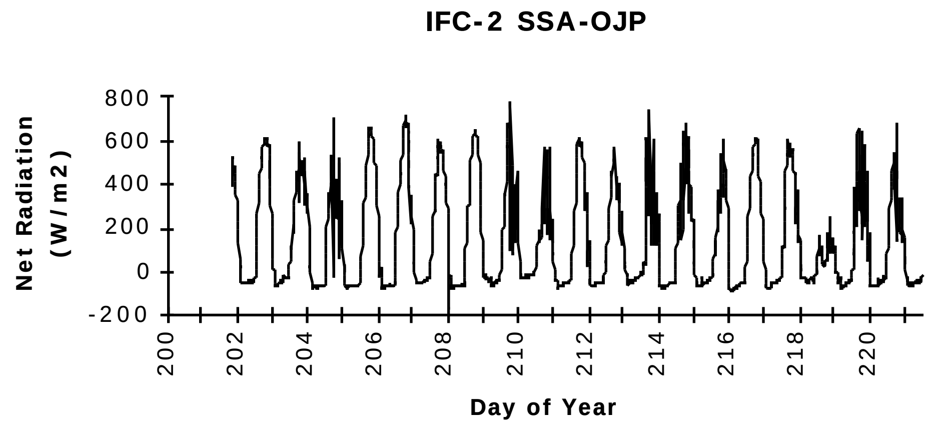
After a few more days activity near Prince Albert, the bulk of the BOREAS aircraft moved up to Thompson, Manitoba on 26 July 1994, to work at the Northern Study Area (NSA) on 26 July 1994. At this point, the streak of good luck that BOREAS had enjoyed from the beginning showed signs of flagging. A number of huge forest fires were raging across Northern Canada from Manitoba all the way to British Columbia. The nearest fire to the NSA was located in the bush some 30 miles north (and directly upwind) of the area; this fire alone was burning on a twenty mile front. Visibility at Thompson Airport dropped steadily for several days to the point where all incoming air traffic was subject to instrument flight rules (less than 3/4 miles forward visibility). Collecting good data under these conditions was difficult for many parts of the project and obviously impossible for most of the aircraft equipped with optical remote sensing equipment, see Figure 14.

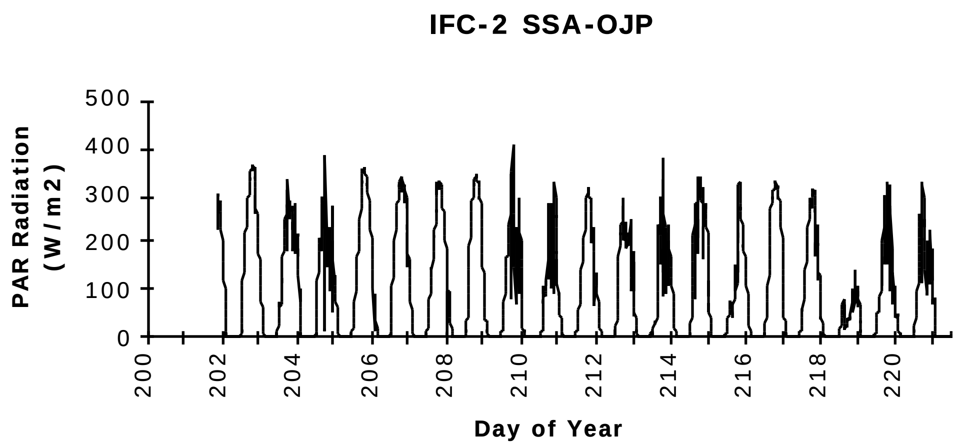
On the last morning of IFC-2, the skies cleared for just over two hours; long enough for the NASA C-130 to acquire a minimum data set. Among other things, the NASA C-130 acquired MODIS (Moderate Resolution Imaging Spectrometer) Airborne Simulator (MAS) data over both the SSA and NSA during this campaign.

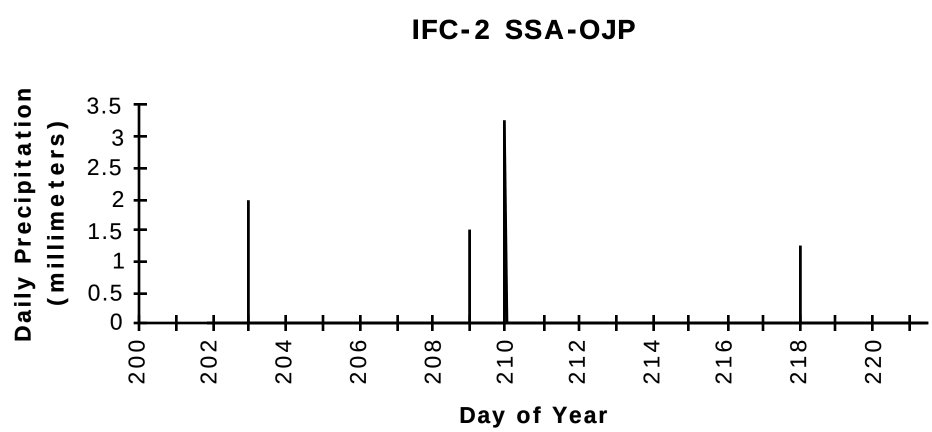
2.2.4.1 Meteorological Data from SRC towers during IFC-2



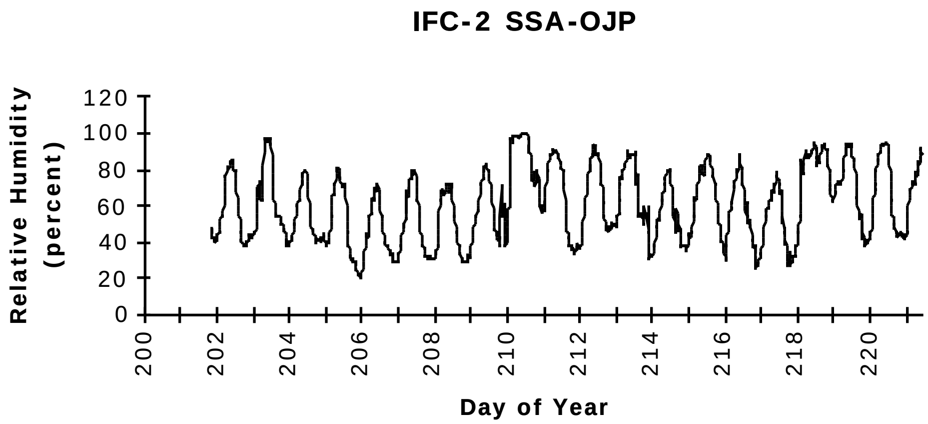
2.2.4.1 Meteorological Data – IFC-2 (cont.)

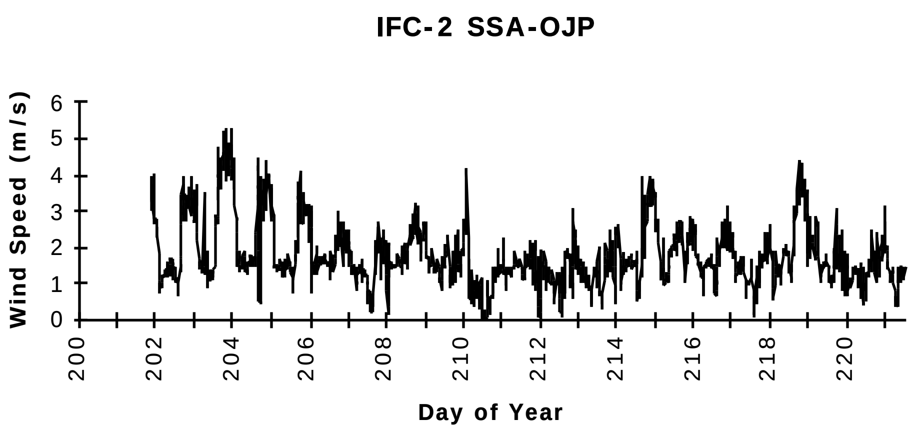


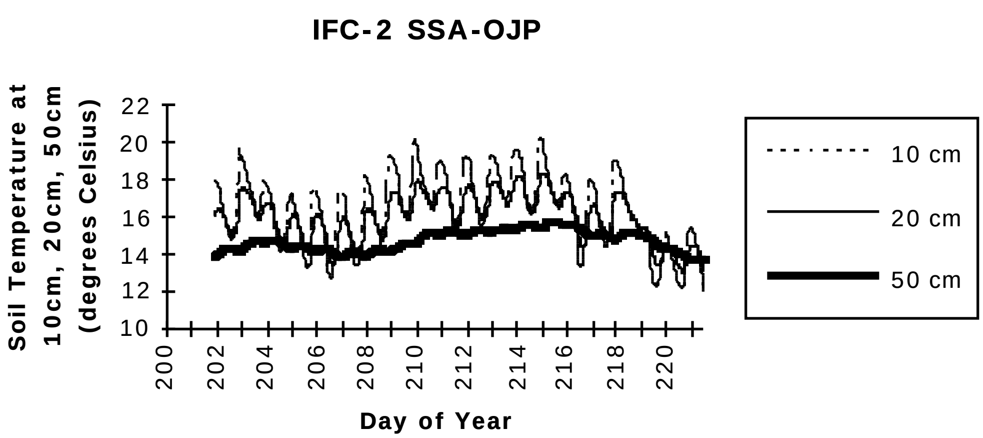




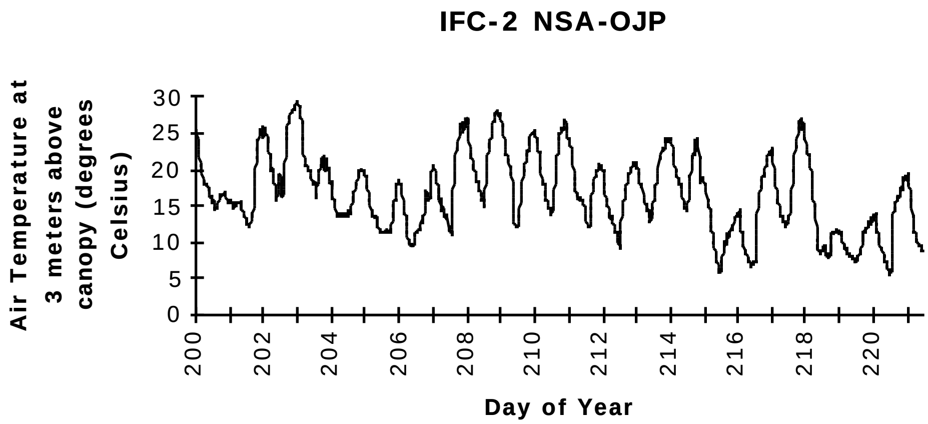
2.2.4.1 Meteorological Data – IFC-2 (cont.)

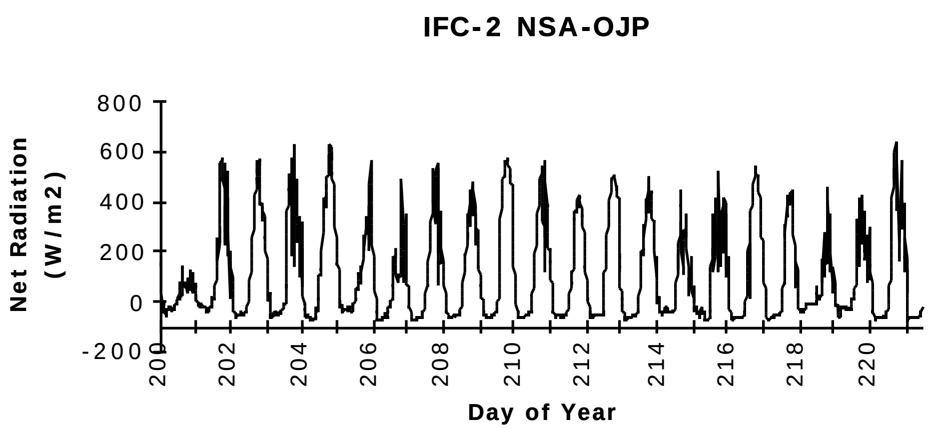


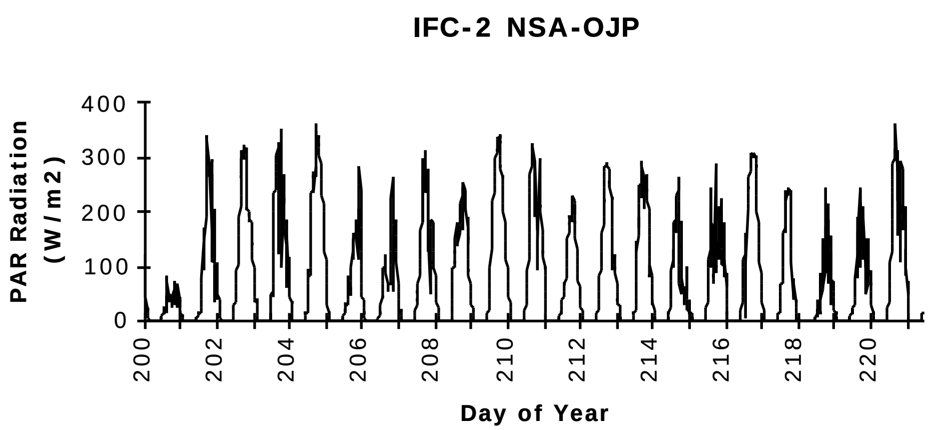




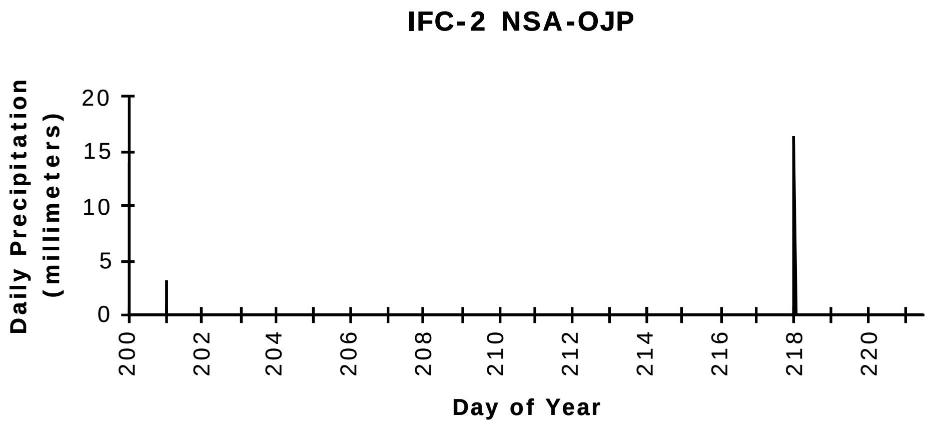
2.2.4.1 Meteorological Data – IFC-2 (cont.)

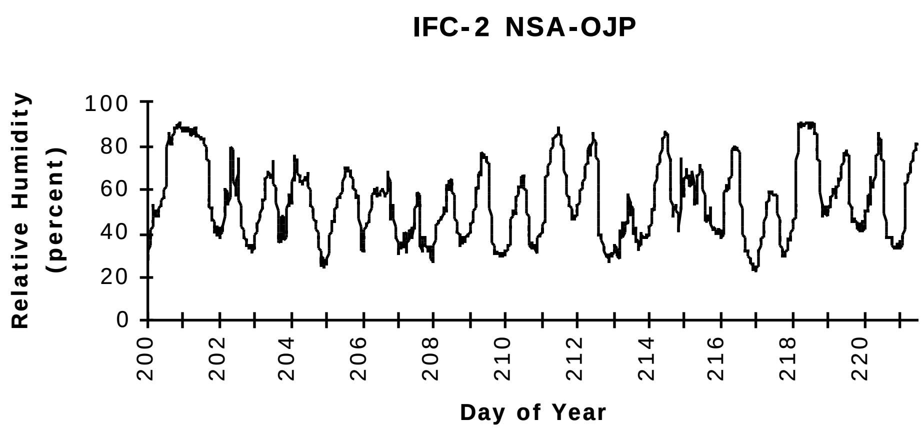


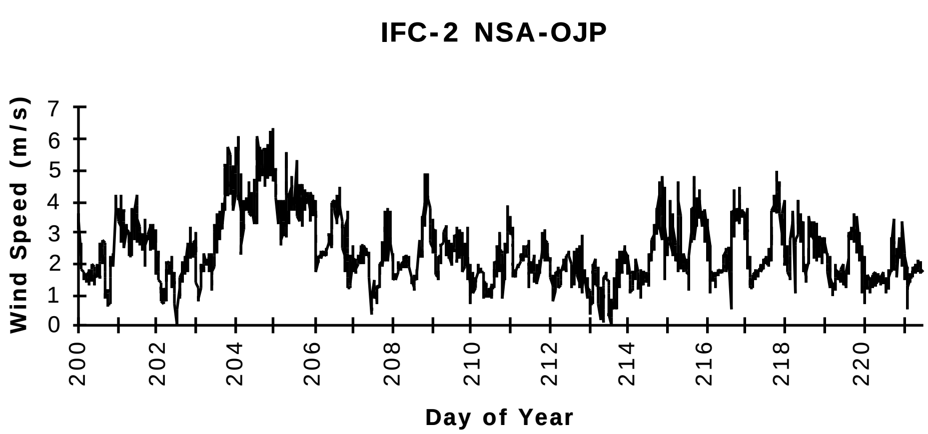




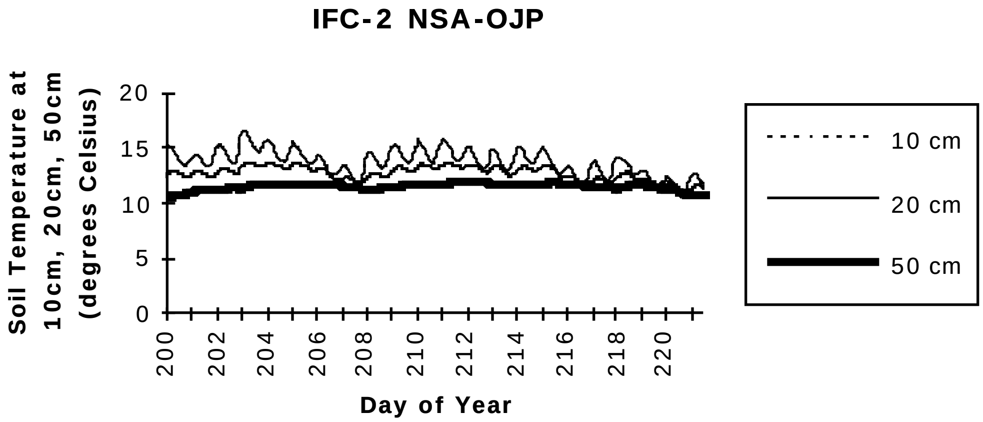
2.2.4.1 Meteorological Data – IFC-2 (cont.)







2.2.4.1 Meteorological Data – IFC-2 (cont.)



2.2.4.2 IFC-2 Aircraft Operations

		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28
GOLDEN	**NSA**										
DAYS	**SSA**										
ER-2				MS							
(RE)											
C-130				MS-TS		TS	TS				
(RC)											
Chieftain				TS	TS	TS	TS, CAL	TS,TS			
(RP)											
Helicopter				TS, TS,	TS, BS	TS,BS	TS,TS-	TS,TS,TS			TN,TN
(RH)				BS		BS	CAL,BS				
DC-8				MN-RT-		BS, BS		BS			BS-BN-RT
(RD)				MS							
CV-580				MN,RT-MS		BS, BS	BS-MS				BS-RT-BN
(RV)											
Twin Otter											
(RT)											
Aerocommand							WN	WN		WS	WS
(RA)											
Electra			CS	RT							
(FE)							RT (SSA)				
King Air		TEST	CS	GS		CS	GS	CS	RT	GN	LN
(FK)											
Twin Otter			GS	GS,TS-CS	TS	CS	GS,LS	TS,TS-CS	GS-TS	RT	GN
(FT)											
Long EZ		TEST	CS	CS,CS,		CS,TS	LS,LS	CS	TS, TS	GS	CS
(FL)				CS							
LANDSAT											
								SSA			
SPOT											
				SSA			SSA				

BN: Radar or microwave baseline, NSA
BS: Radar or microwave baseline, SSA
CAL: Calibrating instruments
CS: Candle Lake Run, SSA
GN: Grids/stacks, NSA
GS: Grids/stacks, SSA
LN: Regional/mini transect, NSA
MN: Mapping, NSA
MS: Mapping, SSA
RT: Regional transect
TEST: Testing instruments
TN: TF site specific run, NSA
TS: TF site specific run, SSA
WN: Soil moisture survey, NSA
WS: Soil moisture survey,SSA

2.2.4.2 IFC-2 Aircraft Operations (cont.)

	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
GOLDEN NSA											
DAYS SSA											
ER-2							MN-RT				
(RE)											
C-130					TEST		MN-TN				MN
(RC)											
Chieftain			TN				TN, TN				
(RP)											
Helicopter				TEST			TN, TN,				
(RH)							TN				
DC-8											
(RD)											
CV-580											
(RV)											
Twin Otter											
(RT)											
Aerocommand	WS	WS		WS	WS	WS-WT	WN	WN			
(RA)											
Electra		RT		CS	CS	RT	RT				
(FE)											
King Air			GN								
(FK)											
Twin Otter	TN			GN	TN		GN, TN	TEST			
(FT)											
Long EZ	CS, CS	CS									
(FL)											
LANDSAT											
SPOT							NSA				
							SSA				

CS: Candle Lake Run, SSA
GN: Grids/stacks, NSA
MN: Mapping, NSA
RT: Regional transect
TEST: Testing instruments

TN: TF site specific run, NSA
WN: Soil moisture survey, NSA
WS: Soil moisture survey, SSA
WT: Soil moisture survey, Transect

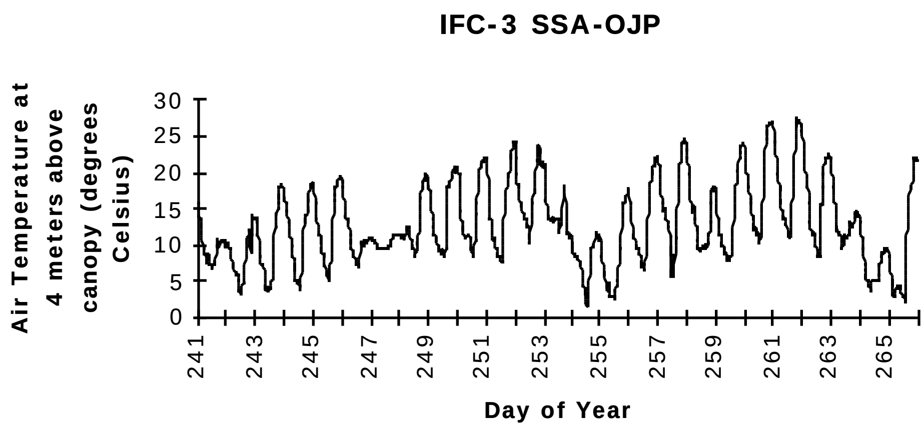
2.2.4.3 IFC-2 Ground Operations

Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AFM – NSA		*	*	*	*		*	*				*											
AFM – SSA	*	*	*	*	*	*	*	*				*											
TF – NSA			*					*		*													
TF – SSA	*	*		*	*	*	*		*		*												
TE – NSA		*			*	*			*				*										*
TE – SSA	*	*		*	*	*	*	*		*	*	*	*		*					*		*	*
TGB – NSA	*		*	*	*	*																	
TGB – SSA								*	*	*													
HYD – NSA	*							*	*														
HYD – SSA	*					*			*														
RSS – NSA		*	*				*				*						*		*	*			
RSS – SSA	*	*	*	*			*	*			*	*	*	*	*	*	*	*	*	*			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

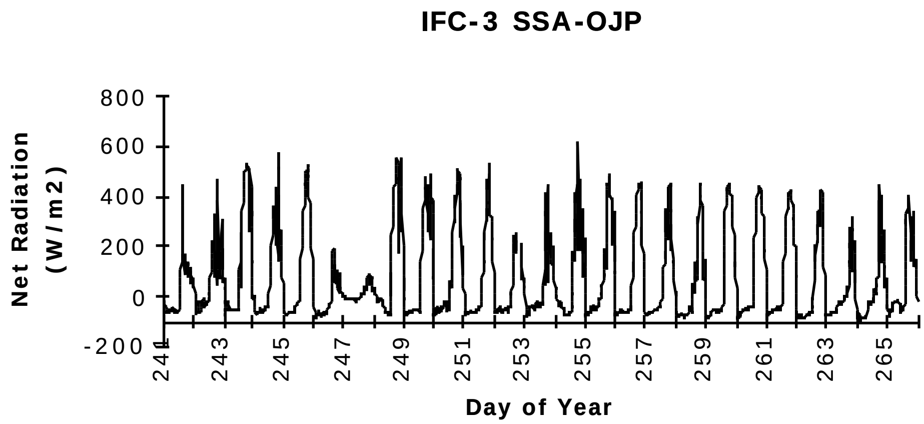
2.2.5 Intensive Field Campaign #3 1994 (IFC-3)

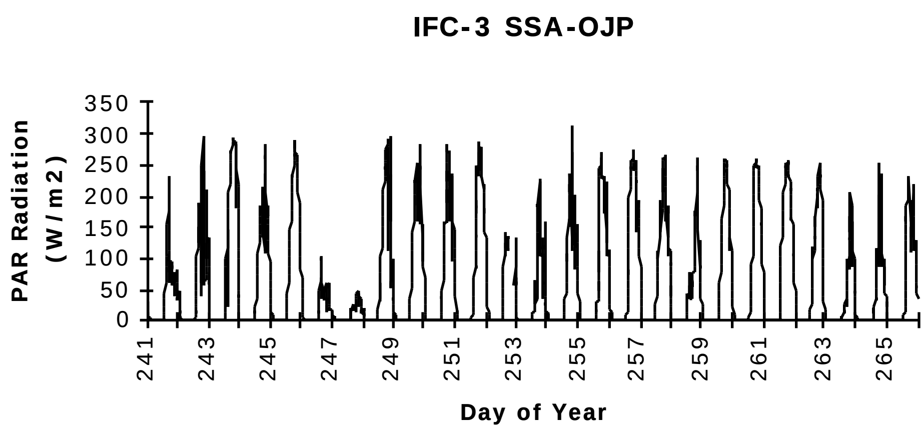
IFC-3 ran from 30 August to 19 September 1994 with most of the aircraft starting in the NSA and migrating south to the SSA on 8 September. This was done even though a far from complete remote sensing data set had been gathered in the NSA by the ER-2 and C-130 due to clouds and/or smoke. After a long and trying wait, a repeat situation of FFC-T and IFC-1 was predicted by the meteorologist supporting the project; that is, a high pressure air mass moving from the SSA to the NSA over a period of two days. This late and narrow window of opportunity was used to complete the full program of airborne optical remote sensing missions under perfect blue skies at both study areas; SSA on 16 September and NSA on 17 September. As a capstone, the Twin Otter aircraft carried out a last mission over the NSA on its way home on 19 September to characterize the forest in close to its dormant state. A final pair of radar remote sensing missions were flown by the DC-8 and CV-580 on 20 September. More than 350 airborne missions (remote sensing and eddy correlation) were flown during the 1994 field year.

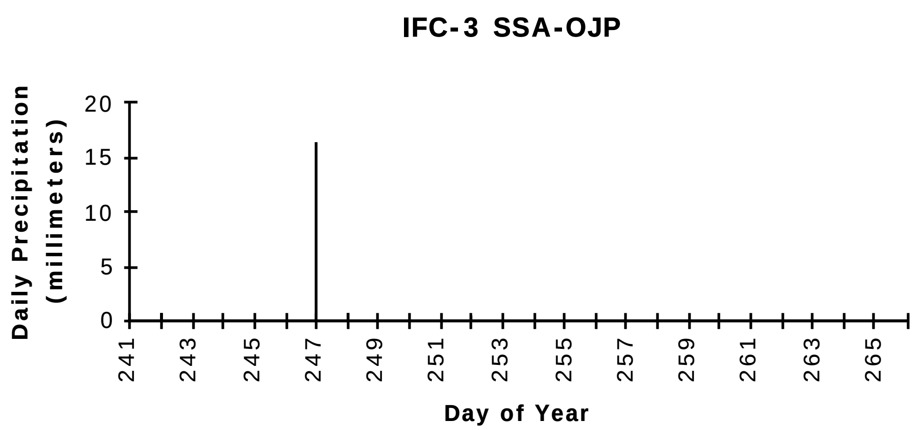
2.2.5.1 Meteorological Data from SRC towers during IFC-3



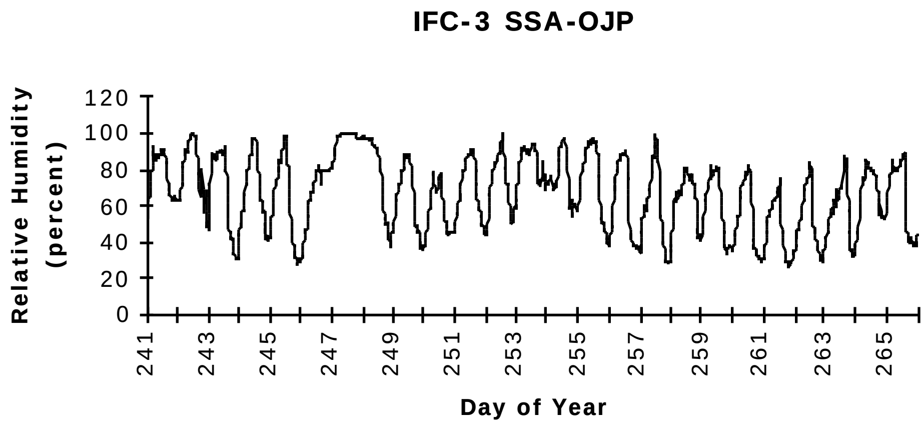
2.2.5.1 Meteorological Data – IFC-3 (cont.)

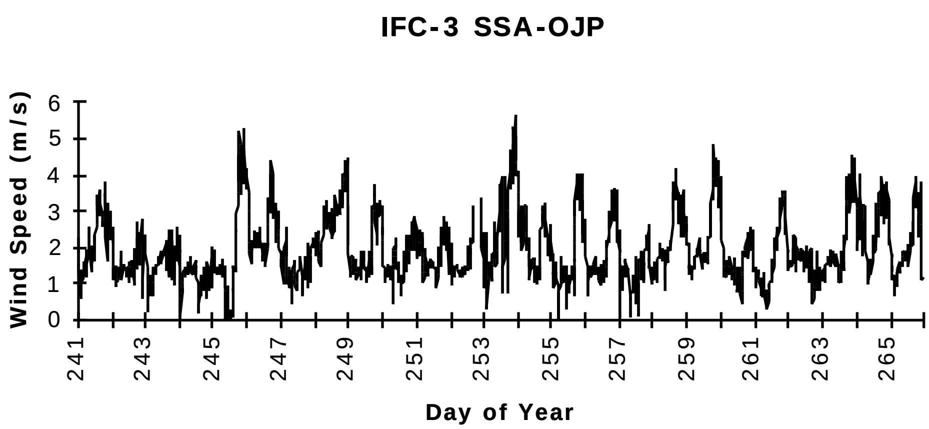


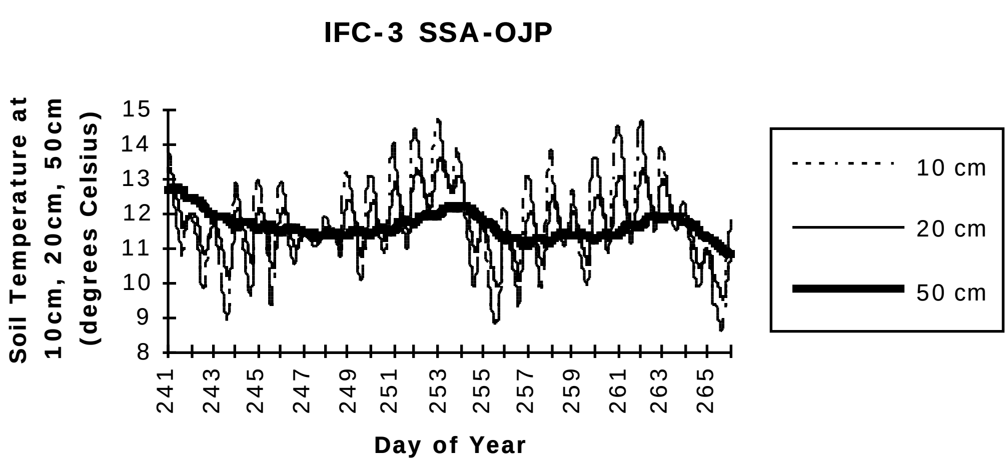




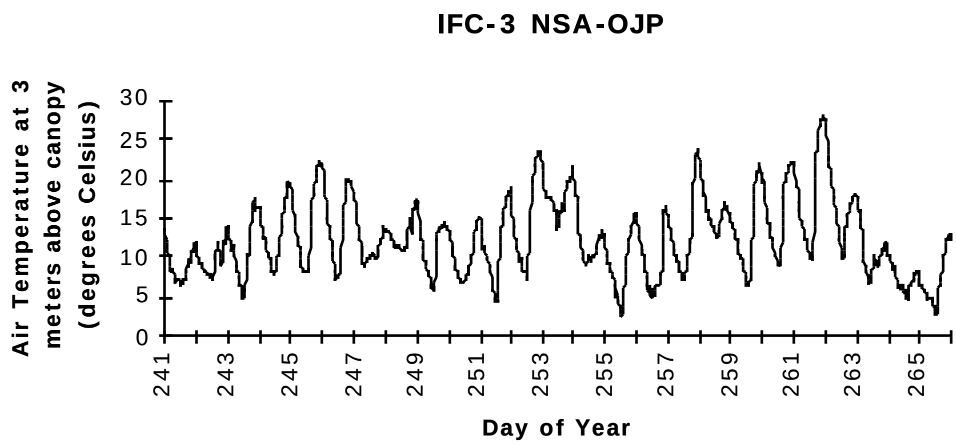
2.2.5.1 Meteorological Data – IFC-3 (cont.)

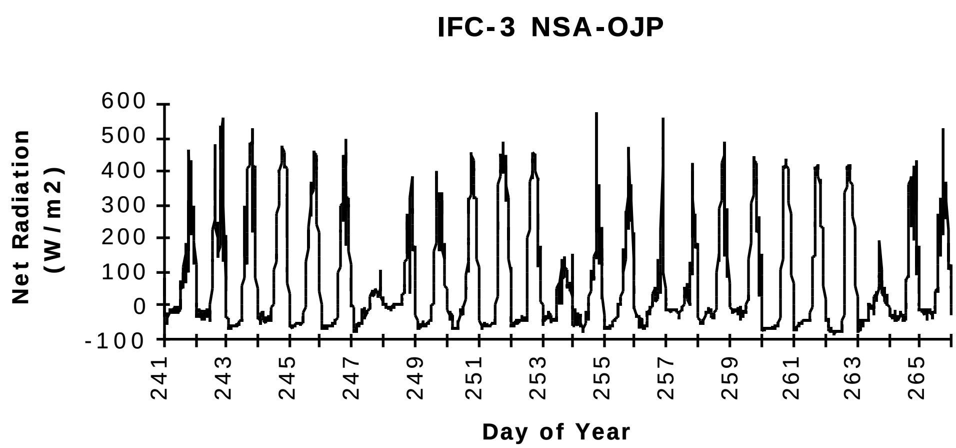


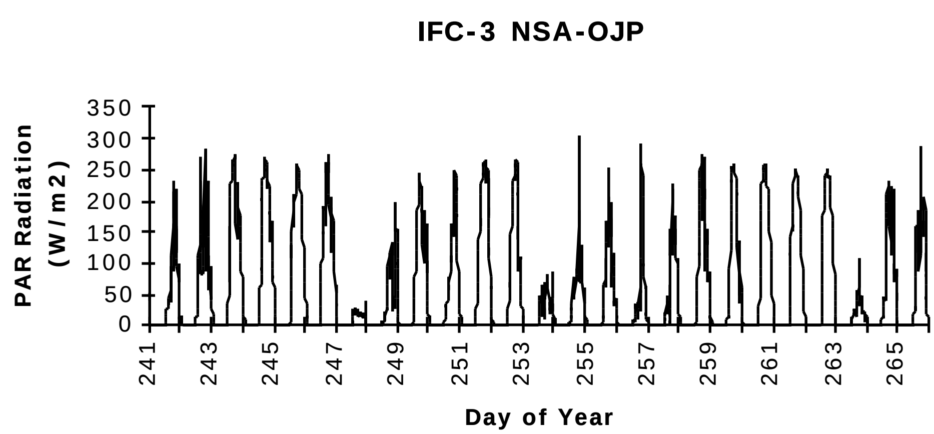




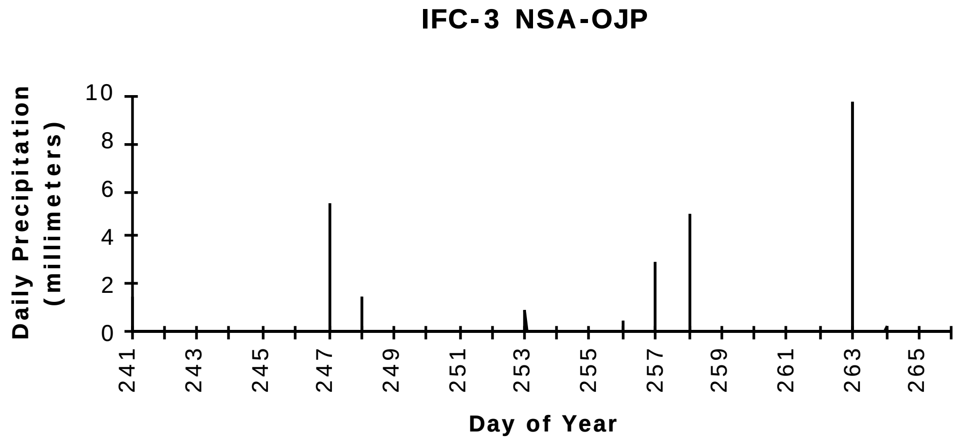
2.2.5.1 Meteorological Data – IFC-3 (cont.)

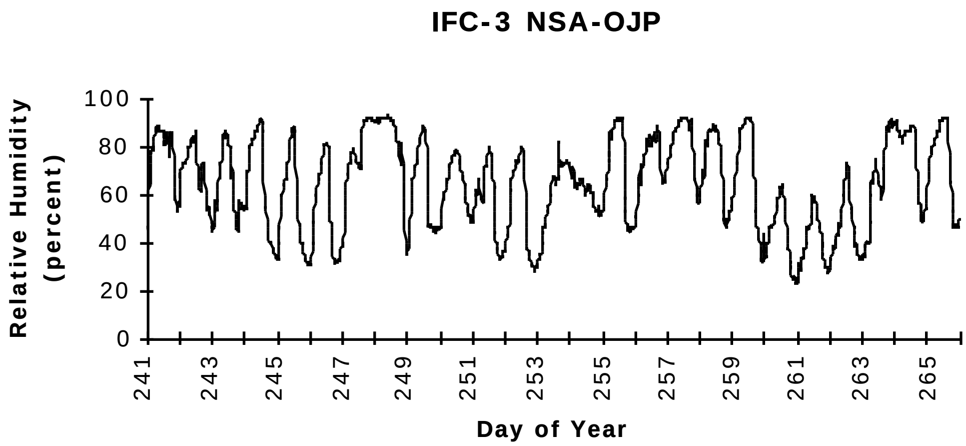


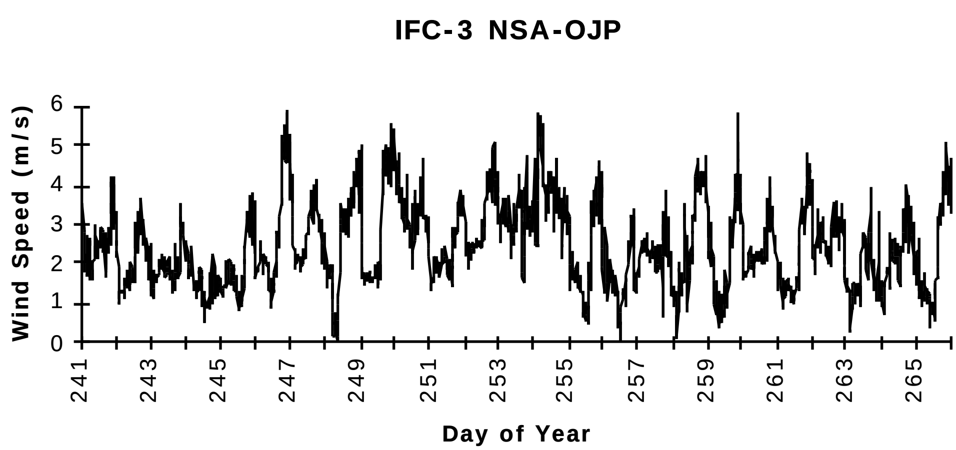




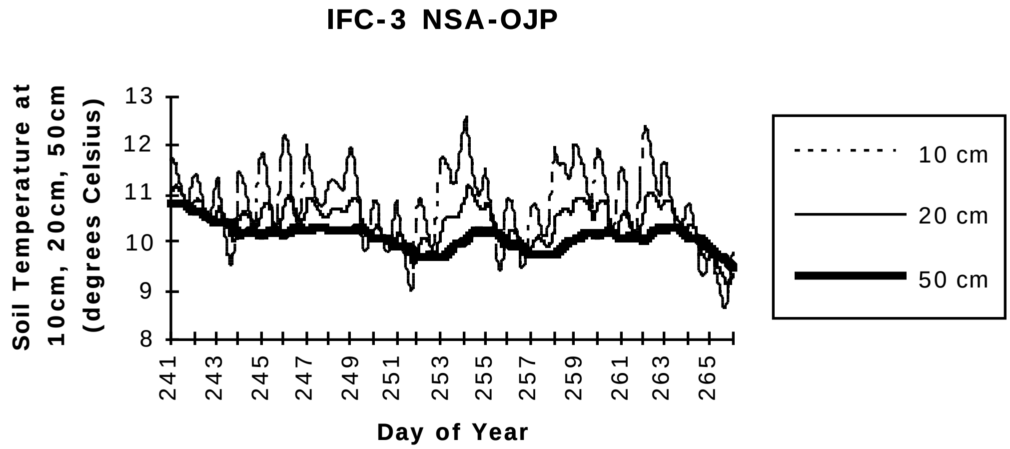
2.2.5.1 Meteorological Data – IFC-3 (cont.)







2.2.5.1 Meteorological Data – IFC-3 (cont.)



2.2.5.2 IFC-3 Aircraft Operations

	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11
GOLDEN NSA													
DAYS SSA													
ER-2													
(RE)													
C-130								TN		TN			TN
(RC)													
Chieftain		TN, TN	TN					TN	TN	TN	RT		TS
(RP)													
Helicopter					TEST			TN, TN	TN	TN, TN	TN		TS
(RH)													
DC-8													
(RD)													
CV-580													
(RV)													
Twin Otter													
(RT)													
Aerocommand	WS	WS	WS	WS	WS		WS	WS	WS	WS	WS	WS	
(RA)													
Electra	CS	CS		RT	RT			RT	CS		RT		
(FE)													
King Air	TEST	GN	LN		GN			GN		RT	CS		CS
(FK)													
Twin Otter	TN	GN	TN	GN	GN-TN			GN-TN		TS,			TS
(FT)										TS-RT			
Long EZ	CS,TEST	CS	CS-TS		TS		TS	CS	TS, TS	GS,GS	TS		CS
(FL)													
LANDSAT													
				SSA									
SPOT										NSA	NSA		

CS: Candle Lake Run, SSA
GN: Grids/stacks, NSA
LN: Regional/mini transect, NSA
RT: Regional transect

TEST: Testing instruments
TN: TF site specific run, NSA
TS: TF site specific run, SSA
WS: Soil moisture survey,SSA

2.2.5.2 IFC-3 Aircraft Operations (cont.)

	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19	9/20	9/21
GOLDEN DAYS NSA										
GOLDEN DAYS SSA										
ER-2 (RE)					MS	MN-RT				
C-130 (RC)		TS		TEST	TS-MS	TN-MN-RT				
Chieftain (RP)		TS		TS	TS	RT				
Helicopter (RH)		TS, TS	BS	BS,TS	TS, TS,BS	CAL				
DC-8 (RD)									BN-RT-BS	
CV-580 (RV)									BN-RT-BS	BS
Twin Otter (RT)										
Aerocommand (RA)										
Electra (FE)		RT			CS					
King Air (FK)	CS	GS			GS-CS	CS				
Twin Otter (FT)	TS	GS	LS	TS, TS	GS	TS	RT, RT	GN-TN		
Long EZ (FL)	TS	TS		TS-CS						
LANDSAT										
							SSA			
SPOT						NSA	NSA			
		SSA			SSA					

Shaded cells (Golden Days): NSA 9/17; SSA 9/12–9/17.

BN: Radar or microwave baseline, NSA
BS: Radar or microwave baseline, SSA
CAL: Calibrating instruments
CS: Candle Lake Run, SSA
GN: Grids/stacks, NSA
GS: Grids/stacks, SSA
LS: Regional/mini transect, SSA
MN: Mapping, NSA
MS: Mapping, SSA
RT: Regional transect
TEST: Testing instruments
TN: TF site specific run, NSA

2.2.5.3 IFC-3 Ground Operations

Team		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
AFM –	NSA		*	*	*	*		*	*			*	*											
	SSA	*	*	*	*	*	*	*	*															
TF –	NSA			*					*		*													
	SSA	*	*		*	*	*	*		*		*												
TE –	NSA		*			*	*			*							*							*
	SSA	*	*		*	*	*	*	*		*		*	*			*							*
TGB –	NSA	*		*	*	*																		
	SSA								*	*	*													
HYD –	NSA	*							*	*														
	SSA	*					*			*														
RSS –	NSA		*	*				*				*								*	*			
	SSA	*	*	*				*				*	*	*			*		*	*	*			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

3.0 Staff Support

3.1 Staff Monitoring Program

3.1.1 Meteorological Measurements

3.1.1.1 AMS Stations

Investigator: Stan Shewchuk — SRC

Objectives: Collect continuous fifteen-minute core climate data from ten automated towers located across the BOREAS region. All ten towers measure such parameters as air temperature, soil temperature and moisture, relative humidity, station pressure, wind speed and direction, incoming and reflected shortwave radiation, PAR, net radiation, and precipitation. Five of these towers are supplemented with incoming diffuse shortwave radiation and incoming longwave radiation.
Please see AFM-7 for more information.

3.1.1.2 AES Surface

Investigator: Barrie Atkinson

Objectives: Capture data from existing Environment Canada autostations within the BOREAS region at a frequency of 15 minutes and supply to BORIS.

Types of Data Collected, Equipment Used:
Campbell Scientific Autostations

Data Type	Instrument Code	Instrument Type
Data Logger	A	CR10
	H	CR21X
Pressure	B	Setra 270
Hydro Thermistor	C	CS 207F
radiation shield	D	Gill type
	I	wooden Stevenson screen, pipe stand
	J	wooden Stevenson screen, wooden stand
Precipitation		
Tipping Bucket	E	AES TBRG (Tipping Bucket Rain Gauge)
Weighing gauge	K	Fisher and Porter with Nipher shield
	L	Fisher and Porter with alter shield
Snow Depth sensor	M	UDG01 ultrasonic depth gauge
Anemometer	F	RM Young
tower	G	Hossick Tilting
	N	

Campbell Scientific Autostations (cont.)

Station	**WBL**	**WWC**	**WFO**	**WGX**	**WHH**	**WLE**	**WLJ**
Data Logger	A	H	H	H	A	A	A
Pressure sensor	B	B	B	B	B	B	B
Hygro-Thermistor	C	C	C	C	C	C	C
height (cm)	200	120	115	115	280	120	120
radiation shield	D	I	I	I	D	J	J
Precipitation							
Tipping Bucket	E	E	E	E	E	E	E
rim height (cm)	75	75	75	75	75	75	75
Weighing gauge							
rim height (cm)							
Snow depth							
sensor height (mm)							
Anemometer	F	F	F	F	F	F	F
cup height	10	10	10	10	10	10	10
tower	G	G	G	G	G	G	G

Station	**WFF**	**WBU**	**WRJ**	**WJH**	**WSR**	**WLV**	**WIW**
Data Logger	A	H	A	H	A	H	A
Pressure sensor	B	B	B	B	B	B	B
Hygro-Thermistor	C	C	C	C	C	C	C
height (cm)	120	122	137	120	115	120	134
radiation shield	J	I	J	J	J	J	J
Precipitation							
Tipping Bucket	E	E	E	E	E	E	E
rim height (cm)	75	75	75	75	75	75	75
Weighing gauge				K		K	
rim height (cm)				200		200	
Snow depth						M	
sensor height (mm)						1240	
Anemometer	F	F	F	F	F	F	F
cup height	10	10	10	10	10	19.8	10
tower	G	G	G	G	G	N	G

Remote Environmental Automatic Data Acquisition Concept (READAC) autostation

ID	Location
ZHB	Hudson Bay, SK

Meteorological Automatic Reporting System II (MARS II) autostation

ID	Location
WDC	Uranium City, SK
WEQ	Swan River, MB
WJD	Grand Rapids, MB
WOY	Wynyard, SK
WSZ	Fisher Branch, MB
WVT	Buffalo Narrows, SK

Summary of Places and Times of Measurements:

Campbell Scientific Autostations, every 15 minutes from August 1993, at:

ID	Name	SYNO#	Latitude	Longitude	Elevation (m)
WBL	Bachelors Island, MB	71143	5145	9954	255.9
WWC	Collins Bay, SK	71075	5811	10342	492.1
WFO	Flin Flon, MB		5441	10141	303.9
WGX	Gillam, MB	71912	5622	9442	145.3
WHH	Hunters Point, MB	71142	5302	10056	256.1
WLE	Lucky Lake, SK	71455	5057	10709	664.7
WLJ	Meadow Lake, SK	71125	5408	10831	481.0
WFF	Melfort, SK	71456	5249	10436	490.0
WBU	Nipawin, SK	71130	5220	10400	371.9
WRJ	Rosetown East, SK	71510	5134	10755	586.0
WJH	Southend, SK	71451	5620	10317	344.1
WSR	Spiritwood West, SK	71133	5322	10733	584.3
WLV	Waskesiu Lake, SK	71454	5355	10604	569.4
WIW	Watrous East, SK	71511	5140	10524	525.6

Campbell Scientific Autostation Data Produced

Column	Units	Explanation
ID		Station Identifier
Name		Station Name
SYNO#		International synoptic number for station
Latitude	Deg*100+mins	
Longitude	Deg*100+mins	
Elevation	m	Station elevation above Mean Sea Level
JulnDy		Julian day; day of the year
TimeUTC	Hrs*100+mins	Coordinated Universal Time
MSL P	millibars	Mean Sea Level pressure
Stn P	millibars	Station pressure
Temp	degrees C	Air temperature (~1.5 m)
DewPt	degrees C	Dew point (~1.5 m)
Windspd	knots	scalar Wind speed (2 minute mean at ~10 m)
Rmwnd	knots	Resultant mean wind speed
RWnddr	deg (true N)	Resultant mean Wind direction
SigThet	degrees	Standard deviation of wind direction
Gust	knots	Peak wind (over 10 minutes at ~10 m)
Pcp	millimeters	Liquid precipitation since last hour (minute 00)
T Max	degrees C	Maximum temp since last synoptic hour
T Min	degrees C	Minimum temp since last synoptic hour
P tend	millibars	3 hour pressure tendency (valid only at minute 00)
PcpFmSy	millimeters	liquid precipitation since last synoptic hour
RH/100	percent	Relative Humidity divided by 100
Fisher	millimeters	Fisher and Porter weighing precipitation gauge
SnwDp	centimeters	Snow depth

Remote Environmental Automatic Data Acquisition Concept (READAC) autostation available about every 15 minutes during IFCs 1994.

ID	Name	SYNO#	Latitude	Longitude	Elevation (m)
ZHB	Hudson Bay, SK	71868	5249	10219	358

Column	Units	Explanation
JulnDy		Julian day; day of the year
Time EST	Hrs*100+mins	Eastern Standard Time (= Coordinated Universal Time - 5 hours)
Rpt.	SA or SP	Report type; regular (SA) or special (SP)
Sky	100s feet	Sky condition, up to 4 cloud layers, and up to 1 surface based layer
Vis.	nautical miles	Meteorological Optical Range; a V may be appended if the visibility is variable)
MSL P	hPa	Mean Sea Level pressure is not calculated
Temp	degrees Celsius	Air temperature (~1.5 m)
DewPt	degrees Celsius	Dew point (~1.5 m)
Wind	10s degrees	First 2 digits, true wind direction (2 minute mean at ~10m)
	knots	2 or 3 digits, wind speed (2 minute mean at ~10 m)
	G	gust indicator (optional)
	knots	2 or 3 digits, peak 5 second mean wind speed over 2 minutes at ~10 m (optional)
Alt.	1/100s inches Hg	altimeter (most significant digit (2 or 3) omitted)
Opacity	10s percent eg 1246	summation opacity, percentage in each layer reported 10% for first layer, 20% for first two layers, 40% for first three layers, 60% for first four layers
MMVis	1/10s nau. miles except 9+ nm	first group, minimum visibility (last 10 minutes) second group, maximum visibility (10 minutes)
	'V' between	visibility variable
Stn P	1/10 hPa	Station pressure
TMin	1/10 degrees C	Minimum temperature last 60 minutes
TMax	1/10 degrees C	Maximum temperature last 60 minutes
WndGrp	10s degrees	first 2 digits, true wind direction (10 minute mean at ~10m)
	knots	3 digits, wind speed (10 minute mean at ~10m)
	G	gust indicator (always present)
	knots	3 digits, peak 5 second mean wind speed (over 10 minutes at ~10m)
	10s degrees	2 digits, peak wind speed direction (over 60 minutes at ~10m)
	knots	3 digits, peak 5 second mean wind speed (over 60 minutes at ~10m)
	degrees	one digit, units digit from the 2 minute mean wind direction
Pcp	1/10s mm	first group, accumulated liquid precipitation since last servicing
	1/10s mm	second group, accumulated liquid precipitation in last 60 minutes

Meteorological Automatic Reporting System II (MARS II) autostation available about every 15 minutes during IFCs 1994.

ID	Name	SYNO#	Latitude	Longitude	Elevation (m)
WDC	Uranium City, SK	71076	5934	10829	318
WEQ	Swan River, MB	71443	5207	10114	335
WJD	Grand Rapids, MB	71858	5311	9916	226
WOY	Wynyard, SK	71865	5146	10412	561
WSZ	Fisher Branch, MB	71442	5105	9733	253
WVT	Buffalo Narrows, SK	71077	5550	10826	431

Column	Units	Explanation
JulnDy		Julian day; day of the year
Time EST	Hrs*100+mins	Eastern Standard Time (UTC - 5 hours)
Temp	1/10 degrees C	Air temperature (~1.5 m)
DewPt	1/10 degrees C	Dew point (~1.5 m)
Vis	index	Visibility
Wndspd	1/10 knots	Wind speed (10 minute mean at ~10 m)
Gust	1/10 knots	Peak wind over 10 minutes at ~10 m
Wnddir	deg from true N	Wind direction (10 minute average at ~ 10 m)
CldGrp1	ChChCwC%	ChCh Height of last detected cloud (100s feet) within the last 6 minutes Cw 1 = cloud overhead at time of observation 0 = no cloud C% 10s percent of time cloud detected overhead during previous hour
CldGrp2	C1C2C3C4 HEIGHTS C1 0 - 500 feet C2 501 - 1000 feet C3 1001 - 2000 feet C4 above 2001 feet	 NUMBERS (any number can appear in any height) 0 - no cloud in the past 50 minutes or more 1 - no cloud in the past 40 minutes or more 2 - no cloud in the past 30 minutes or more 3 - no cloud in the past 20 minutes or more 4 - no cloud in the past 10 minutes or more 5 - transition - cloud became significant or insignificant in the last 10 minutes 6 - cloud detected for the past 10 minutes or more 7 - cloud detected for the past 20 minutes or more 8 - cloud detected for the past 30 minutes or more 9 - cloud detected for the past 40 minutes or more
Pcpn	count	count of bucket tips since last servicing; each count equals 0.2mm of liquid precipitation
Stn P	1/10 millibars	Station pressure; if greater than 1000, the '1' is understood

Known Problems or Caveats:
Some missing data, mostly due to power outages.

3.1.1.3 Upper Air Network

Investigator: Alan Barr — AES

Objectives: Deploy radiosondes from BOREAS locations. Collect, process, and quality check data from these locations and pre-existing sites in the BOREAS region. Sondes were launched from two times up to seven times daily during Intensive Field Campaigns. Soundings have also been interpolated to five millibar levels for a Level-2 data set. Please see AFM-5 for more information.

3.1.1.4 ECMWF Data

Investigator: BOREAS Staff

Objectives: A gridded surface data set for all of 1994 has been acquired from the European Centre for Medium-Range Weather Forecasts (ECMWF). This data set covers the BOREAS region in a Latitude/Longitude grid at a grid length of 0.5 degrees and is comprised of parameters from the ECMWF/WCRP Level III-A Global Atmospheric Data Archive. Parameters are reported four times daily at six hour intervals. Parameters include surface pressure, mean sea level pressure, wind components, air temperature and dewpoint temperature, surface temperature at three levels, surface wetness at three levels, surface soil wetness, deep soil wetness, deep soil temperature, surface geopotential, land-sea mask, surface roughness, albedo, climatological deep soil wetness, climatological deep soil temperature, snow depth, snowfall, large scale precipitation, convective precipitation, and evaporation. Total precipitation is given daily at 1200 UTC. Data is archived on 8mm Exabyte tape in FM 92-VIII Ext. GRIB format. Similar data sets are planned for 1995 and 1996.

3.1.2 Hydrology Measurements

3.1.2.1 Soil Survey and Characterization
Investigators: Hugo Veldhuis, Elissa Levine

Objectives: The objective of the NSA soil characterization was to provide investigators with a map of soil types in the modeling sub-area and around the towers.

Types of Data Collected:
The map of the NSA modeling sub-area was done at a scale of 1:50,000 while the maps of the tower areas were done at 1:5,000. This characterization also includes information about physiography, surficial deposits, soil moisture regime, and permafrost.

The types of data collected included aerial photography taken between 1971 and 1978. The field data were used in conjunction with the photos to delineate soil polygons.

Summary of Places and Times of Measurements:
Most of the field data were collected at the NSA tower sites and at various remote locations in the modeling sub-area during the 1994 field campaigns.

Known Problems and Caveats:
There are no obvious caveats mentioned in Hugo Veldhuis' report, although his report should be reviewed thoroughly before using or inferring anything from this data set.

3.1.2.2 Soil Properties
Investigator: Hugo Veldhuis, Elissa Levine

Objectives: The objective of collecting the soils properties data is to provide investigators with detailed data about specific soil properties at the tower sites. This data is important for modeling at the site level.

Summary of Places and Times of Measurements:
Samples of soils at the NSA tower sites were collected and analyzed. TE-1 collected and analyzed soil samples for the same soil properties at the SSA towers.

Types of Data Collected:
The samples were collected at the various soil horizons at about 5 different soil pits per tower site. Field samples were collected and analyzed for particle size, total nitrogen, total organic and inorganic carbon, water pH, CaCl2 pH, extractable acidity, exchange capacity, exchangeable Ca Mg Na and K, field moisture, saturated moisture, and wilting moisture.

3.1.3 Biophysical Measurements

3.1.3.1 Allometry/Biometry

Allometric relationships were developed from sacrificed trees to determine LAI, biomass and NPP by the TE-6 group. At tower and auxiliary sites DBH, tree height distributions, and species composition data were collected. TE-23 calculated gap fractions, effective LAI, and Fpar from hemispherical photographs collected at the tower and auxiliary sites.

3.1.4 GIS Data

Forest Cover: Forest cover data sets were acquired from various Canadian agencies. The forest cover data of the SSA identifies map polygons in terms of softwood/hardwood combinations, year of stand origin, height class, and canopy closure. This data was produced at a scale of 1:12,500. The forest cover data of the NSA includes species, crown closure, and cutting class (age). The NSA data was produced at a scale of 1:15,840.

DEMs: Digital elevation models (DEMs) of the modeling sub-areas of the NSA and SSA were produced from contours at 1:50000 scale by HYD-8. The contour interval of the original vector data is 25 feet. The contours are gridded at a cell resolution of 100 meters in the UTM projection. BORIS staff reprojected this data to the BOREAS grid projection at a cell size of 30 meters.

A DEM of the BOREAS region was produced by the USGS EROS Data Center. This DEM was produced at a cell resolution of 30 arc seconds. This was reprojected into the BOREAS grid projection with a cell resolution of 1000 meters.

Soils: Soils map data existed for the SSA at a scale of 1:125,000. This data was gridded by BORIS staff and made available to investigators. This data provided information about the soil names. Ancillary information was also provided that included detailed information about each soil name. However, caveats about inferring too much from this data are included.

Soils data for the entire BOREAS region was also available from Canadian government agencies. This soils data was mapped at the provincial scale. These data sets were combined for Saskatchewan and Manitoba, converted to the BOREAS grid projection, and gridded to a cell size of 1000 meters. Unfortunately, because of differences in the mapping between the 2 provinces, there is a polygonal discontinuity along the border.

3.1.5 GPS Locations

Investigator: Darcy Snell

Objectives: The objective of collecting GPS locations was to get precise locations for the sites to compare ground measurements to the satellite and aircraft imagery.

Summary of Places and Times of Measurements:
The auxiliary and tower sites as well as other special sites were located with GPS in the NSA and SSA. Darcy Snell collected the GPS data during the 1994 field campaigns.

Types of Data Collected:
A wide area correction technique was used that allowed determination of locations to +/- 5 meters without using a base station. A six channel Trimble Pathfinder Basic Plus rover unit was used.

Known Problems and Caveats:
Snell duplicated many of the locations that he collected. His locations were found to be consistent within a few meters. His GPS work helped us to discover some large location errors in the 1:50,000 scale NTS maps of the NSA. The maps of the SSA were found to be accurate to within about 60 meters.

As a result of finding errors in the maps of the NSA, GPS locations of some selected road intersections were collected for BOREAS by the Geodetic Survey of Canada. These locations were used to geotag the satellite imagery of the NSA.

3.1.6 Instrument Calibration

3.1.6.1 Aircraft Instruments

3.1.6.1.1 Radiometric Scale Realization

Prior to BOREAS'94 two calibration comparisons were conducted between radiometric calibration sources used by GSFC, Ames Research Center (ARC), the Institute for Space and Terrestrial Science at York University and the Canadian Center for Remote Sensing. During the first comparison the ARC sources used to calibrate MAS and NS001 were calibrated to the GSFC radiometric scale. During the second comparison the ISTS and CCRS sources were cross compared to the GSFC sources.

3.1.6.1.2 On site Radiometric and Spectral Calibration sources

A 76 cm hemispherical integrating source was maintained on site at the active airport (Prince Albert or Thompson) during the IFC's. This source was radiometrically calibrated at GSFC prior to deployment and recalibrated during IFC-2 on site at Thompson. Calibration radiances of the source were provided to users of the calibration source. ASAS, CASI, the helicopter SE590 and MMR and the Exotech on the Twin Otter all viewed the hemisphere during the campaign, most at least once per IFC. An extended area blackbody source was also available on site and was used at least once for calibration of the PRT-5 on the Twin Otter.

3.1.6.1.3 Diffuse Reflectance Reference panels

The University of Nebraska characterized the reflectance of calibration panels used by investigators measuring surface reflectance prior to the start of the BOREAS field season.

3.1.6.1.4 In-Flight Calibration and Comparison of Aircraft Instrumentation

A ground reference calibration site was set up and maintained by RSS-19 near the airport in the SSA during IFC's 1 and 3. The surface reflectance of this site was characterized in the 400 to 2500 nm spectral region to provide a calibration of the various ground looking reflective sensors.

3.1.6.2 Satellite Instruments

Satellite sensor calibration parameters were obtained directly from M. Dinguirard for SPOT HRV as opposed to using the data available on the data tapes. For Landsat TM and NOAA AVHRR the current values as implemented in the Canadian processing systems were used.

3.1.6.3 Thermal Radiance Intercomparison

Lake temperatures were measured for aircraft and satellite thermal instrument intercomparison and calibration. The temperature was measured by two ways. One was the IR thermometer method. A boat was taken out to several points on the lake and the IR thermometer was pointed at the surface from a height of about 2 - 3 feet on the four sides of the boat. The second way was with a glass bulb mercury thermometer - these data were no longer collected after the mercury thermometer found its way to the bottom of the lake. The position on the lake was obtained by shore sighting and in IFC-3 by a GPS system.

3.1.6.4 Gas Calibration
Staff: Betsy Middleton, Michele Ernst, Lori Leeder

During the 1994 Field Campaigns, BOREAS provided two sets of 12 calibration cylinders for each laboratory (Paddockwood and Thompson). Each 12 cylinder set was comprised of: 1 each methane in air (0.5, 0.8, 2 and 9 ppmv), 2 each CO_2 in air (300, 355, and 400 ppmv), and 1 each CO_2 in air (700 and 2000 ppmv). In addition, two IRGAs (LI-COR 3200) were loaned to the labs for use with the calibration standards. In 1994, CCRS (Gill Traynor and Jing Chen) arranged a bulk order of working standards to the field labs. All of these were collected by Medigas/PRAXAIR in late September 1994.

CH_4 calibration results dated April 29, 1994

Cylinder id	# of inj. in avg.	CH_4 ppm	Std ppm
15779	7	0.5079	0.0004
15761	7	0.5078	0.0009
15746	7	0.9006	0.0022
15741	7	0.8988	0.0016
15755	9	2.0455	0.0005
15758	9	2.0515	0.0015
15777	10	9.1145	0.0017
15752	10	9.1302	0.0029

CO_2 calibration results dated May 2, 1994

Serial Number	Concentration ppmv	Std ppmv
78301	299.661	0.0180
15653	356.104	0.0228
15763	397.353	0.0300
15628	299.164	0.0168
15796	356.170	0.0091
15760	398.089	0.0315

4.0 Data Collected

This section provides tables which describe generally the types of data collected by each group, the sites at which the groups collected the data, and the dates the groups were in the field.

4.1 Data Types Collected

The following tables list the types of data collected by the science groups at the different study areas.

BOREAS Data Types Collected — Northern Study Area (NSA)

Field measurements of C, H2O flux	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	**Mixed**
Soil CO2	TGB1, 12 TF3	TGB3	TGB12, 1	TGB3, 1	TGB12 TE6		
Litter fall	TE6		TE6		TE6		
Leaf Respiration	TE2,9		TE2, 9		TE2, 9		
Wood Respiration	TE2		TE2		TE2		
Photosynthesis	TE9, 5		TE9, 5	TE9	TE9, 5		
Stomatal Conductance	TE9, 5		TE9, 10	TE9	TE9		
ANNP	TE6	TGB3	TE6		TE6		
BNPP	TE6	TGB3	TE6		TE6		
Net Ecosystem Flux	TF3	TF10	TF8	TF10			
Soil CO2/CH4 flux	TGB1, 3	TGB3	TGB1	TGB3, 1	TGB3		
Bark Photosynthesis							
Dissolved Organic Carbon	TGB3	TGB3	TGB3				

OM & Nutrient Distribution	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	**Mixed**
Soil C, Nutrients	TGB12 TE6		TGB12, TE6	TGB12	TE6		
Root Biomass	TE6		TE6		TE6		
Wood Biomass	TE6		TE6		TE6		
Leaf Area	TE6		TE6, 7		TE6, 7		
Leaf Biomass	TE6		TE6		TE6		
Biomass nutrients	TE2, 9		TE2, 9		TE2, 9		

BOREAS Data Types Collected — Northern Study Area (NSA) (cont.)

Other Measurements	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	**Mixed**
Leaf Optical Properties	TE9		TE9	TE9	TE9		
Delta 13 of leaf, wood, air	TE5		TE5				
Delta O-18 of air, water	TE5		TE5				
Canopy Architecture	TE6		TE6		TE6		
Max Photosynthesis	TE9		TE9, 10		TE9		
Bark PSN, Trans, Chlorophyll							
Specific Leaf Area			TE7		TE7		
Sapflow							
LWP, Substrate Opt Properties							

Structural Properties - Stand	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	**Mixed**
Stem Density	TE13, 23 RSS16, 19		TE6, 23 RSS16, 19	TE23, TF10, RSS19	TE13, RSS16		
Basal Area	TE13, 23		TE6, 23	TE23, TF10			
DBH distribution	TE13, 23		TE6, 23	TE23, TF10	TE13		
Species	TE13	TGB3	TE6	TF10	TE13		
Tree Height distribution	TE13, 23 RSS16		TE6, 23 RSS16	TE23, TF10	TE13 RSS16		
% Canopy Cover							
Canopy Position	TE13		TE6		TE13		
Canopy Topography							
Direct Est of LAI	TE13		TE6	TE10	TE13		
Forest Floor Mass	TE13		TE6	STAFF	TE13		
Soil Texture	STAFF TE1		STAFF TE1	STAFF TE1	STAFF TE1		
Effective Rooting Depth	STAFF TE1		STAFF TE1	STAFF TE1	STAFF TE1		
% Coarse Fragments	STAFF TE1		STAFF TE1	STAFF TE1	STAFF TE1		
Stem Mapping, crown shape, rad	RSS19 TE23		RSS19 TE23	RSS19 TE23			
ANPP (1935-94), biomass,detritus	TE6		TE6		TE6		
Fpar, LAI (hemis-photos)	TE23		TE23	TE23			

BOREAS Data Types Collected — Northern Study Area (NSA) (cont.)

Structural Properties - Branch	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Live & Dead biomass/area	TE13		TE6		TE13		
Stem Sapwood Volume	TE13		TE6		TE6		
Total tree ht, crown depth	TE13		TE6		TE6		
Sapwood Area @ DBH, crown base	TE13		TE6		TE6		
Live & Dead Branch Biomass	TE13		TE6		TE6		
Average branch length, angle	TE13 RSS16		TE6, RSS16	RSS16	TE6, RSS16		

Structural Properties - Shoot, Leaf	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Silhouette Area	RSS16		RSS16		RSS16		
Needle Area Ratio	RSS16		RSS16		RSS16		
Twig Biomass Ratio	TE13 RSS16		TE6 RSS16		TE13 RSS16		
Needle Biomass & Area	TE13 RSS16		TE6 RSS16		TE13 RSS16		
Specific Needle Area	TE13 RSS16		TE6 RSS16		TE13 RSS16		
Leaf Density	TE13 RSS16		TE6 RSS16		TE13 RSS16		

Remote Sensing Parameters	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**BP**	**Auxiliary Sites**
Fpar	RSS7	RSS7	RSS7	RSS7	RSS7		RSS7
BRDF	RSS1, 2	RSS1,2	RSS1,2	RSS2			RSS2
APAR							
PAR Albedo	RSS1, 2	RSS2	RSS2	RSS2			RSS2
SW Albedo							
Canopy Chemistry							
Canopy Cover	RSS7	RSS7	RSS7	RSS7	RSS7		RSS7
Dielectric Constant	RSS17, 16, 15	RSS16, 15	RSS17, 16, 15	RSS16, 15			
Height							
LAI	RSS7	RSS7	RSS7	RSS7	RSS7		RSS7
Surface Roughness	RSS16	RSS16	RSS16	RSS16			
Soil Moisture	RSS16	RSS16, TGB3	RSS16	RSS16			
Soil Temperature	RSS17, TGB1	TGB3	TGB1	TGB1		TGB1	
Vegetation Temperature	RSS17						
Xylem Flow	RSS17						
Aerosol Optical Thickness				RSS11			RSS11

BOREAS Data Types Collected — Northern Study Area (NSA) (cont.)

Optical Properties - Leaf	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Reflectance	TE9 RSS19		TE10 RSS19	TE9 RSS19	TE9		
Transmittance	TE9 RSS19		TE10 RSS19	TE9 RSS19	TE9		
Surface BRDF							

Optical Properties - Twig, Branch	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Reflectance							
BRDF							

Optical Properties -Stem	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Reflectance	TE8		TE8		TE8		

Optical Properties -Understory	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
In situ Reflectance	RSS19 TE8,9		RSS19 TE8,9	RSS19 TE9	RSS19 TE8,9		
BRDF	TE9		TE9	TE9	TE9		

Trace Gas Fluxes	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**Beaver Pond**	**JP-Aux Site**
CH4	TGB1	TGB3	TGB1	TGB3,1		TGB4,1	TGB3
CO2	TGB1		TGB1	TGB3,1		TGB4,1	TGB3
Soil CH4	TGB1	TGB3	TGB1	TGB1		TGB4,1	
Soil CO2	TGB1	TGB3	TGB1	TGB1			
Isotope CH4 Flux	TGB6	TGB6, TGB3	TGB6	TGB6		TGB6	TGB6
Isotope CO2 Flux	TGB6	TGB6	TGB6	TGB6		TGB6	TGB6
Isotope Soil CO2	TGB12, 6	TGB12, 6	TGB12, 6	TGB12, 6		TGB12, 6	TGB12
Isotope Soil CH4	TGB6	TGB6	TGB6	TGB6		TGB6	
Substrate 13/14C (dom)	TGB12	TGB12	TGB12	TGB12		TGB12	TGB12
Substrate Mass (dom)	TGB12	TGB12	TGB12	TGB12		TGB12	TGB12
Tower CO2	TF3		TF8			TGB4	
Tower CH4			TGB1			TGB1	

Soil Moisture	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Neutron Probe			HYD1	HYD1			
TDR			HYD1	HYD1			
Gamma Ray							

BOREAS Data Types Collected — Southern Study Area (SSA)

Field measurements of C, H2O flux	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	**Mixed**
Soil CO2	TE1, TF7	TF11, TE1	TE1	TF4	TE1,TF1		TE6
Litter fall	TE6, TF7		TE6		TE6		
Leaf Respiration	TE2, 4, 12	TF11	TE2, 4	TE4	TE2, 4, 12		TE2, 4
Wood Respiration	TE2		TE2		TE2		TE2
Photosynthesis	TE4, 5, 10, 12	TF11	TE4, 5, 10, 11	TE4,10	TE4,5,10, 12		TE4, 5, 10
Stomatal Conductance	TE4, 5, 10, 12	TF11	TE4, 10	TF4, 10	TE4, 5, 10, 12		TE5, 10
ANNP	TE6		TE6		TE6, STAFF		
BNPP	TE6		TE6		TE6, STAFF		
Net Ecosystem Flux	TF9	TF12	TF5	TF4	TE1, 2		
Soil CO2/CH4 flux	TE1, TF7	TF11	TE1, 5	TF4	TE1, TF4		TE6
Bark Photosynthesis				TE8	TE8		
Dissolved Organic Carbon							

OM & Nutrient Distribution	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	**Mixed**
Soil C, Nutrients	TE1, 6		TE1, 6	TE1	TE1,6	TE1	
Root Biomass	TE6		TE6		TE6		
Wood Biomass	TE6		TE6		TE6		TE7
Leaf Area	TE6		TE6, 7		TE6		TE7
Leaf Biomass	TE6		TE6		TE6		
Biomass nutrients	TE2, 4, 10		TE2, 4, 10, 11	TE4	TE2, 4, 10	TE4	

Other Measurements	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	**Mixed**
Leaf Optical Properties	TE4, 10, 12		TE10, 14	TE4, 10, 12	TE4, 10, 12	TE4, 10	TE4, 10
Delta 13 of leaf, wood, air	TE5		TE5		TE5		
Delta O-18 of air, water	TE5		TE5		TE5		
Canopy Architecture	TE6		TE6		TE6		
Max Photosynthesis	TE10		TE10		TE10		
Bark PSN, Trans, Chlorophyll				TE8	TE8	TE8	
Specific Leaf Area			TE7				TE7
Sapflow			TE11				TE7
LWP, Substrate Opt Properties	TE12			TE12			

BOREAS Data Types Collected — Southern Study Area (SSA) (cont.)

Structural Properties - Stand	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	**Mixed**
Stem Density	TE13, 23, RSS16		TE6, 23 RSS15, 16	RSS15, 19 TE23	TE13, 23 RSS15, 16		
Basal Area	TE13, 23		TE6, 23	TE23,	TE13, 23		
DBH distribution	TE13, 23 RSS16		TE13, 23 RSS15, 16	RSS15	TE13, 23 RSS15, 16		
Species	TE13		TE6		TE13		
Tree Height distribution	TE13, 23 RSS16		TE6, 23, RSS16	TE23	TE13, 23 RSS16		
% Canopy Cover							
Canopy Position	TE13		TE6		TE13		
Canopy Topography							
Direct Est of LAI	TE13		TE6		TE13		
Forest Floor Mass	TE13		TE6		TE13		
Soil texture	Staff, TE1		Staff, TE1	Staff, TE1	Staff, TE1		
Effective Rooting Depth	Staff, TE1		Staff, TE1	Staff, TE1	Staff, TE1		
% Coarse Fragments	Staff, TE1		Staff, TE1	Staff, TE1	Staff, TE1		
Stem Mapping, crown shape, rad	TE23, RSS19		TE23, RSS19	TE23, RSS19	TE23, RSS19		
ANPP (1935-94), biomass,detritus	TE6		TE6		TE6		
Fpar, LAI (hemis-photos)	RSS19, TE23		RSS19, TE23		RSS7,19 TE23		

Structural Properties - Branch	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Live & Dead biomass/area	TE13		TE6		TE13		
Stem Sapwood Volume	TE13		TE6		TE13		
Total tree ht, crown depth	TE13		TE6		TE13		
Sapwood Area @ DBH, crown base	TE13		TE6		TE13		
Live & Dead Branch Biomass	TE13		TE6		TE13		
Average branch length, angle	TE13 RSS16		TE6, RSS16		TE13, RSS16		

BOREAS Data Types Collected — Southern Study Area (SSA) (cont.)

Structural Properties - Shoot, Leaf	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Silhouette Area	TE6 RSS16		TE6 RSS16		TE6 RSS16		
Needle Area Ratio	TE6 RSS16		TE6 RSS16		TE6 RSS16		
Twig Biomass Ratio	TE13 RSS16		TE6 RSS16		TE13 RSS16		
Needle Biomass & Area	TE13 RSS16		TE6 RSS16		TE13 RSS16		
Specific Needle Area	TE13 RSS16		TE6 RSS16		TE13 RSS16		
Leaf Density	TE13 RSS16		TE6 RSS16		TE13 RSS16		

Remote Sensing Parameters	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	**Auxiliary Sites**
Fpar	RSS7	RSS7	RSS7	RSS7	RSS7		RSS7
BRDF	RSS1, 2	RSS1, 2	RSS1, 2	RSS2	RSS1, 2		
APAR	RSS1		RSS1		RSS1		
PAR Albedo	RSS1, 2	RSS2	RSS1, 2	RSS2	RSS1, 2		RSS2
SW Albedo	RSS1		RSS1		RSS1		
Canopy Chemistry	RSS4		RSS4	RSS4	RSS4		
Canopy Cover	RSS7, 16	RSS7	RSS7, 16	RSS7, 16	RSS7, 16		RSS7
Dielectric Constant	RSS15, 17		RSS15, 17	RSS15, 17	RSS15, 17		
Height	RSS16		RSS16	RSS16	RSS16		RSS15
LAI	RSS4, 7	RSS7	RSS4, 7	RSS4, 7	RSS4, 7		RSS7
Surface Roughness	RSS16, 15		RSS15	RSS15	RSS16, 15		RSS15
Soil Moisture	RSS16	RSS16	RSS16	RSS16	RSS16		RSS16
Soil Temperature	RSS17		RSS17	RSS17	RSS17		
Vegetation Temperature	RSS17		RSS17	RSS17	RSS17		
Foliage, Wood Moisture			RSS15	RSS15	RSS15		
Xylem Flow	RSS17		RSS17	RSS17	RSS17		
Aerosol Optical Thickness				RSS11			RSS11, 12, 18

Optical Properties - Leaf	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Reflectance	TE10, 12		TE10		TE10, 12		
Transmittance	TE10, 12		TE10		TE10, 12		
Surface BRDF	TE12				TE12		

Optical Properties - Twig, Branch	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Reflectance	TE12				TE12		
BRDF	TE12				TE12		

BOREAS Data Types Collected — Southern Study Area (SSA) (cont.)

Optical Properties -Stem	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Reflectance	TE8		TE8		TE8		

Optical Properties -Understory	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
In situ Reflectance	RSS1, 19 TE8		RSS1, 19 TE8	RSS19	TE8		
BRDF							

Trace Gas Fluxes	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
CH4	TE1	TF11, TE1	TF4	TF4	TF1		
CO2	TE1,7	TF11, TE1	TF4	TF4	TF1		
Soil CH4	TE1	TF11	TF4	TF4	TE1		
Soil CO2	TE1	TF11	TF4	TF4	TE1		
Isotope CH4 Flux		TGB6	TGB6	TGB6			
Isotope CO2 Flux		TGB6	TGB6	TGB6			
Isotope Soil CO2	TGB12		TGB12, 6	TGB12, 6	TGB12		
Isotope Soil CH4				TGB6			
Substrate 13/14C (dom)	TGB12	TGB12	TGB12	TGB12	TGB12		
Substrate Mass (dom)	TGB12	TGB12	TGB12	TGB12	TGB12		
Tower CO2	TF7, 9	TF11	TF5	TF4	TF1, 2		
Tower CH4		TF11	TF7		TF1, 2		

Soil Moisture	**OBS**	**Fen**	**OJP**	**YJP**	**OA**	**YA**	
Neutron Probe			HYD1	HYD1	HYD1		
TDR			HYD1	HYD1	HYD1		
Gamma Ray							

4.2 Sites Visited

These tables describe the dates which teams visited sites during IFCs. Each table describes visits to a specific site for a given IFC or FFC. The columns are the dates, the rows are for the investigator teams identified by team code and PI name.

BOREAS Northern Study Area (NSA)

NSA Fen FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30
RSS-19	Miller										X									
TF-10	McCaughey	X	X					X	X	X	X	X	X	X	X	X	X	X	X	

NSA Fen IFC-1 1994		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
HYD-1	Cuenca												X		X									
HYD-9	Soulis						X																	
TE-2	Ryan											X						X			X			
TE-6	Gower																	X						
TF-10	McCaughey		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-3	Moore	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-4	Roulet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

NSA Fen IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
HYD-1	Cuenca						X					X		X						X		
RSS-7	Chen													X			X		X			
RSS-14	Smith															X	X					
TE-2	Ryan									X												
TE-22	Shugart																			X	X	
TF-10	McCaughey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-1	Crill				X																	
TGB-3	Moore	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-4	Roulet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-12	Trumbore															X						

NSA Fen IFC-3 1994		8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
HYD-1	Cuenca							X					X									X	
RSS-7	Chen						X																
TE-2	Ryan															X							
TF-10	McCaughey			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-1	Crill												X							X			
TGB-3	Moore	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
TGB-4	Roulet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
TGB-5	Zepp								X														
TGB-12	Trumbore																				X	X	X

NSA Beaver Pond FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30
TGB-5	Zepp													X						

NSA Beaver Pond IFC-1 1994		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
TE-2	Ryan					X																		
TGB-1	Crill			X				X	X		X	X	X	X					X			X	X	
TGB-4	Roulet	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
TGB-5	Zepp	X	X			X			X		X	X		X		X	X	X	X	X				

NSA Beaver Pond IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
TGB-1	Crill		X	X			X	X	X	X	X					X		X	X			
TGB-4	Roulet	X	X	X	X	X	X	X	X	X		X		X	X	X		X			X	X
TGB-05	Zepp					X	X		X	X	X	X		X	X	X					X	
TGB-12	Trumbore						X															

NSA Beaver Pond IFC-3 1994		4/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
HYD-8	Band																			X			
TGB-1	Crill				X	X							X		X	X	X		X		X	X	
TGB-3	Moore													X									
TGB-4	Roulet		X		X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	
TGB-5	Zepp								X	X						X							X
TGB-12	Trumbore																			X			

NSA Old Aspen FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30
RSS-19	Miller														X					
TGB-12	Trumbore																	X		

NSA Old Aspen IFC-1 1994		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
RSS-7	Chen																X							
TE-2	Ryan										X	X										X		X
TE-5	Ehleringer												X						X	X				
TE-6	Gower			X	X									X		X				X				
TE-9	Margolis							X								X	X			X	X			X
TGB-3	Moore												X											

NSA Old Aspen IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
HYD-1	Cuenca															X				X		
RSS-7	Chen																		X			
RSS-19	Miller													X								
TE-2	Ryan							X		X												
TE-5	Ehleringer													X	X	X	X	X	X			
TE-6	Gower							X							X				X	X		
TE-9	Margolis		X		X	X	X	X						X	X	X	X	X	X		X	

NSA Old Aspen IFC-3 1994		4/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
RSS-6	Williams									X													
RSS-7	Chen						X				X												
TE-2	Ryan		X	X	X											X	X			X	X		
TE-5	Ehleringer								X	X	X												
TE-6	Gower						X										X						
TE-9	Margolis								X				X	X	X			X		X		X	

NSA Old Black Spruce FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30
HYD-3	Davis							X	X	X	X	X	X		X	X				
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-19	Miller											X								
TE-9	Margolis																		X	X
TGB-12	Trumbore									X	X				X	X				

NSA Old Black Spruce IFC-1 1994		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
RSS-7	Chen																		X					
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TE-2	Ryan													X			X	X	X					
TE-5	Ehleringer											X				X	X							
TE-6	Gower										X		X		X						X	X		
TE-9	Margolis	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X			X
TF-3	Wofsy	X	X	X	X	X	X	X	X				X			X	X	X	X	X	X	X	X	
TF-6	Bessemoulin											X												
TGB-1	Crill		X		X		X			X							X							X
TGB-3	Moore										X						X							X

NSA Old Black Spruce IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
HYD-1	Cuenca									X							X	X		X		
HYD-9	Soulis																X					
RSS-7	Chen																	X				
RSS-14	Smith															X	X					
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-19	Miller													X								
TE-2	Ryan							X							X	X						
TE-5	Ehleringer											X										
TE-6	Gower								X	X					X							
TE-9	Margolis		X	X	X	X	X	X	X			X	X									
TF-3	Wofsy	X	X	X	X	X		X	X		X	X	X	X	X	X		X	X	X	X	X
TGB-1	Crill		X							X					X	X						
TGB-3	Moore			X						X												
TGB-4	Roulet							X											X			
TGB-12	Trumbore																	X				

NSA Old Black Spruce IFC-3 1994		8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
AFM-13	Schuepp									X	X												
HYD-1	Cuenca		X	X		X		X					X		X	X	X	X		X		X	
HYD-8	Band											X	X		X	X	X	X	X		X		
HYD-9	Soulis		X		X	X	X	X	X														
RSS-2	Irons																	X					
RSS-7	Chen					X																	
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-19	Miller												X										
TE-2	Ryan		X										X				X				X	X	
TE-5	Ehleringer					X																	
TE-6	Gower				X		X	X	X														
TE-9	Margolis							X			X					X	X	X			X		
TF-3	Wofsy		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-1	Crill										X	X					X	X					
TGB-3	Moore									X									X				
TGB-4	Roulet																X						

NSA Old Jack Pine FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30
HYD-3	Davis													X	X					
RSS-19	Miller										X				X					
TE-9	Margolis																		X	X
TGB-12	Trumbore													X						

NSA Old Jack Pine IFC-1 1994		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
HYD-1	Cuenca	X	X	X		X	X	X	X	X		X	X	X		X		X		X	X	X	X	X
HYD-9	Soulis											X												
RSS-7	Chen															X							X	
TE-2	Ryan							X		X	X									X				
TE-6	Gower			X	X	X	X							X						X				
TE-9	Margolis	X		X	X	X	X		X	X	X	X		X	X				X					X
TF-8	Fitzjarrald	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-1	Crill			X		X	X	X					X	X	X	X				X	X	X		
TGB-3	Moore										X													
TGB-4	Roulet					X	X	X	X	X					X				X					

NSA Old Jack Pine IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
AFM-6	Banta	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HYD-1	Cuenca		X	X	X			X	X		X		X		X	X	X		X		X	
HYD-9	Soulis																	X				
HYD-6	Peck							X														
RSS-7	Chen														X				X	X	X	
RSS-14	Smith															X		X	X			X
RSS-19	Miller													X								
TE-2	Ryan	X	X		X														X			
TE-6	Gower							X	X			X	X	X	X						X	
TE-9	Margolis	X	X	X		X	X			X		X			X			X	X	X		
TE-13	Apps																				X	
TF-3	Wofsy																				X	
TF-8	Fitzjarrald	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-1	Crill	X		X	X	X	X		X			X	X		X			X		X	X	
TGB-3	Moore	X		X						X					X							
TGB-4	Roulet			X																		
TGB-5	Zepp					X																
TGB-12	Trumbore															X						

NSA Old Jack Pine IFC-3 1994		8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
AFM-13	Schuepp						X		X														
HYD-1	Cuenca				X		X		X		X		X	X	X		X				X		
HYD-9	Soulis												X										
RSS-6	Williams									X													
RSS-7	Chen		X	X	X				X		X												
RSS-19	Miller						X			X													
RSS-20	Vanderbilt						X																
TE-2	Ryan		X								X	X		X	X	X	X			X	X	X	
TE-6	Gower								X								X						
TE-9	Margolis		X	X		X			X	X	X	X	X				X			X	X		
TF-7	Desjardins								X													X	
TF-8	Fitzjarrald		X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-1	Crill				X	X	X	X	X	X	X	X			X	X			X	X	X	X	
TGB-3	Moore											X		X									
TGB-4	Roulet															X							

NSA Young Jack Pine FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30
HYD-3	Davis									X		X	X			X	X			
RSS-17	Way																X			
RSS-19	Miller											X	X			X				
TF-10	McCaughey	X																		
TGB-12	Trumbore											X	X			X	X	X		

NSA Young Jack Pine IFC-1 1994		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
HYD-1	Cuenca	X	X	X		X	X	X		X		X	X	X		X	X	X	X	X		X		X
HYD-9	Soulis						X					X												
RSS-7	Chen																	X					X	
RSS-11	Markham							X		X	X					X						X	X	
TE-6	Gower							X																
TE-9	Margolis	X	X		X				X				X	X		X		X						X
TE-23	Rich																		X					
TF-10	McCaughey	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
TGB-1	Crill					X							X	X		X					X	X	X	
TGB-4	Roulet													X										

NSA Young Jack Pine IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
HYD-1	Cuenca	X	X	X	X	X		X	X		X		X		X	X			X		X	
RSS-7	Chen														X	X						
RSS-11	Markham										X	X	X	X	X	X	X	X	X	X		
RSS-14	Smith																	X		X		
RSS-19	Miller													X								
TE-2	Ryan																					X
TE-6	Gower																			X		
TE-9	Margolis				X		X	X		X					X	X	X		X			
TE-23	Rich	X																				
TF-10	McCaughey	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-1	Crill					X							X							X	X	
TGB-3	Moore		X																			

NSA Young Jack Pine IFC-3 1994		8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
AFM-13	Schuepp											X	X										
HYD-1	Cuenca				X		X		X		X	X	X		X		X		X		X		
RSS-7	Chen		X	X	X				X														
RSS-11	Markham	X	X	X	X	X	X	X	X	X	X												
RSS-19	Miller			X	X																		
TE-5	Ehleringer													X									
TE-9	Margolis									X				X						X			
TF-10	McCaughey		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-1	Crill						X	X															
TGB-3	Moore							X	X														
TGB-12	Trumbore																		X				

BOREAS Southern Study Area (SSA)

SSA Fen FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30
TE-1	Anderson														X			X		

SSA Fen IFC-1 1994		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
HYD-1	Cuenca											X		X		X		X		X		X		X
RSS-2	Irons												X											
RSS-19	Miller												X											
TE-1	Anderson	X	X	X	X	X		X		X	X	X	X	X	X		X				X	X	X	
TE-4	Berry						X																	
TF-11	Verma	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X
TGB-10	Westberg											X												

SSA Fen IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
HYD-1	Cuenca																		X			
RSS-7	Chen		X	X			X			X	X											
RSS-14	Smith							X	X													
TE-1	Anderson						X			X		X	X	X		X						
TE-4	Berry																			X	X	
TE-1	Middleton	X																				
TE-12	Walter-Shea																		X			
TF-11	Verma	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X

SSA Fen IFC-3 1994		8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
HYD-1	Cuenca			X		X						X					X						
RSS-7	Chen																		X				
TE-1	Anderson			X	X	X		X		X							X	X					X
TE-4	Berry						X																
TF-11	Verma	X	X	X	X	X	X	X				X	X	X	X	X	X	X		X	X	X	X

SSA Old Aspen FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2
AFM-7	Shewchuk			X																		
RSS-1	Deering									X	X	X	X	X	X	X						
RSS-15	Ranson									X												
RSS-16	Saatchi															X						
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TF-1	Black	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TF-2	den Hartog	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

SSA Old Aspen **IFC-1 1994**		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15	6/16	6/17
HYD-1	Cuenca				X																					
RSS-1	Deering	X	X	X														X	X	X	X	X	X	X	X	X
RSS-2	Irons														X											
RSS-3	Walthall				X																					
RSS-6	Williams																									
RSS-7	Chen		X							X	X															
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
RSS-18	Green																	X	X	X						
RSS-19	Miller		X																							
RSS-20	Vanderbilt														X											
TE-1	Anderson			X				X		X		X		X		X		X		X						
TE-2	Ryan	X								X	X	X	X	X												
TE-5	Ehleringer					X	X	X																		
TE-6	Gower																				X			X		
TE-7	Hogg		X	X	X																					
TE-8	Kharuk			X			X																			
TE-10	Middleton		X				X											X	X							
TE-12	Walter-Shea								X						X											
TE-23	Rich										X															
TF-1	Black	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
TF-2	den Hartog	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		
TGB-9	Niki																			X	X					
TGB-10	Westberg																			X	X	X				

SSA Old Aspen IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
RSS-1	Deering	X	X	X	X	X																
RSS-6	Williams								X													
RSS-7	Chen										X											
RSS-14	Smith						X															
RSS-15	Ranson								X													
RSS-16	Saatchi						X		X													
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TE-1	Anderson														X			X				
TE-2	Ryan		X	X		X																
TE-4	Berry																		X			
TE-5	Ehleringer							X	X					X		X			X			
TE-6	Gower				X																	
TE-7	Hogg		X	X							X											
TE-8	Kharuk								X													
TE-10	Middleton		X	X													X	X				
TE-11	Saugier																				X	
TF-1	Black	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TF-2	den Hartog	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-8	Monson																	X				
TGB-9	Niki																	X		X	X	X
TGB-10	Westberg	X	X	X	X																	

SSA Old Aspen IFC-3 1994		8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
HYD-6	Peck						X																
RSS-1	Deering		X	X	X																X	X	
RSS-7	Chen																				X		
RSS-08	Running																		X				
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-18	Green																				X	X	
RSS-19	Miller														X	X				X	X		
RSS-20	Vanderbilt																						
TE-1	Anderson								X	X							X				X		
TE-2	Ryan	X	X		X																		
TE-5	Ehleringer							X	X									X					
TE-6	Gower									X				X									
TE-7	Hogg													X									
TE-9	Margolis							X															
TE-19	Harriss												X										
TF-1	Black	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TF-2	den Hartog	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-9	Niki															X	X	X			X		
TGB-10	Westberg									X													

SSA Old Black Spruce FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2
HYD-3	Davis			X	X																	
HYD-9	Soulis			X	X																	
RSS-1	Deering	X	X	X	X	X			X													
RSS-15	Ranson										X											
RSS-16	Saatchi																X	X				
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-19	Miller				X	X																
TGB-8	Monson																				X	X

SSA Old Black Spruce IFC-1 1994		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
HYD-1	Cuenca										X		X			X		X		X		X		X
RSS-1	Deering													X	X	X		X						
RSS-2	Irons														X									
RSS-7	Chen					X			X		X													
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-18	Green														X									
RSS-19	Miller				X				X															
RSS-20	Vanderbilt														X									
TE-1	Anderson		X		X	X			X				X		X	X	X		X	X			X	
TE-2	Ryan			X											X	X	X	X	X					
TE-4	Berry		X					X																
TE-5	Ehleringer	X	X	X	X													X	X	X				
TE-6	Gower																						X	
TE-10	Middleton				X				X	X														
TE-12	Walter-Shea								X	X			X			X							X	
TE-23	Rich	X	X		X																			
TF-7	Desjardins	X	X	X	X	X	X	X	X	X	X	X	X											
TF-9	Jarvis	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X	X	X
TGB-8	Monson							X	X	X	X	X	X	X	X	X								
TGB-9	Niki							X	X	X	X	X	X	X										
TGB-10	Westberg							X	X	X	X	X	X	X										

SSA Old Black Spruce IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8	8/9
HYD-1	Cuenca										X	X			X		X		X		X		
RSS-1	Deering																	X			X	X	X
RSS-7	Chen							X				X											
RSS-14	Smith							X	X	X	X												
RSS-15	Ranson												X										
RSS-16	Saatchi				X	X				X		X											
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
RSS-19	Miller		X						X														
TE-1	Anderson		X	X	X	X	X			X	X	X	X		X	X	X	X	X	X			
TE-2	Ryan				X																		
TE-4	Berry				X	X	X		X														
TE-5	Ehleringer		X	X	X					X		X	X	X	X								
TE-6	Gower		X			X																	
TE-7	Hogg			X																			
TE-8	Kharuk												X										
TE-10	Middleton										X				X		X						
TE-12	Walter-Shea												X			X							
TE-22	Shugart		X	X																			
TE-23	Rich			X	X					X			X										
TF-7	Desjardins	X	X	X	X	X	X	X	X									X	X	X	X	X	
TF-9	Jarvis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
TGB-8	Monson		X				X	X	X	X	X	X											
TGB-9	Niki		X	X	X	X	X																
TGB-10	Westberg					X	X	X	X	X		X	X										

SSA Old Black Spruce IFC-3 1994		8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
AFM-8	Betts												X										
AFM-11	Mahrt																X		X	X	X		
HYD-1	Cuenca					X					X							X				X	
HYD-6	Peck			X		X	X																
HYD-8	Band													X									
HYD-9	Soulis			X																			
RSS-1	Deering										X	X				X	X	X	X	X			
RSS-7	Chen														X	X	X						
RSS-8	Running																				X	X	
RSS-16	Saatchi																					X	
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-18	Green																			X			
TE-1	Anderson			X	X	X			X						X							X	
TE-2	Ryan								X	X													
TE-4	Berry	X	X																				
TE-5	Ehleringer			X	X									X			X						
TE-6	Gower										X	X		X									
TE-10	Middleton												X				X						
TE-12	Walter-Shea								X		X												
TE-19	Harriss												X										
TF-7	Desjardins										X	X	X	X	X	X	X	X	X	X	X		
TF-9	Jarvis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TGB-1	Crill		X																				
TGB-8	Monson	X	X	X	X	X																	
TGB-9	Niki					X	X		X	X	X												
TGB-10	Westberg						X	X	X		X	X	X										

SSA Old Jack Pine FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30
AFM-7	Shewchuk			X																
HYD-3	Davis	X	X																	
HYD-9	Soulis		X																	
RSS-15	Ranson/Lang			X			X	X	X		X	X								
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-19	Miller					X	X													
TE-11	Saugier													X	X		X			
TGB-8	Monson																	X	X	X

SSA Old Jack Pine IFC-1 1994		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
AFM-6	Banta	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
HYD-1	Cuenca	X	X	X		X		X	X		X	X	X		X		X		X		X		X	
RSS-1	Deering				X		X		X	X	X	X	X											
RSS-2	Irons												X											
RSS-7	Chen			X				X																
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-18	Green						X		X															
RSS-19	Miller			X							X													
TE-1	Anderson	X	X	X	X	X						X	X	X										
TE-2	Ryan	X	X				X		X							X								
TE-4	Berry	X	X							X														
TE-5	Ehleringer	X	X	X	X													X		X				
TE-6	Gower	X	X																	X			X	
TE-10	Middleton									X														
TE-23	Rich																X							
TF-5	Baldocchi	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
TGB-8	Monson		X	X	X		X	X	X															
TGB-9	Niki				X						X	X			X	X	X	X	X	X				X
TGB-10	Westberg	X	X	X	X	X	X		X		X	X			X	X	X		X	X		X		

SSA Old Jack Pine IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
HYD-1	Cuenca			X		X	X	X		X		X		X		X		X		X		
HYD-6	Peck											X										
RSS-1	Deering					X	X	X	X	X			X	X		X	X					
RSS-4	Curran												X									
RSS-6	Williams								X													
RSS-7	Chen						X					X										
RSS-13	Gogineni								X													
RSS-14	Smith						X					X										
RSS-15	Ranson/Lang					X	X	X		X												
RSS-16	Saatchi	X	X		X	X					X											
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-19	Miller								X													
TE-1	Anderson			X		X	X		X	X	X	X	X	X	X	X		X	X	X	X	X
TE-2	Ryan			X	X																	
TE-4	Berry				X																	
TE-5	Ehleringer				X	X	X				X	X	X	X			X			X	X	
TE-6	Gower	X	X		X																	
TE-10	Middleton							X														
TE-11	Saugier		X	X		X	X	X	X		X	X	X	X	X	X		X	X	X	X	X
TE-12	Walter-Shea							X							X							
TE-23	Rich				X																	
TF-5	Baldocchi	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TF-7	Desjardins									X	X	X										
TGB-8	Monson			X	X	X	X															
TGB-9	Niki									X	X	X	X	X	X	X						
TGB-10	Westberg	X	X	X	X			X	X	X		X	X	X	X	X	X	X		X		X

SSA Old Jack Pine IFC-3 1994		8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
AFM-6	Banta													X	X		X	X	X	X			X
HYD-1	Cuenca		X	X	X		X										X		X				
HYD-6	Peck					X																	
RSS-1	Deering					X		X	X	X													
RSS-3	Walthall																					X	
RSS-7	Chen													X									
RSS-8	Running																			X			
RSS-11	Markham																					X	
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-19	Miller														X		X	X					
TE-1	Anderson			X	X	X			X	X			X	X	X						X		
TE-2	Ryan																			X	X	X	
TE-4	Berry			X	X	X		X	X														
TE-5	Ehleringer										X	X		X	X								
TE-6	Gower													X	X		X						
TE-7	Hogg															X							
TE-9	Margolis							X															
TE-19	Harriss													X									
TF-5	Baldocchi	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	
TF-8	Fitzjarrald								X														
TGB-1	Crill													X									
TGB-8	Monson					X	X		X	X	X	X											
TGB-9	Niki				X							X	X		X				X	X			
TGB-10	Westberg	X	X	X	X	X																	

SSA Young Aspen FFC-T 1994		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30
RSS-2	Irons								X											

SSA Young Aspen IFC-1 1994		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
RSS-3	Walthall				X																			
TE-6	Gower																							X
TE-8	Kharuk				X							X	X	X	X	X	X	X	X	X				
TE-10	Middleton											X	X											
TE-12	Walter-Shea		X				X							X		X								X
TE-23	Rich							X																

SSA Young Aspen **IFC-2 1994**		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
HYD-1	Cuenca				X				X		X		X		X		X		X		X	
RSS-14	Smith										X	X										
TE-4	Berry															X						
TE-8	Kharuk		X	X	X	X	X		X			X		X								
TE-10	Middleton											X	X									
TE-11	Saugier		X																			
TE-12	Walter-Shea			X	X							X										
TE-13	Apps						X															
TE-23	Rich		X																			
TF-6	Bessemoulin	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

SSA Young Aspen **IFC-3 1994**		8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
AFM-6	Banta																				X		
AFM-8	Betts																		X				
HYD-1	Cuenca					X					X							X					
HYD-6	Peck								X														
HYD-9	Soulis															X							
RSS-12	Wrigley														X								
TE-8	Kharuk							X															
TE-10	Middleton								X							X					X		
TE-12	Walter-Shea										X												
TF-6	Bessemoulin		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

SSA Young Jack Pine **FFC-T 1994**		4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30
RSS-15	Ranson		X	X	X		X	X	X	X	X	X								
RSS-16	Saatchi											X		X	X	X				
RSS-19	Miller								X								X			

SSA Young Jack Pine **IFC-1 1994**		5/24	5/25	5/26	5/27	5/28	5/29	5/30	5/31	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10	6/11	6/12	6/13	6/14	6/15
HYD-1	Cuenca	X	X	X		X		X	X		X	X	X		X		X		X		X		X	
RSS-7	Chen						X																	
RSS-11	Markham				X																			
RSS-19	Miller			X							X		X											
TE-2	Ryan		X		X	X																		
TE-4	Berry						X																	
TE-6	Gower																			X				
TE-8	Kharuk				X			X			X		X			X								
TE-10	Middleton			X												X								
TE-12	Walter-Shea			X															X				X	
TE-23	Rich		X		X																			
TF-4	Anderson	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

SSA Young Jack Pine IFC-2 1994		7/19	7/20	7/21	7/22	7/23	7/24	7/25	7/26	7/27	7/28	7/29	7/30	7/31	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8
HYD-1	Cuenca			X		X	X	X		X		X		X		X	X	X		X		
HYD-9	Soulis																		X			
RSS-4	Curran												X			X						
RSS-7	Chen								X													
RSS-11	Markham									X												
RSS-13	Gogineni								X													
RSS-14	Smith							X	X													
RSS-15	Ranson	X	X	X	X	X	X	X	X													
RSS-16	Saatchi		X			X					X											
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-19	Miller		X																			
TE-1	Anderson														X							
TE-2	Ryan							X				X	X	X	X	X						
TE-4	Berry		X	X													X	X				
TE-10	Middleton				X	X																
TE-12	Walter-Shea			X				X						X					X			
TE-23	Rich		X																			
TF-4	Anderson	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X

SSA Young Jack Pine IFC-3 1994		8/29	8/30	8/31	9/1	9/2	9/3	9/4	9/5	9/6	9/7	9/8	9/9	9/10	9/11	9/12	9/13	9/14	9/15	9/16	9/17	9/18	9/19
HYD-1	Cuenca		X	X	X		X										X					X	
RSS-2	Irons																					X	
RSS-7	Chen													X									
RSS-8	Running																				X	X	
RSS-17	Way	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
RSS-19	Miller																	X		X			
TE-2	Ryan					X	X	X	X														
TE-9	Margolis				X																		
TE-10	Middleton											X		X									
TE-12	Walter-Shea											X						X					
TF-4	Anderson	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
TF-11	Verma																						X
TGB-1	Crill													X									

5.0 Science Teams

In 1992, 85 science teams were selected out of over 240 proposals to take part in BOREAS. These were organized into six disciplinary groups for easier organization doing the field phase. The objectives and team descriptions of these six science groups are listed in the following sections.

5.1 Airborne Flux and Meteorology (AFM)

The National Research Council Twin Otter flux aircraft (AFM-4) flew a total of 22 double-grid patterns (9 in the SSA, 13 in the NSA), during the 1994 IFC's. These patterns consisted of a series of nine 16-km parallel tracks with a spacing of 2.0 km. Three of the flux tower sites were contained within this grid, and the grid itself lies entirely within the modeling sub-area of the SSA. Many of the Twin Otter grid patterns were flown in coordination with the University of Wyoming King Air, which flew a 32 x 32 km grid that encompassed both the Twin Otter grid and another of the flux tower sites (Old Black Spruce). The Twin Otter was flown at an altitude of approximately 35 m, while the King Air operated at 60 m. On each occasion, the grid was flown twice, with the second pass flown in the opposite direction to the first. This technique ensures that each pair of legs flown are time-centered on the same reference time, a technique designed to remove time trends from the data.

Two points are worth noting: first, the SSA is generally associated with lower Bowen ratio values (i.e. higher latent heat fluxes) over the period and; second, the values are consistently higher than the science team members expected prior to the field season. Most of the time, the area-averaged daytime sensible heat flux is greater than the latent heat flux (Bowen ratio greater than one). These data were acquired under a wide range of radiation conditions, from smoky and cloudy through to clear-sky; if anything, Bowen ratios were consistently higher under clear-sky conditions. These high Bowen ratios suggest significant stomatal control by the vegetation. Other data collected by the TF and TE teams support this and indicate that under warm, clear-sky conditions, the coniferous trees' stomata almost completely close down in response to the associated high atmospheric vapor pressure deficit, presumably a self-protective mechanism to prevent desiccation of the foliage.

The continuous program of radiosonde launches in BOREAS complemented the airborne and tower-mounted flux measurements. The effects of the large sensible heat fluxes released into the lower atmosphere over the region manifested themselves in greatly increased turbulence over the forest relative to the adjoining agricultural areas and impressively deep boundary layer development during the spring and early summer. Atmospheric boundary layer heights of 3000m or more were observed frequently during the field phase.

A goal of the AFM group is to apply results from large-scale field experiments like BOREAS to improve the performance of atmospheric general circulation models (GCMs). Data from a previous land surface experiment, the First ISLSCP Field Experiment (FIFE), were used by Betts et al. (1993) to improve the land surface and boundary layer components in the European Center for Medium Range Weather Forecasting (ECMWF) model. This work led to a remarkable increase in precipitation forecast skill for the anomalously wet summer of 1993 in the U.S. Midwest (Betts et al., 1994; Viterbo et al., 1994). A similar methodology is now being used to test and improve the land-surface parameterizations in the National

Meteorological Center (NMC) mesoscale model (Mitchell et al., 1994).

ECMWF and NMC provided operational forecasts to BOREAS, and ECMWF will produce two special research data sets. One is an hourly time-series of model output at full vertical resolution (31 levels) for 7 "grid-point" sites (representative of 50 x 50 km) which form a SW-NE cross-section across the BOREAS region; these are intended for direct comparison with time-series data collected at instrumented sites. The second data set will be a 4 x 4 array of cells of hourly model output (each cell averaged over 4 x 4 grid points), again at full vertical spatial resolution (31 levels) with full model diagnostics, to define the large-scale spatial structure across the BOREAS region. These model products will be compared with BOREAS data to test and improve the global model, and at the same time the biases between model and observations will be used to correct the global model output, so that the corrected model fields can be used to drive ecosystem models over the whole BOREAS region.

5.1.1 AFM Team Science Activities

5.1.1.1 AFM-1

PI: Timothy L. Crawford — NOAA Atmospheric Turbulence and Diffusion Division (ATDD)
Collaborators: Dennis Badocchi, Robert McMillen, and Ronald Dobosy — NOAA ATDD

Title: Experimental and Modeling Studies of Water Vapor, Sensible Heat, and CO2 Exchange Over and Under a Boreal Forest

Objectives: The primary objective was to measure the spatial structure of sensible and latent heat, CO_2, and momentum to allow for extrapolating surface-based measurements to regional scales. The Long-EZ (FL) flew 270 hours during the spring, summer and fall IFC's. Current analyses are focused on comparison of measurements with those from other aircraft and flux towers, improvement in data reduction algorithms, and exploration of the variance of spatial exchange. An ultimate objective is to develop algorithms to relate boundary-layer processes to satellite-derived data.

Type of Data/Instrumentation:
Airborne measurements were made of the three-component turbulent wind velocity, temperature, humidity, and carbon dioxide, along with incident and reflected PAR, net radiation, and surface temperature. Eddy flux data were recorded at 40 Hz. The BOREAS data base contains a complete description of the Long-EZ and its instrument systems, and describes the data reduction process and appropriate data use. The data consist of 3-km horizontal averages of state variables, along with turbulent fluxes and radiometric data. High frequency data are available on request from NOAA/ATDD for specific studies.

Place and Times of Measurements:
All Long-EZ flights occurred in the southern study area. The 115 km Candle Lake transect was the focus of many missions. Site-specific missions focused on the Old Jack Pine (OJP), Old Aspen (OA), or the Black Spruce (BS) sites. Additional Grid or "L" patterns were flown. The 1994 flight summary is given by the below table. The BOREAS data base contains a complete description of all flights.

NOAA Long-EZ Flight Operations Summary

ITEM	IFC 1	IFC 2	IFC 3	TOTAL
Flight Hours	83	75	68	226
SSA-OJP Passes	98	33	71	202
SSA-OA Passes	44	47	23	114
BS Passes	37	—	32	69
Candle Lake	35	55	32	122
Grid Pattern	—	5	3	8
"L" Pattern	6	14	—	20
Calibrations	28	5	2	35
Intercomparisons	18	8	2	28

Known Problems and Caveats:
The vertical-wind-velocity variance determined from the Long-EZ was elevated compared to that from the other flux airplanes. In intercomparison with towers the fluxes appear to be only marginally affected, the extra fluctuations in vertical wind being generally uncorrelated with fluctuations in temperature, moisture and other quantities. We have installed fast-response GPS receivers for future work to minimize this apparently spurious variance. Other problems are episodic and are reported in the BOREAS data base.

5.1.1.2 AFM-2

PI: Robert D. Kelly — University of Wyoming
Collaborator: Donald H. Lenschow — National Center for Atmospheric Research (NCAR)
(See also notes for AFM-3)

Title: Airborne Investigation of Biosphere — Atmosphere Interactions Over the Boreal Forest

Objectives: The primary objectives were to use the University of Wyoming King Air research aircraft for measurement of fluxes, profiles, and budgets of sensible heat, latent heat, and carbon dioxide in the boundary layer over the BOREAS experiment areas. Analyses are focused in several areas, including: 1) comparison of King Air flux measurements with those from the other 3 flux aircraft (Twin Otter, Electra, Long-EZ) and from the surface tower, 2) studies of the scales of boundary layer processes, including the fluxes, by means of spectral analysis and conditional sampling, 3) footprint analysis in coordination with similar studies for the Twin Otter, 4) the effects of seasonal changes, vegetation types, and clouds and smoke on the various fluxes, and 5) error analysis of the flux values.

Type of Data/Instrumentation:
The King Air flux measurements were obtained with the eddy covariance method, using the following instruments: 1) a boom-mounted gust probe with a laser-ring inertial navigation system and accelerometers for 3-D wind and gust components, 2) a fast-response temperature probe (modified at UW from original design by Friehe et al.), and 3) a LICOR 6262 infrared spectrometer for fast-response measurement of water vapor and carbon dioxide concentrations. Other measurements include up- and down-welling total and infrared radiation, as well as all the other "standard" dynamic and thermodynamic atmospheric variables.

Places and Times of Measurement:
The King Air was flown over both the northern and southern study areas of BOREAS in each of the three intensive field campaigns of 1994, logging 90 hours of research flight time during 29 flights (47 specific missions). Nearly all the flights were in the period 0900-1400 local time. Missions using the majority of King Air flight time were 1) horizontal passes at various heights along a 120-km transect across the southern study area, 2) single-level passes on multiple, parallel lines above 32x32 km areas in both study areas, 3) low-level transects between the two study areas, and 4) wing-to-wing intercomparison runs with other flux aircraft.

Known Problems and Caveats:
The spectra for carbon dioxide concentration show lower SNR values than those for vertical velocity, temperature, and water vapor, with correspondingly greater scatter in the carbon dioxide fluxes. The radiation measurements are probably not appropriate for estimates of net radiation.

5.1.1.3 AFM-3

PIs: Donald Lenschow, NCAR and Robert Kelly — Univ. of Wyoming
Collaborators: Steven Oncley, Ken Davis, Qing Wang, Jakob Mann, Andi Gietz, Gerhard Erhard, Christoff Kiemle, Al Cooper — Univ. of Wyoming

Title: Airborne Investigation of Biosphere — Atmosphere Interactions Over the Boreal Forest

Objectives: The Electra aircraft was used to measure the fluxes of momentum, sensible and latent heat, carbon dioxide, and ozone over the entire BOREAS region to tie together measurements made in both the Southern and Northern Study Areas. It also was used to study the planetary boundary layer using both in situ and remote-sensing measurements.

Type of Data/Instrumentation:
In situ measurements of turbulent fluctuations of the three-component wind velocity, temperature, humidity, carbon dioxide and ozone were made by sensors onboard the Electra. Also measured were aerosol and cloud droplet size distributions, radiation (upward and downward-going broadband shortwave (visible), infrared, and infrared temperatures), and surface radiation at 650 and 862 nm (to calculate the Normalized Difference Vegetation Index (NDVI). Video imagery from the Electra also is available.

A water vapor Differential Absorption Infrared Lidar (DIAL) system was deployed by the Deutsche Forschungsanstalt fur Luft- und Raumfahrt (DLR). This system looked downward and measured the aerosol backscatter and will be processed to produce profiles of water vapor through the boundary layer.

A special air sampler was used for the first time to measure fluxes of water and carbon dioxide, and also collected samples for analysis of turpenes.

Places and Times of Measurement:
The Electra usually flew along some portion of the "transect" between Saskatoon, Saskatchewan and a point north of Churchill, Manitoba. Most flight legs were at an altitude of

100 m above ground, however some legs were flown higher in and above the planetary boundary layer.

The Electra flew 25 missions during the three 1994 IFCs. Each flight was about 7 hours in duration and approximately centered around local noon.

Known Problems and Caveats:
There were several instrument malfunctions during this program, however most can be worked around by use of data from redundant sensors. The LiCor CO_2 calibration is still somewhat uncertain, though we are using the best that is currently available.

We have seen at times significant differences (factors of 2) between most second-order statistics calculated from data collected during wing-to-wing intercomparison flights with the University of Wyoming King-Air. We are attempting to resolve these differences.

5.1.1.4 AFM-4

PI's: J. Ian MacPherson — National Research Council of Canada; R. Desjardins — Agriculture Canada
Collaborators: P. Schuepp — McGill University; L. Mahrt — Oregon State University; A. Betts — Atmospheric Research

Title: Areal Estimates of Mass and Energy Exchange from a Boreal Forest Biome

Objectives: The NRC Twin Otter (FT) was flown to measure the fluxes of energy and trace gases on site-specific tracks near the primary flux towers, as well as on a 16x16-km grid, and regional transects during all three growing season IFC's of BOREAS. The data will be used to develop various techniques to obtain large area flux estimates of mass and energy using aircraft, tower and remotely sensed data. Measurements made along the transect between the SSA and the NSA will be used to characterize the spatial variations of canopy conductance and determine its usefulness for inferring mass and energy exchange of radiatively important trace gases.

Types of Data/Equipment Used:
The NRC Twin Otter atmospheric research aircraft was instrumented to make accurate measurements of the three orthogonal components of atmospheric motion, as well as supporting meteorological parameters such as temperature and dew point, and radiometric data, including incident and reflected solar radiation, surface temperature, greenness index (IR/R), and a four channel satellite simulator. Trace gas analyzers included the Agriculture Canada infrared absorption C02/H20 analyzer, a LICOR-6262 C02/H20 analyzer, three ozone analyzers (2 fast-response, and a TECO-49 for means). All data were recorded at a rate of 16-Hz. BORIS contains run-average meteorological, radiometric and flux data, a run being typically 10-16 km in length. Interested scientists can acquire 16-Hz data from the NRC directly for specific studies.

Flight Summary:
The flight summary that follows includes the operational area (SSA, NSA or transect between), and a brief summary of the tracks flown. Grid flights consist of 9 parallel 16-km tracks at a spacing of 2 km, each grid flown twice for a total of 18 lines. 'Ag' refers to a 18-km agricultural track just NE of Prince Albert. Site specific runs were flown past the principal flux towers identified by: OBS (Old Black Spruce), OJP (old Jack Pine), OA (old Aspen), YJP (Young Jack Pine) and the Fen (SSA only); these runs were usually done in sets of several repeated reciprocal runs; the number in brackets after each entry is the number of runs flown. Another track was flown in the NSA over the 1979 burn in the south half of the grid area. 'CL' refers to the Candle Lake run, a 115-km transect in the SSA across a variety of surface cover from aspen, to mixed forest, a burn, and old black spruce, as well as three lakes (Halkett, Candle, and White Gull). 'L' indicates the L-pattern flown from way points h-i-j identified in the BOREAS Operations Plan, and 'R' denote a special overflight of the NOAA radar set up near OJP in the NSA. 'S' indicates that a sounding, or atmospheric profile was flown, generally from near the surface to above the top of the mixed layer. 'INT' means an intercomparison was accomplished between the Twin Otter and one of the other flux aircraft (KA for King Air, LE for Long-EZ)

This summary refers to just those flights archived in BORIS; it excludes transit and test flights. The Twin Otter flew a total of 57 project flights in the growing season phase of BOREAS. Including transit and test flights, 116 flights totaled 257 flying hours.

IFC-1 Flight Summary

Flight	Date	DoY	Area	Runs Flown
01	May 23	143	SSA	Ag, OBS(2)
02	May 24	144	"	Ag(2), +test
03	May 25	145	"	Ag, S(2), CL(3), OA(6)
04	May 26	146	"	Ag(2), S(2), GRIDS
05	May 27	147	"	Ag, OJP(6), OBS(6), OA(6), CL
06	May 29	149	"	Ag(2), S, L(4), + cal runs on CL
07	May 31	151	"	Ag(2), INT (LE,KA), GRIDS
08	Jun 01	152	"	Ag, OBS(12), CL, INT(LE), OA(6), S
09	Jun 04	155	"	Ag(2), S, GRIDS, OBS(9)
10	Jun 04	155	"	OA(8), S
11	Jun 06	157	SSA/Tr	Ag, CL(2), Transect to Flin Flon
12	Jun 06	157	Tr/NSA	Continue Transect to Thompson
13	Jun 07	158	NSA	OBS(4), GRID, S
14	Jun 08	159	"	GRIDS, S, INT(KA)
15	Jun 08	159	"	GRIDS, Flux Divergence Study(6), S
16	Jun 09	160	"	OBS(8), OJP(14), Burn(6), S
17	Jun 10	161	"	GRIDS, OJP(2), S
18	Jun 11	162	"	S(2), Flux Divergence Study at OBS(12), YJP(8)
19	Jun 13	164	"	GRIDS, Flux Divergence Study(6), S
20	Jun 13	164	"	OBS(7), OJP(8), Burn(6), S, 2 runs at top of mixed layer

IFC-2 Flight Summary

Flight	Date	DoY	Area	Runs Flown
21	Jul 20	201	SSA	Ag(2), GRIDS, S
22	Jul 21	202	"	Ag(2), GRIDS, INT(KA), S
23	Jul 21	202	"	Ag, CL, OBS(7), INT(LE), S
24	Jul 22	203	"	Ag, OA(8), S
25	Jul 23	204	"	Ag, CL, OA(6), OBS(6), OJP(5)
26	Jul 24	205	"	Ag(2), GRIDS, S
27	Jul 24	205	"	Ag(2), L(4), S
28	Jul 25	206	"	Ag, CL, OA(6), OBS(6), OJP(6), Fen(10), S
29	Jul 25	206	"	CL(2), OBS(6), S
30	Jul 26	207	"	Ag(2), GRIDS, OBS(6), S
31	Jul 27	208	SSA/Tr	Ag, CL, S, Transect to Flin Flon
32	Jul 27	208	Tr/NSA	Continue transect to Thompson
33	Jul 28	209	NSA	GRIDS, R(4), S
34	Jul 29	210	"	OBS(7), OJP(8), YJP(8), Burn(5), R(3), S
35	Aug 01	213	"	GRIDS, R(3), S
36	Aug 02	214	"	OBS(8), OJP(4), YJP(9), Burn(6), R(3), S
37	Aug 04	216	"	GRIDS, S
38	Aug 04	216	"	OBS(7), OJP(6), YJP(8), SF-6 Study at OJP(25)
39	Aug 08	220	"	GRIDS, OBS(6), OJP(6), YJP(6), S

IFC-3 Flight Summary

Flight	Date	DoY	Area	Runs Flown
40	Aug 31	243	NSA	GRIDS, S
41	Sep 01	244	"	OBS(11), OJP(8), YJP(9), Burn(6), INT(KA)
42	Sep 02	245	"	GRIDS, S
43	Sep 03	246	"	GRIDS, OBS(6), YJP(10)
44	Sep 06	249	"	GRIDS, OBS(6), Burn(6), OJP(6)
45	Sep 08	251	NSA/Tr	OBS(5), OJP(6), S, Transect to Flin Flon
46	Sep 08	251	Tr/SSA	Transect to PA, CL, OA(5), S, Ag
47	Sep 11	254	SSA	Ag(2), OBS(6), OJP(6), S
48	Sep 12	255	"	Ag, CL, OA(8), OBS(5), S
49	Sep 13	256	"	Ag(2), GRIDS, OJP(6), S
50	Sep 14	257	"	Ag, L(4), S(2)
51	Sep 15	258	"	OA(7), INT(LE), S
52	Sep 15	258	"	Ag, OBS(6), S
53	Sep 16	259	"	Ag(2), GRIDS, S
54	Sep 17	260	"	Ag, CL, OA(5), OBS(5), OJP(5), INT(KA), S, Mahrt(2)
55	Sep 18	261	SSA/Tr	CL, S(2), Transect to Flin Flon
56	Sep 18	261	Tr/NSA	Continue transect to Thompson, S
57	Sep 19	262	NSA	GRIDS, OBS(4), OJP(6), YJP(6), S(2)

Instrumentation Status:
A flight-by-flight listing of instrumentation problems and status is given in BORIS. Only the main points are listed here.

- Satellite simulator in Landsat MSS mode, 15-deg field of view, for Flights 01-27 and 49-57; in SPOT mode, 15-deg field of view, for Flights 28-48
- Wind data all corrected for INS drift using Kalman filtering technique
- The LOZ-3 ozone analyzer removed from aircraft after Flight 22: Archived fluxes are from the German DLR fast-response analyzer for all flights.
- The Agriculture Canada fast-response C02 analyzer appears to have over-estimated C02 fluxes, due to a noise problem correlated with vertical gust at wavelengths of around 100m. Although H20 signal appeared to be unaffected, the LICOR C02 and H20 data have been used in the BORIS submission.

5.1.1.5 AFM-5

PI: Barrie Atkinson — Environment Canada
Manager: Chris Winowich
Post-processing: Alan Barr

Title: Upper Air Network

Objectives: Provide large scale definition of the atmosphere by supplementing the existing Environment Canada aerological network, both temporally and spatially.

Three additional aerological stations were established during IFCs in 1993 and 1994, and the FFC Thaw in 1994. Additional releases were arranged at 5 existing stations in 1993 and 4 stations in 1994. Two cooperative sites (WQH and YYL) provided flights in 1993, and one cooperative site (YYL) provided some flights during IFC-2 in 1994.

Types of Data Collected, Equipment Used:
Standard flights: Vertical profiles of temperature, moisture, and wind direction and speed. Reprocessed flights: 1. measured pressure, temperature, relative humidity, and radiosonde position (range, azimuth and elevation); 2. wind speed and direction as derived by the radiosounding system; 3. geopotential height, corrected relative humidity, dewpoint temperature, equivalent potential temperature, mixing ratio, and the u and v components of the wind as calculated during post-processing.

Vaisala and GMD radiosondes (standard Environment Canada equipment) were used. Observations were made according to existing Environment Canada procedures, and provided to national and international communications systems in real time. Observations were reprocessed to provide increased resolution for stations within the BOREAS region before being provided to BORIS.

Summary of Places and Times of Measurements:
Places; see Experiment Plan Version 3.0, table 3.2.2a. Times; generally two/day (0000Z and 1200Z); except generally three/day (+1800Z) during IFCs at YKJ, YYQ, YQD, YXE, and WIQ; and generally seven/day (1200Z + every two hours) at YTH and WLZ.

A detailed listing of flights made at Candle Lake and Thompson that were reprocessed and provided to BORIS in 1994 is available in BORIS in the report "Preliminary Summary of

BOREAS Upper-Air Soundings Candle Lake and Thompson 1994 Intensive Filed Campaigns" by Barr and Betts.

Known Problems or Caveats:
The Upper-Air data has few gaps and little data are missing. Notably, there are no wind data at Thompson between 24 May and 6 June 1994 due to a hardware malfunction.

Comparison of 2 hour serial soundings by Barr and Betts shows a high degree of internal consistency.

Field and laboratory evaluation by Barr and Betts shows near-zero mean bias errors for wind speed and direction, and high precision for relative humidity. However, also shown was a negative bias for relative humidity, reaching a maximum at about 70% relative humidity of about 10%.

Vaisala wind profiles in the lowest 1 km are often suspiciously smooth, as though interpolated from the surface wind to some first measured wind at about that height. Also, a few soundings have serious oscillations in wind direction.

The surface wind observations at Candle Lake were made subjectively, and are often questionable.

5.1.1.6 AFM-6

PIs: R. Banta, (overall), B. Martner (cloud radar), J. Wilczak (wind profiler) — NOAA/ Environmental Technology Laboratory, Boulder, Colorado.

Title: Outer-Boundary-Layer Effects on Surface Fluxes of Momentum, Heat, Moisture, and Greenhouse Gases from the Boreal Forest

Objectives: The field work objective was to use ground-based remote sensors to measure mean winds, boundary layer depth, and turbulence characteristics in the outer boundary layer (> 100 m AGL) as well as the structure and kinematics of tropospheric clouds. The analysis goals are to document diurnal evolution of boundary layer conditions and to examine how motions in the outer boundary are affected by cloudiness and how they, in turn, are related to surface fluxes.

Instruments:
(1) 35 GHz (Ka-band) cloud- and turbulence-sensing radar,
(2) 915 MHz UHF boundary layer wind profiler with Radio Acoustic Sounding System (RASS).

Kinds of Data Collected:
(1) Cloud/turbulence radar:

(a) Vertical mode - continuous measurement of vertical velocity and radar reflectivity in the clear air of the convective boundary layer and tropospheric clouds.

(b) Conical scan mode - vertical profiles every 6 minutes of mean wind vector, momentum flux and higher order turbulence terms in the boundary layer and in tropospheric clouds for a large cylindrical volume of sky over the radar site. Range is 12.5 km; resolution is 37.5 m and 3 seconds.

(2) Wind profiler: hourly measurements of vertical profiles of the mean 3-D wind vector (to 4

km AGL, typical) and virtual temperature (to 1 km AGL, typical). Height of the top of the mixed layer is a derived product. Resolution is 100 m, and 6 minutes (raw data).

Operating Locations and Times:
(1) Cloud/turbulence radar: fixed site in NSA near the OJP flux tower. Near-continuous operation from 16Jul94-8Aug94 (IFC2+). Total data collected = 315 hours in vertical mode and 173 hours in conical scan mode.
(2) Wind profiler: fixed site in SSA near the OJP flux tower. Continuous, unattended operation from 2May94-21Sep94, including IFC-1,2,3. Data recovery rate 99% .

5.1.1.7 AFM-7

PI: Stan Shewchuk — Sask. Research Council
Collaborators: Brett Smith, Heather Osborn and Kim Young

Title: Mesonet Meteorological Data

Objectives: The Saskatchewan Research Council, located in Saskatoon, has implemented and maintained a meso network of nine (9) or ten (10) automated meteorological stations located in the Northern and Southern study areas and the intervening transect. Standard meteorological and radiation data is being collected and 15 minute average values produced for BORIS. Some limited analysis of fields is also available. These data are available from the fall of 1993 through the fall of 1994.

Types of Data Collected:
Synoptic scale surface data

Equipment Used:
Standard Instrumentation

Summary of Places and Times of Measurements:
Measurements were collected at all sites listed in EXPLAN continuously throughout the IFC campaign periods for the AMS system

Known Problems:
Aside from normal wear of sensors in continuous operation, our MESONET sensors were particularly sensitive to lightning induces transient currents at various times during the project.

5.2 Hydrology (HYD)

The Hydrology team installed stream gages on catchments within the SSA and the NSA. Reconnaissance and placement of soil moisture neutron probe tubes were also carried out.

Surface, airborne and satellite data from the winter and thaw campaigns are being analyzed in order to develop improved algorithms for estimating snow cover, depth and temperature from satellite optical and microwave data. The work will concentrate on the problems of satellite remote sensing of snow water equivalent, which can be very difficult where there is significant forest canopy.

During the growing season IFCs, the HYD-1 team made soil moisture measurements and conducted a range of soil hydraulic experiments at all the non-saturated TF sites in the study areas.

During the growing season of 1994, a truck-mounted C-band weather radar was located near Paddockwood just to the south of the prairie-forest boundary along the southern edge of the SSA.

5.2.1 HYD Team Science Activities

5.2.1.1 HYD-1

P.I.: Richard H. Cuenca — Oregon State University
Team: David Stangel

Title: Coupled Atmosphere-Forest Canopy-Soil Profile Monitoring and Simulation

Objectives: To design a coordinated program of data collection for soil properties and soil monitoring over the BOREAS tower flux sites. Quantify soil water and hydraulic properties at flux tower sites, including the development of a soil water retention function for each site.

Data Collected:
Soil water content data was collected using neutron probe and time domain reflectometry equipment at depths down to 1.7 meters. Soil hydraulic properties were assessed using tension infiltrometer equipment. Soil tension data was collected using tension blocks buried at depths down to 1.4 meters located near the neutron probe access tubes. Below-canopy precipitation measurements were made using manual precipitation gauges.

Soil water monitoring was conducted on an every other day basis at the NSA and SSA Old Jack Pine, Young Jack Pine and Old Black Spruce (OBS IFC's 2-3) sites during the 1994 summer IFC's. Soil water was monitored approximately every other day at the SSA Young Aspen site during IFC's 2 and 3. Soil water measurements were conducted at the SSA Old Aspen by TE-1 during the 1994 summer IFC's. Six to ten unsaturated hydraulic conductivity tests were conducted at all sites except SSA and NSA FEN sites. Soil tension measurements were conducted in conjunction with the soil water measurements at all the Jack Pine sites and at the Young Aspen site in the South. Below-canopy precipitation measurements were made at each neutron probe access tube at all the Jack Pine sites during the 1994 summer IFC's. Precipitation measurement was conducted on an every other day basis.

Known Problems and Caveats:
The only data collection problem encountered involved the inability to obtain an adequate soil to sensor interface using the tension block equipment. The tension measurements are therefore being evaluated and will not be submitted to BORIS unless they meet the acceptance criteria.

5.2.1.2 HYD-2

P.I.: A.T.C. Chang — NASA/GSFC
Co-I: J.L. Foster and D.K. Hall — NASA/GSFC

Title: Validation of a passive microwave snow water equivalent algorithm using an energy balance model

Objectives: Passive microwave data have been used to infer the areal snow water equivalent (SWE) over forested areas, but the accuracy of these retrieved SWE values cannot be easily validated for heterogeneous vegetated regions. Energy balance models have been used to account for the amount of snow storage in snowpacks. We are proposing to utilize the extensive meteorological data to be collected by the BOREAS project, as inputs to an energy balance model in order to measure and monitor snow parameters in the boreal forest region. In-situ observed SWE and SWE derived from an energy model will be compared to the SWE inferred from air-borne and space-borne microwave data and the accuracy of microwave retrieval algorithms will be evaluated.

Types of Data Collected, Equipment Used:
Microwave radiometers (18, 37 and 92 GHz) were successfully integrated onto the Canadian National Research Council's Twin Otter aircraft for BOREAS-94. Brightness temperatures were measured during the experiment.

Summary of Places and Times of Measurements:
The plane started the deployment on January 30 and arrived at Prince Albert on February 1. On February 3, a local test flight was flown to make sure the overall system functioned properly. A liquid nitrogen calibration was performed inside the RCMP hanger. The first data flight was on February 6 from Prince Albert. A total of fourteen flights were flown from February 6 to 13. Flight lines for the south site and the north site were covered by these flights. On February 14, the Twin Otter returned to Ottawa via Thunder Bay and Sault Ste. Marie.

Known Problems and Caveats:
The calibrated brightness temperature is believed to be accurate to about 2 K. A minor problem uncovered during this mission, that the calibration of the 92 GHz was noisier than expected. This is due to the fact that the radiometer uses outside ambient air temperature as the cold calibration reference. For targets with low brightness temperatures, the signal to noise ratio is not optimal

5.2.1.3 HYD-3

PIs: R.E. Davis, J.P. Hardy and R. Jordan — U.S. Army Cold Regions Research & Engineering Lab (CRREL)

Title: Distributed Energy Transfer Modeling in Snow and Soil for Boreal Ecosystems

Objectives: The goal of this project is to model the spatial and temporal distributions of critical snow pack properties and processes at scales up to about 1 square kilometer and to develop tools linking model predictions to remote sensing. The three principal objectives of the project are:

1. to classify the boreal forest biome based on the spatial distribution of tree stands, vegetation and soils, and to establish land cover units which have similar attributes in the context of the upper and lower boundary conditions required by energy and mass transfer models.

2. to investigate methods for incorporating the effects of different tree canopy and stem characteristics into stand scale estimates of snow properties and surface energy exchange.

3. to identify the capabilities and limitations of remote sensing measurements to monitor the state of the snow pack.

Data Collected and Equipment Used:

Data Type	Equipment
Snow water equivalence (SWE)	centimeter scale
	100 cc snow density cutter
	electronic top loader balance
	Canadian Snow Sampler
Snow pack properties:	
snow pack temperatures	digital thermometer
snow density profile	100 cc snow density cutter
air permeability of snow	double chamber permeameter
grain size distribution	sieves and photos
snow microstructure	sample collection and image analysis
Snow distribution around conifer trees (measurement of tree well geometry)	centimeter scale
Canopy closure	forest densiometer
Within canopy wind speed	
and direction	RM Young wind monitor
air temperature	107 Temperature probe
relative humidity	207 RH probe
Subcanopy radiation and temp.	
solar radiation	Eppley pyranometer
thermal radiation	Eppley pyrgeometer
snow surface temperature	radiant thermometer
canopy temperature	radiant thermometer
Spectral reflectance of the snow surface	ASD Personal Spectrometer
Radiation Scatterers: number of needles and twigs in randomly selected areas on several trees.	manual labor - counting needles and measuring twig lengths

Places and Times of Measurement:
FFC-W 1994: SWE, snow pack properties, snow distribution, and canopy closure were measured at SSA: OJP, OA, and the Gamma flight line BP-110, as well as NSA: YJP, OJP, and OBS. Within canopy wind speed, wind direction, and subcanopy solar radiation were measured in SSA: OJP and OA.

FFC-T 1994: SWE, snow pack properties, and snow distribution were measured at NSA: YJP, OJP and OBS. Canopy closure was measured at NSA: YJP and OBS. Subcanopy solar radiation was measured at NSA: YJP and OBS. Spectral reflectance measurements of the snow were made at a variety of incidence angles and azimuths at NSA: OBS.

March 1995: The following measurements were made at NSA, OBS: snow distribution, snow pack properties, canopy closure, subcanopy solar and thermal radiation, snow surface and canopy temperatures, as well as within canopy wind speed, wind direction, air temperature and relative humidity. Additionally, we quantified radiative scatterers (needles and twigs) at 25, randomly selected, 1000 cc areas on five different trees to be incorporated into a canopy radiation model.

Problems and Caveats:
1. Low values of wind speed collected during FFC-W in NSA, OJP are close to the threshold value for the instrument and therefore are not accurate.
2. Studies have shown that densiometer derived canopy closure is not the most precise method of determining canopy closure, but that it is the best available "quick and easy" method. Data are considered approximate measures of canopy closure.

5.2.1.4 HYD-4

P.I.(s): B.E. Goodison, A.E. Walker — Climate and Atmospheric Research Directorate, Atmospheric Environment Service

Title: Determination of Snow Cover Variations in the Boreal Forest Using Passive Microwave Radiometry

Objectives: To investigate snow cover variations within and between the BOREAS study areas using passive microwave radiometry. It involves algorithm development and validation to derive snow water equivalent and extent from passive microwave radiometer data, incorporating variations in surface land cover. Co-incident airborne microwave radiometer (Twin Otter) and airborne gamma Snow Water Equivalent (SWE) observations are critical to algorithm development. Ground, airborne, and satellite data will facilitate scaling up to the satellite resolution. The effects of forest cover (density, type) on snow cover retrievals will be assessed and incorporated in the determination of snow cover variability. The use of passive microwave data in combination with optical and thermal IR data to improve snow cover retrievals will be explored in conjunction with RSS-19 Airborne radiometer flights during dry snow conditions are mandatory; flights during a wet snow condition are desirable as well. The flights were mandatory during the winter FFC. The airborne radiometer and airborne gamma were not flown during the FFC-T.

5.2.1.5 HYD-5

P.I.(s): R.J. Harding — Institute of Hydrology

Title: The Regional Representation of the Energy and Moisture Fluxes from Snow Covered Areas in the BOREAS Experiment

Objectives: To characterize the energy and water vapor fluxes, as well as related properties (density, depth, temperature, melt) for forested and non-forested areas. Equipment was set up in the winter FFC and run through to the Thaw FFC. Two sites were operated in or near the Prince Albert Park area. One was above a mixed jack pine and aspen forest stand near Bear Trap Creek (this site was run in conjunction with the NHRI GEWEX experiment). The second site was near the centre of Namekus Lake (750 m from the western edge). Eddy correlation and full set of meteorological measurements were made.

An extensive program of meteorological and SVAT modeling is underway to investigate the problems of aggregation of surface fluxes in a snow covered landscape. One and two dimensional boundary layer models are being used to investigate scales from 100m to 10km. A three dimensional mesoscale model is being used to aggregate from 10 km to 1000 km. This latter model requires extensive meteorological and ground cover data from the BOREAS study region. Improved snow parameterisations for GCM's will be one of the important products of this research.

5.2.1.6 HYD-6

PIs: Eugene Peck — Hydex Corporation; Thomas Carroll — NWS NOAA

Title: Remote Sensing of Hydrologic Variables in Boreal Areas

Objectives: The objectives of this study are: 1) to obtain improved estimates of the soil moisture (SM) of the mineral soil, 2) to develop techniques for measuring the water content (WC) of the moss/humus layer, 3) to provide assistance to HYD-4 in measuring the water equivalent (WE) of the snow cover, 4) to provide information on temporal and spatial variations in the SM and of the WC of the moss/humus layer.

Data Collected and Equipment Used:
The National Weather Service, NOAA, airborne detector package is used to collect airborne radiation, temperature, pressure, and aircraft altitude data over selected flight lines for providing airborne estimates of the SM and of the WC of the moss/humus layer.

Airborne soil moisture measurements are based on the difference between the measured natural terrestrial gamma radiation flux for comparatively wet and dry soils. Over 800 in situ ground measurements of the SM, the WC of the moss/humus layer, and of the soil and vegetative cover were collected for calibration purposes.

Places and Times of Measurements:
Airborne gamma ray surveys were flown for 48 BOREAS flight lines during IFC-W (February 1994), and during IFC-2 and IFC-3 n the summer of 1994. Surveys over the BOREAS Northern Study Area (NSA) and along transect lines between the NSA and SSA were collected only a few times for calibration of the flight lines in support of the snow survey program of HYD-4.

In situ soil moisture measurements were collected once for most flight lines for calibration of the natural terrestrial radioisotope signal. Airborne surveys were flown over the SSA for consecutive days during IFC-2 and IFC-3.

Known Problems:
The airborne measurement of the SM and WC is not reliable for extremely wet areas. The ground measurements for calibration of the flight lines must be representative of average conditions.

Observed High Cosmic Radiation: The airborne radiation measurements include a measure of incoming cosmic radiation. Only during three days in September 1994 were high energy cosmic rays measured (considered as a rare event) that may have importance for other BOREAS radiation measurements.

5.2.1.8 HYD-8

P.I.(s): L.E. Band — University of Toronto
CO-I(s): T. Price — Univ. of Toronto, J.C. Coughlan —NASA ARC

Title: Simulation of Boreal Ecosystem Carbon and Water Budgets: Scaling from Local to Regional Extents

Objectives: This project is primarily a modeling effort, which seeks to describe the scaling behavior of water and carbon flux processes from local and regional extents. A suite of simulation models are being used to describe photosynthesis, respiration, evapotranspiration, and surface and subsurface flow over a range of scales. The underlying hypothesis is that the spatial patterns of surface-atmosphere fluxes are strongly influenced by the spatial distribution of soil moisture and inundation areas in the study sites, which, in conjunction with disturbance regime, are thought to provide the key to scaling from stand to regional simulations. The smallest scale to be modeled will be essentially hillslopes or subcatchments for which the spatial resolution will be 10 to 30 meters; these subcatchments or hillslopes will probably be located in or around the catchments monitored by HYD-9, in the vicinity of the tower sites to facilitate use of the surface flux data collected there. The larger scale will be on the order of the size of the NSA and SSA site, with data resolution extending down to that of AVHRR. The primary external data requirements are for high resolution DEM data, particularly for the hillslope sites, and vegetation and soil data at resolutions comparable to that of the DEM. Limited monitoring of canopy interception (throughfall and stemflow), and of moss water retention will be carried out in the Southern Study Area in association with HYD-9.

5.2.1.9 HYD-9

P.I.(s): E.D. Soulis — University of Waterloo
CO-I(s): J. Jasinski — NASA; G. Kite — National Hydrology Research Institute; N. Kouwen — Univ. of Waterloo; R. Leconte — Univ. of Quebec a` Monteal; D. Lettenmaier — Univ. of Washington; D. Marks — USGS

Title: From Micro-Scale to Meso-Scale Snowmelt, Soil Moisture and Evapotranspiration from Distributed Hydrologic Models

Objectives: This project seeks to identify, through field measurements and computer modeling, the space-time distribution of meltwater supply to the soil during the spring melt period, and the evolution of soil moisture, evaporation, and runoff from the end of the snowmelt period through freeze-up. The snow modeling activity consists of two components: The first makes use of existing, "off-the-shelf" models to forecast the onset and spatial extent of snowmelt and meltwater supply to the soil column prior to the 1994 IFCs. The second phase extends, implements, and verifies a physically based energy balance snowmelt model of the two sites, and evaluates approaches to aggregating snowmelt predictions and measurements based on the model to large scales, up to the size of a rectangle of several hundred km containing the northern and southern sites. The soil moisture modeling is being conducted by Soulis and Engman, based on a grouped response unit method, and allows characterization of soil moisture, evaporation, and runoff for the entire northern and southern sites. The primary external data requirements of the project are for:

- winter period surface meteorological and energy flux data
- high quality DEM data
- vegetation characterization, at the scale of the DEM
- supplemental snow-free period precipitation data at the local (hillslope) scale, perhaps along selected transects

Data Collected and Equipment Used:
A C-band weather radar logging rain coverage

Places and Times of Measurements:
The radar operated from May 12 to Sept. 23, 1994 from a location 7 km southeast of Paddockwood, scanning a circle of 220 km radius.

5.3 Remote Sensing Science (RSS)

The overriding objective for studies using remote sensing in BOREAS is to derive parameters that can be used in climate and/or ecosystem models. The interactions of electromagnetic radiation with a forest are controlled by the type, amount and physiological status of the trees and understory, as well as the ground surface condition. Remote sensing instruments record these interactions as either reflectance (scattering) or emittance in a variety of wavelengths, see Hall et al. (1993). During BOREAS several remote sensing instruments were employed that are sensitive to energy over the optical (e.g., 0.4 to 14.0 μm) or microwave (e.g., 1 cm to 68 cm) regions of the electromagnetic spectrum. Important quantities under study in BOREAS include forest composition, leaf area index, biomass and phenology; other parameters and variables that can be related to ecosystem functioning are also under study, including the fraction of absorbed photosynthetically active radiation absorbed by the green portion of the vegetation canopy (FPAR), forest canopy albedo and surface temperature.

FPAR was estimated from in-situ optical and direct measurements for the many vegetation covers represented at the auxiliary sites. These and other measurements will be used to develop relationships between leaf area index, FPAR and satellite data to estimate regional scale net primary productivity from orbit. Other investigator teams will concentrate on measurements of canopy architecture, moisture content and electrical properties (i.e., dielectric constant) of vegetation and soils to acquire data for optical and microwave scattering models of forest canopies.

The NASA Jet Propulsion Laboratory (JPL) airborne Synthetic Aperture Radar (SAR) was flown on-board the NASA DC-8 over both the northern and southern study areas. Early results indicate that species and above-ground biomass may be identified from images.

One of the most spectacular results from BOREAS was the use of ERS-1 imaging radar to monitor the early March thaw, which triggered soil respiration, and later canopy thaw, which initiated net carbon uptake. The image backscatter shifts in the ERS-1 data associated with the thaw is due to a large shift in soil and canopy dielectric constant associated with the freeze/thaw phase transition of water in the soil and canopy.

Lastly, analysis of optical satellite data have revealed the important role of fire in the carbon dynamics of the region. Fire is probably the dominant mechanism for releasing the surface carbon stocks back to the atmosphere in this biome; analyses of these and similar data should permit a precise quantification of the fire frequency.

5.3.1 RSS Team Science Activities

5.3.1.1 RSS-1

P.I.: D.W. Deering — NASA GSFC
Co-Is: E.M. Middleton — NASA GSFC; S.P. Ahmad and T.F. Eck — Hughes STX Corp.
Collaborators: M. Verstraete, B. Pinty, and R. Myneni

Title: Radiative Transfer Characteristics of Boreal Forest Canopies and Algorithms for Energy Balance and PAR Absorption

Objectives: The general objectives are (1) to characterize the multidirectional interactions of solar energy in various types of boreal forest canopies through intensive measurements and through modeling and (2) to relate these characteristics to ecologically important biophysical parameters. Provide bidirectional reflectance measurements of the various boreal forest canopies. Determine the variability of reflected and transmitted fluxes in selected spectral wavebands as a function of canopy type, phenological growth stage and solar zenith angle. Estimate surface albedo and PAR albedo from bidirectional reflectance and irradiance data.

Equipment Used and Data Collected:
PARABOLA bidirectional reflectivity/directional transmittance data were collected at 5 degree solar zenith angle intervals, clouds permitting, from approximately 75 degrees SZA to solar noon. The PARABOLA measures a 4 pi hemisphere area with 15 degree IFOV sectors in 11 seconds. Measurements of the reflected radiances from a characterized barium sulfate reference panel with a Barnes Modular Multiband Radiometer (MMR) were taken concurrently with PARABOLA measurements during the BOREAS experiment in order to characterize spectral solar irradiance. Pyranometers were used to measure irradiance, albedo, and transmittances (Eppley PSP pyranometers and Skye Probetech PAR sensors), but only on the sites and dates of PARABOLA data acquisitions. ASD PS II Spectroradiometer reflectance factors from nadir PS II spectrometer measurements were also taken on selected sites on 8 dates in IFC-2 and IFC-3 combined.

Summary of Places and Times of Measurements:
Measurements were made at 3 sites in the BOREAS Southern Study Area (SSA): Old Aspen (OA), Old Black Spruce (OBS), and Old Jack Pine (OJP). Above canopy measurements are denoted by (a) and below canopy measurements are denoted by (b).

- FFC-Thaw: OBS-4/16 (a) & 4/19/94 (a): OA- 4/24 (a) & 4/26/94 (b)
- IFC-1: OA- 5/25 (a), 5/26 (a), 6/11 (a) & 6/17 (b) ; OJP-5/29 (a), 5/31 (a), 6/1 (b) & 6/4 (b); OBS-6/6 (a) & 6/7/94 (a)
- IFC-2: OA- 7/21 (a) & 7/23 (b) ; OJP-7/24 (b), 7/25 (a), 7/30 (a), & 8/2 (a) ; OBS-8/4 (a), 8/8 (b), & 8/9 (b)
- IFC-3: OA- 8/31 (a), 9/01 (b), 9/17 (a), & 9/18 (b); OJP- 9/2 (b), 9/5 (a), & 9/6 (a) ; OBS- 9/12 (a), 9/13 (a), & 9/16 (b)

5.3.1.2 RSS-2

PIs: J. Irons — NASA GSFC; P. Dabney and C. Russell — Univ. of Maryland

Title: Advanced Solid-state Array Spectroradiometer (ASAS) on the NASA/ARC C-130

Objectives: Study bidirectional reflectance properties of snow background, and boreal forest canopies through seasons. Simulate MISR data by acquiring data at MISR view zenith angles.

Equipment Used and Data Collected:
Multiangle, hyperspectral digital image data, at-sensor radiance for 62 spectral channels (404-1025 nm) in up to 10 view angles for FFC-T data and up to 8 view angles for IFCs 1-3 data.

NASA C-130 Flight Coverage of the BOREAS Sites

Site	Coverage by Date	# Flight Lines	GMT range (start times)
SSA-OBS	4/19/94	3	17:11-17:35
	5/31/94	3	17:16-17:38
	6/01/94	3	14:47-15:07
	6/06/94	3	15:32-15:57
	7/21/94	3	18:46-19:11
	9/13/94	3	17:31-17:59
SSA-OA	4/19/94	3	18:43-19:08
	5/31/94	3	15:29-15:59
	7/21/94	3	17:46-18:17
	9/16/94	3	17:10-17:40
SSA-OJP	4/19/94		17:57-18:28
	5/31/94	3	16:25-17:02
	6/01/94	3	15:20-15:41
	6/04/94	3	14:48-15:11
	7/21/94	3	19:24-19:49
	7/24/94	3	16:33-16:58
	9/13/94	3	18:09-18:32
SSA-YJP	6/01/94	3	15:52-16:14
	7/21/94	3	19:59-20:22
	9/13/94	3	19:17-19:50
SSA-Fen	6/04/94	3	15:32-15:57
	6/06/94	3	16:12-16:35
	7/21/94	3	20:35-21:10
	7/24/94	3	15:57-16:23
	9/13/94	2	18:43-18:53
SSA-YA	7/23/94	1	15:48
	7/24/94	3	17:08-17:33
AVIRIS-Cal	5/26/94	1	17:25
	7/23/94	1	16:20
	9/16/94	2	20:01-20:12
Candle Lake	5/31/94	1	16:08
	9/16/94	1	?

Site	Coverage by Date	# Flight Lines	GMT range (start times)
NSA-OBS	4/20/94	3	17:17-17:54
	6/07/94	3	16:04-16:41
	8/04/94	3	16:23-16:14 (smoke)
	9/06/94	1	16:08
	9/17/94	3	17:13-17:35
NSA-OA	6/08/94	3	17:09-17:29
	9/06/94	2	15:39-15:54
	9/17/94	3	15:57-16:16
NSA-OJP	4/20/94	3	17:32-18:22
	6/07/94	3	15:25-15:52
	8/04/94	3	16:47-17:10 (smoke)
	9/17/94	3	16:30-17:04
NSA-YJP	4/20/94	3	18:30-18:58
	6/07/94	3	17:30-17:55
	9/17/94	3	18:14-18:52
NSA-Fen	4/20/94	3	19:10-19:35
	6/07/94	3	16:54-17:17
	9/17/94	3	17:44-18:05

Known Problems and Caveats:
Compared to limited ground measurements, ASAS agreed very well with the ground observations for wavelengths 490-870 nm. Below 490 nm and above 870 nm, ASAS reflectance factors fell below the response observed by ground sensors. USE CAUTION working with spectral channels below 490 nm or above 870 nm, due to low signal-to-noise ratios and uncertainty in the absolute radiometric calibration.

5.3.1.3 RSS-3

PI: C. Walthall — University of Maryland
CO-I(s): D. Williams — NASA GSFC; S. Goward — Univ. of Maryland

Title: Biophysical Significance of Spectral Vegetation Indices in the Boreal Forest

Objectives: A Bell UH-1H helicopter with a pointable mount was used as a platform for a Barnes Modular Multiband Radiometer (MMR), a visible/near infrared Spectron Engineering SE590 spectroradiometer, an infrared thermometer (IRT), a pyranometer, a PAR sensor, two video cameras and a 70 mm photographic camera. An experimental sun tracking photometer was mounted on the helicopter cabin. The POLDER instrument and a 3 frequency scatterometer system were also flown on selected missions. The primary objective of this study was to acquire multispectral, bidirectional reflectance and surface temperature data of the study sites for assessments of spectral, spatial, temporal and bidirectional variability, and the impacts of these variables on vegetation indices.

Summary of Places and Times of Measurements:
Data was collected during IFCs 1, 2, and 3 at both study areas. The helicopter was deployed from a clearing near the Snow Castle Lodge in Candle Lake during SSA data collection, and from Thompson Airport during NSA data collection. Transit between study areas and reassembly or storage of the instrumentation system took less than a day. Between IFC-1 and IFC-2, the helicopter was stored at the Prince Albert Airport and between IFCs 2 and 3 it was stored at the Thompson Airport.

Equipment Used and Data Collected:
Data was collected while hovering over the study sites at 1000 feet above ground level and while slowly flying over transects leading away from the tower sites. Recognition of study sites on the surface by air crew was via maps, aerial photographs large concentrations of flagging at the sites and with the assistance of additional observers. Data collection was coordinated on selected days with surface-based measurements and other airborne measurements. All of the data was collected using only a nadir view angle to conserve mission time and thereby maximize the number of study sites covered in a single mission. Sun photometer data was collected during missions coincident with spectroradiometer and multiband radiometer data or immediately after. The collection strategy focused on obtaining measurements of each of the category I and II sites first, followed by category III sites and other surface covers deemed useful for providing a more complete measure of landscape spectral variability. Real-time voltage readouts from the sun photometer were used as additional decision making criteria when dealing with marginal sky conditions. Measurements of

radiometric and spectral calibration sources were made between missions while on site.

Known Problems and Caveats:
In-field checks of selected spectroradiometer and multiband radiometer data showed that they appeared to be of high quality with some gaps due to system malfunctions. A considerable number of technical difficulties were encountered during the deployment which resulted in damage to the IRT, one video camera, the photographic cameras and the sun photometer system. Data from these systems are either incomplete or unusable as a result. Significant modifications to the data collection system and the mounting platforms were required during and between IFCs for data collection to continue.

5.3.1.4 RSS-4

PIs: S. Plummer — British National Space Centre; P. Curran and N. Lucas — University of Swansea

Title: Coupling Remotely Sensed Data to Ecosystem Simulation Models

Objectives: The objectives of the research proposed by RSS-4 were to examine methods for deriving LAI, Fpar and leaf chlorophyll/nitrogen concentration from remotely sensed data for input into the Forest-BGC Model using constrained empirical methods and by comparison with a forward canopy radiation model.

Current Status:
To achieve the first element of the research it was necessary to acquire point estimates of forest LAI, Fpar and canopy chemistry. In 1993 several indirect methods for determining LAI were compared at three of the four flux tower sites in the Southern Study Area (Plummer and Lucas, 1993). Based on this experience it was decided to restrict further data collection to one species, Jack Pine, and cover as many of the tower/auxiliary sites as possible. As in 1993 measurements were obtained with the LAI-2000 and a Ceptometer to derive LAI and Fpar. In addition samples were acquired from the upper canopy for determination of canopy chemistry - water, nitrogen, chlorophyll, lignin, cellulose. These samples were divided into current and previous year needles, frozen and shipped back to the UK in CO_2 where they are being analyzed. Data were acquired at the following sites and will be released to BORIS shortly:

Site	Ceptometry			LAI-2000		Chemistry
G1K9P	√	x	x	x√	√	
G4K8P	√	x	x	x√	√	
G9L0P	√	x	x	x√	√	
G7K8P	√	x	x	x	√	
G8L6P	√	x	x	x√	√	
F7J0P	√	x	x	x	√	√
F7J1P	√	x	x	x√	√	
F5I6P	√	x	x	x√	√	
G2L3T	√	x	x	x√	√	
F8L6T	√	x	-	x	√	
D06HS	√	x	-	-		
D6H4T	√	x	-	-		
D9I1M	√	x	-	-		

These data will be compared with AVIRIS and possibly CASI data. The second element of the work comprised the development and testing of a forest reflectance model. The model was tested on ASAS data from the FED-MAC site at Howland, Maine and the simulation results for this site were presented at IGARSS'94 and will shortly be published (North and Plummer, 1994, North, 1995). It is intended to extend this model by inclusion of a conifer needle reflectance model, LIBERTY, currently under development by a doctoral student (Dawson et al. 1995) and to explore methods for inversion of the model using neural networks. The latter element is the subject of a grant proposal. Research is also underway to test the predictions of a global ecosystem model over the BOREAS sites.

References:

Dawson, T.P., Curran, P.J. and Plummer, S.E., 1995, Modeling the spectral response of coniferous leaf structures for the estimation of biochemical concentrations, Proc. Remote Sensing Society Annual Conference, 587-594.

North, P.R., 1995, A three-dimensional forest light interaction model using a Monte-Carlo method, IEEE Trans. Geosci. and Rem. Sens., in press

North, P.R. and Plummer, S.E., 1994, Estimation of conifer bi-directional reflectance using a Monte Carlo method, IGARSS'94, IEEE, Piscataway, NJ, Vol. I, 114-116.

Plummer, S.E. and Lucas, N.S., 1993, Report of the BOREAS Intensive Field Campaign 1993, Remote Sensing Applications Development Unit Report No. 93/5.

5.3.1.5 RSS-5

P.I.(s): N. Goel — Wayne State University

Title: Boreal Forest Community Composition and Structure, Photosynthesis, Remote Sensing, Scaling and Net Carbon Flux

Objectives: To address the following questions related to two quantities — photosynthesis and soil radiation absorption — or boreal forest:

- How important is the detailed architecture and species distribution in boreal forest canopy in determining these quantities and how do they vary as a function of season when canopy architecture undergoes changes?
- Can they be estimated using a simpler equivalent model using surrogate parameters for canopy architecture?
- Are these parameters correlated to each other under different canopy architectural conditions, and can one estimate photosynthesis using measurement of radiation absorbed by the soil?
- Can photosynthesis be estimated using radiation leaving a canopy? In particular, how does the relationship between FPAR (fraction of photosynthetically active radiation) and NDVI (normalized difference vegetation index) depend upon the complex forest community and architecture?
- How can this estimation be scaled up for a large collection of heterogeneous canopies such

as those found in boreal forest?
• To what degree different forest stands can be differentiated by using remotely sensed data?
• Can the net carbon flux over the area covered by the BOREAS site be estimated by using a combination of vegetation models, scaling strategies, ground observations, and satellite images.

5.3.1.6 RSS-6

P.I.(s): D. Williams, R. Myneni — NASA GSFC

Title: Modeling and Remote Sensing of Radiant Energy Interactions and Physiological Functioning in a Boreal Ecosystem

Objectives: The objectives of this study are:
• to develop and validate a three-dimensional boreal forest canopy/atmosphere radiation model capable of simulating canopy reflectance, absorbance and atmospheric effects
• to develop and validate algorithms for estimating surface albedo, solar and photosynthetically active radiation absorbed by boreal forest canopies, solar radiation absorbed by the background and, boreal forest canopy photosynthetic and bulk conductance efficiencies from spectral, spatial and temporal patterns of surface radiance fields.

The physical problem is posed as a 3D radiative transfer equation (RTE), describing the interaction of photons in the atmosphere/vegetation medium, the solution of which is the remote spectral measurement. We are developing models of boreal forest community at the BOREAS experimental sites using fractals and computer graphics.

5.3.1.7 RSS-7

PI: J.M. Chen — Canada Centre for Remote Sensing
Co-Is: J. Cihlar — Canada Centre for Remote Sensing; J. Penner — Petawawa National Forestry Institute

Title: Retrieval of Boreal Forest Leaf Area Index From Multiple Scale Remotely Sensed Vegetation Indices

Objectives: To develop algorithms for calculating LAI and FPAR for BOREAS study areas and the region based on improved ground measurements.

Types of Data Collected:
(1) LAI, effective LAI, foliage clumping index, needle-to-shoot area ratio, destructive LAI; (2) FAPR, APAR, PAR transmitted, PAR reflected from TOC and forest floor.

Equipment Used:
(1) TRAC (Tracing Radiation and Architecture of Canopies) developed by Chen due to BOREAS. It consists of three LI-COR quantum sensors for measuring the transmitted total and diffuse PAR and the reflected PAR from the forest floor at an interval of 10 mm over transects of up to 300 m by a walking and a high frequency sampling technique. (2) LI-COR LAI-2000

Plant Canopy Analyzer (PCA) which measures the effective LAI from canopy gap fraction at zenith angles. (3) A computerized video-camera/light-table system (AgVision) for measuring the needle-to-shoot area ratio.

Summary of Places and Time of Measurements in 1994:

Site	Time	Equipment	Transect Length and Direction
SSA-OBS	IFC1-3	TRAC, PCA, AgVision	300 m, SE from flux tower (FT)
SSA-OJP	IFC1-3	TRAC, PCA, AgVision	200 m, SE from FT
SSA-YJP	IFC1-3	TRAC, PCA, AgVision	150 m, SE from FT; 150 m, NW of FT
SSA-OA		TRAC, PCA	300 m, SW from FT
SSA-Fen	IFC2	TRAC, PCA	2*50 m, 150 m to S of FT
NSA-OBS	IFC1-3	TRAC, PCA, AgVision	300 m, SE from FT
NSA-OJP	IFC1-3	TRAC, PCA, AgVision	250 m, SE from FT; 170 m, NW from FT
NSA-YJP	IFC1-3	TRAC, PCA, AgVision	170 m, SE from FT; 170 m, NW from FT
NSA-Fen	IFC2	TRAC, PCA	300 m, SE from FT; 250 m, W from FT
NSA-OA	IFC1-3	TRAC, PCA	50 m, E-W

In addition, PCA and/or TRAC measurements were made in IFC2-3 in auxiliary sites T3U9S, T6R5S, T7R9S1, T7R9S2, T8Q9P, F7J0P, F7J1P, G2I4S, G4I3M, G9I4S, G1K9P, T9Q8P,T7T3S and G2I7M in the SSA and W0Y5A, T4U9S, T6T6S, T8S4S and T8T1P in the NSA.

In IFC (September) 1993, TRAC and PCA measurements were made in SSA-OBS, SSA-OJP, SSA-YJP, NSA-OBS, NSA-OJP and NSA-YJP.

5.3.1.8 RSS-8

P.I.(s): S.W. Running — University of Montana
CO-I(s): J-P. Muller — Univ. College London; D. Hall, Y. Kaufman — NASA GSFC; A. Huete — Univ. of Arizona; Z. Wan — CRSEO Univ. of Calif.; C. Justice — NASA GSFC; D. Carneggie — USGS EDC

Title: MODIS Land Team (Modland) Algorithm Development for Boreal Forests: Participation in BOREAS

Objectives: To take ground validation measurements of:
• land cover mapping of the northern and southern sites, using both TM data and MODIS airborne simulator (MAS) data with ground derived
• mapping and satellite monitoring of the seasonal snowcover and snowmelt on both sites using MAS and ASAS sensors
• development of advanced spectral vegetation indices, predominantly using MAS and ground BRDF measurements
• surface temperatures, as monitored by the meteorological tower network planned for each site, and related to both aircraft and satellite measured thermal emittances

Another main purpose is to use carbon and water flux measurements taken from cuvette, tower and aircraft levels by other investigators to validate our hierarchical modeling of ecosystem water and carbon balances done with FOREST-BGC and our current NDVI modeling. We are integrating these core products into new spatially scalable estimates of daily photosynthesis-respiration balances, evapotranspiration, and soil decomposition and CO2 production. These products, tested and validated during the IFCs, will be extrapolated to the global boreal forest biome.

5.3.1.9 RSS-9

P.I.(s): M. Strome — Petawawa National Forestry Institute

Title: High Spatial and Spectral Resolution Image Analysis Techniques for Ecological and Biophysical Data (High Spirited)

Objectives: To develop techniques and algorithms to enable the monitoring of changes in the test sites and to relate the remotely sensed data to forest models. The multitemporal data is being used to attempt to monitor changes resulting from phenologic events, especially those related to vegetative stress where possible. The majority of past efforts to analyze high spectral resolution data have focused upon relatively simple signal processing techniques, such as selection of optimum bands to distinguish features of interest such as species identification, vegetation stress and defoliation due to insect damage. Some techniques have examined features such as the "red shift".

5.3.1.10 RSS-10

P.I.(s): B. Holben — NASA GSFC
CO-I(s): P. Bhartia — NASA GSFC

Title: Satellite Estimation of PAR and UV-B Irradiances and Long Term Estimates of Trends of UV-B from Ozone Depletion and Cloud Variability at the BOREAS Sites

Objectives: To investigate from ground and satellite observations the magnitude of daily, seasonal and yearly variations of UV-B irradiance during the course of the BOREAS field experiment and to examine the 14 year record of Total Ozone Mapping Spectrometer (TOMS) data over the BOREAS sites for ozone and cloud reflectance variability. We are also estimating the incident Photosynthetically Active Radiation (PAR) by refining existing model which utilizes TOMS reflectivity data to account for cloud attenuation. In addition, we plan to extend the results of our algorithm development for application to the entire circumpolar boreal forest biome.

5.3.1.11 RSS-11

P.I.'s: B.L. Markham, B.N. Holben — NASA GSFC
Participating CO-I's: R. N. Halthore — Hughes STX

Title: Aerosol Optical Properties Over BOREAS

Objective:
Characterization of the aerosol optical properties over BOREAS

Data Collected:
Direct sun and sky radiance measurements in the almucanter and principal plane

Data Products:
Aerosol optical thickness, precipitable water column abundances, aerosol size distribution and scattering phase function

Equipment:
Cimel 318 automatic tracking sun photometers (5), 4 channel hand held(Miami) sun photometers(2)

Data Collection Summary:

Cimel Instrument	Site	Data Acquisition Period	Significant data gaps/reason	Degraded data periods/reason
6	Prince Albert Airport	5/26/94 – 6/5/94 7/20/94 – 7/26/94 9/12/94 – 9/18/94	Reduced data collection —azimuth drive intermittent failure (5/26/94 – 6/5/94)	440 nm poor calibration (IFC1), no 380 nm channel(all dates)
6	Thompson Airport	6/7/94 – 6/13/94 7/27/94 – 9/11/94	Reduced data collection — azimuth drive failure (6/7/94 – 6/13/94)	440 nm poor calibration (IFC1), no 380 nm channel (all dates)
11	NSA-YJP	5/16/94 – 10/25/94	5/24-5/30 Communication failure	
			6/5 -6/7 Transmitter failure	
			8/5- 8/8 Sunphoto battery failure	
			8/9-8/13 Sunphoto battery failure	
				6/26-7/4 partial aperture obstruction—recalibrated with on-site Langley
12	Flin Flon	5/19/94 – 10/24/94	9/21-9/25 Transmitter failure-	
			10/9-10/12 Transmitter failure	
			~7/9-8/15 aureole gain setting erratic	
31	SSA-YJP	5/23/94 – 10/17/94	7/21 (partial) Satellite/transmitter failure	
32	Waskesiu	5/25/94 – 10/17/94		~7/20-7/24 Partial aperture obstruction blocking aperture — recalibrated with on-site Langley

Miami Instrument	Site	Data Acquisition Period	Significant data gaps/reason	Degraded data periods/reason
317/319	Thompson	12/1/93 – present		~7/15/94-present -increased signal variability particularly channels 3 and 4 due to filter positioning error
322	Waskesiu	6/15/93 – present	limited data acquisition late fall 1993 to early spring 1994	

5.3.1.12 RSS-12

P.I.(s): R.C. Wrigley — NASA ARC
CO-I(s): M.A. Spanner, R.E. Slye, P.B. Russell, J.M. Livingston — NASA ARC

Title: Aerosol Determinations and Atmospheric Correction for BOREAS Imagery

Objectives: For this study, we are:

- Acquiring sun photometer data using a ground-based instrument as well as the Airborne Tracking Sun Photometer on the C-130. Deriving aerosol optical depths as a function of wave length and submit them to BORIS.
- Using the spectral aerosol optical depths to derive aerosol and size distributions coincident with important BOREAS remote sensing data sets and using the size distributions to calculate aerosol optical properties such as phase functions and single scattering albedos necessary for our atmospheric correction model.
- Incorporating a model of contribution of skylight into our atmospheric correction model to enable calculation of surface reflectances from our surface radiances.
- Extending our atmospheric correction model to data collected by the Advanced Solid-state Array Spectroradiometer (ASAS), incorporating an approximate Rayleigh multiple scattering correction, and provide a detailed evaluation of the results.
- Processing the important remote sensing data sets for BOREAS from the Thematic Mapper (TM), the TM Simulator, System Probatoire de la Terre (SPOT), and ASAS.

Our effort will provide critical atmospheric optical measurements and derive the aerosol optical properties necessary for atmospheric correction of BOREAS data, extend our atmospheric correction model, and provide atmospherically corrected data for BOREAS.

5.3.1.13 RSS-13

P.I: S.P Gogineni — University of Kansas
Co-I's: G. Lance Lockhart and Paul Rich — University of Kansas

Title: Helicopter-based Measurements of Microwave Scattering Over Boreal Forest

Objectives: The objectives of the microwave measurement project are: (1) to acquire the and quantitative backscatter data required to understand better the physics of scattering from vegetative components and (2) to develop a neural-network-based algorithm for estimating component biomass of the boreal forest. Ultimately, we will develop a scattering model and model-based inversion algorithm to estimate biomass from satellite remote sensing data over the boreal forest, in particularly ERS-1, JERS-1 and SIR-C Synthetic Aperture Radar (SAR).

Equipment Used and Data Collected:
To accomplish these objectives, we will use a helicopter-based FM scatterometer operating at 10, 5.3 and 1.5 GHz with all four linear polarizations over incidence angle of 0˚ to 50˚. This system will measure backscatter as a function of range, angle and frequency over the sites. All data will be reduced to backscatter coefficients using vector-correction techniques. After reducing the data, it will be used to train and test a feed-

forward artificial neural network (ANN). The accuracy of the ANN will be evaluated using ground truth data collected with help from Dr. Jon Ranson and Dr. Roger Lang. Upon completion, we will provide data to other investigators via BORIS.

Summary of Places and Times of Measurements:
The following table gives the day and type of data collected. We worked at the SSA during IFC-2 and IFC-3. However, system problems during IFC-2 make the data hard to interpret. Therefore, the table lists activities during IFC-3.

Flight Number	Site Code	Incidence	Polarizations
1 (9/14/94)	YJP - 0	5˚,10˚,15˚,20˚ 30˚,40˚,50˚	VV,HH,VH and HV
1 (9/14/94)	YJP - 1	5˚,10˚,20˚,30˚40˚,50˚	VV,HH,VH and HV
1 (9/14/94)	OBS (OS)	5˚,10˚,20˚,30˚40˚,50˚	VV,HH,VH and HV
2 (9/15/94) h = 110 ft	OA (Old Aspen)	5˚,10˚,20˚,30˚ 40˚,50˚	VV,HH,VH and HV
2 (9/15/94) h = 110 ft	OBS (OS)	5˚	VV,HH,VH and HV
2 (9/15/94) h = 170 ft	OBS (OS)	5˚	VV,HH,VH and HV
2 (9/15/94)	OBS (OS)	10˚,20˚,30˚, 40˚,50˚	VV,HH,VH and HV
3 (9/16/94)	YJP - 0	5˚,10˚,20˚,30˚40˚,50˚	VV,HH,VH and HV
3 (9/16/94)	YJP - 1	5˚,10˚,20˚,30˚ 40˚	VV,HH,VH and HV

5.3.1.14 RSS-14

PI: E. A. Smith — Florida State University
Collaborators: H. J. Cooper, G. Hodges, J. Jing — Florida State University

Objectives:
i) Inter comparison of net radiation measurements
ii) Archiving GOES-7 imagery
iii) Application of Surface SW and LW algorithms using GOES-7 data

Types of Data:
GOES-7 full resolution VIS, IR and water vapor channel data for a 1024 by 1024 pixel image covering the NSA and the SSA. Net radiation measurements at all BOREAS AMS and TF sites in both NSA and SSA.

Summary of Times of Measurement:
Satellite data for 1994. Net radiation data for site visit periods.

Date	Study Area	Action	Site
7/18/94	SSA	Arrived	Saskatoon
7/19/94	SSA	Set-up	Saskatoon AMS
7/19/94	SSA	Set-up	Meadow Lake AMS
7/20/94	SSA	Operating	Meadow Lake AMS
7/21/94	SSA	Take-down	Meadow Lake AMS
7/22/94	SSA	Take-down	Saskatoon AMS
7/22/94	SSA	Set-up	SSA-OA
7/22/94	SSA	Set-up	PANP AMS
7/23/94	SSA	Set-up	SSA-OJP AMS
7/24/94	SSA	Take-down	SSA-OA
7/24/94	SSA	Take-down	SSA-OJP AMS
7/24/94	SSA	Take-down	PANP AMS
7/25/94	SSA	Set-up	SSA-Fen
7/25/94	SSA	Set-up	SSA-OBS
7/25/94	SSA	Set-up	SSA-YJP
7/26/94	SSA	Take-down	SSA-Fen
7/27/94	SSA	Set-up	La Ronge AMS
7/27/94	SSA	Take-down	SSA-OBS
7/27/94	SSA	Set-up	SSA-OJP
7/27/94	SSA	Set-up	SSA-YA
7/28/94	SSA	Operating	SSA-YA
7/29/94	SSA	Take-down	SSA-YA
7/29/94	SSA	Take-down	SSA-OJP
7/30/94	SSA	Take-down	La Ronge AMS
7/30/94	SSA	Set-up	The Pas AMS
7/30/94	SSA	Set-up	Flin Flon AMS
7/31/94	SSA	Operating	
8/1/94	SSA	Take-down	Flin Flon AMS
8/1/94	NSA	Set-up	Thompson AMS
8/2/94	NSA	Set-up	NSA-Fen
8/2/94	NSA	Set-up	NSA-OBS
8/3/94	NSA	Take-down	NSA-FEN
8/3/94	NSA	Take-down	NSA-OBS
8/4/94	NSA	Set-up	NSA-YJP
8/4/94	NSA	Set-up	NSA-OJP
8/4/94	NSA	Set-up	Nelson House AMS
8/4/94	NSA	Take-down	Thompson AMS
8/5/94	NSA	Take-down	Nelson House AMS
8/6/94	NSA	Take-down	NSA-YJP
8/6/94	NSA	Set-up	Lynn Lake AMS
8/7/94	NSA	Set-up	Thompson Zoo
8/7/94	NSA	Take-down	LynnLake AMS
8/8/94	NSA	Take-down	NSA-OJP
8/8/94	NSA	Take-down	Thompson Zoo
8/9/94	SSA	Arrived	Prince Albert
8/10/94	SSA	Arrived	Saskatoon

5.3.1.15 RSS-15

PI: K. Jon Ranson — NASA GSFC
Co-PIs: Roger H. Lang— GWU
Co-I: Guoqing Sun— SSAI; Narinder Chauhan— GWU

Title: Distribution and Structure of Above Ground Biomass in Boreal Forest Ecosystems

Objectives: Determine the amount and distribution of above ground biomass for ecologically distinct areas of the BOREAS study sites . Develop inversion strategies to partition above ground biomass into foliage, branch and bole components. Determine the appropriate radar wavelength, resolution and incidence angle for detection of forest gaps and evaluate the ability of SAR for extraction of information on forest spatial structure.

Acquire required field measurements for biomass mapping algorithm development and validation.

Acquire measurements of tree and ground properties to parameterize backscatter models

Equipment Used and Data Collected:

Forest plot sampling; (dbh, species, height estimates); diameter tapes, hippsometers, sonic range finder. Also with TE-20.

Dielectric measurements (foliage, branch, bole and background); Portable dielectric Probes (C-, L- and P-band frequencies).

Limited tree moisture content. Bole, branches and leaves (Fresh wt -dry wt)*100/(Fresh wt); electronic balance and drying oven.

Tree geometry of selected jack pine and aspen. Including branch angles, Branch and needle sizes, branch and needle densities, Tapes, calipers and inclinometers.

Surface measurements of dielectrics using Portable dielectric probes, Univ. Kansas multifrequency probe.

Summary of Places and Times of Measurements:
RSS-15 1994 BOREAS ACTIVITIES (SSA Only)

Location	Activity	Dates
YJP	C,L band dielectrics	4/13
YJP	C,L band dielectrics	4/14
OJP	C band dielectrics	4/14
YJP	L band dielectrics	4/15
YJP	Tree geometry	4/15
YJP	Plot Sampling, tree moisture	4/ 17
OJP	C,L,P band dielectrics	4/17
OJP	Tree geometry	4/18
OJP	Tree geometry	4/19
OJP(E)	Plot sampling	4/19
YJP(E)	Plot sampling	4/19
OA	Tree geometry	4/20
YJP	Tree geometry	4/21
YJP(ALLG)	Tree geometry	4/21
YJP(ALLG)	Plot sampling	4/21
YJP(ALLG)	Tree geometry	4/22
YJP (SE)	Plot sampling	4/22
YJP (W)	Plot sampling	4/22
YJP	Tree geometry	7/18
YJP	Tree geometry	7/19
YJP	Tree geometry	7/20
YJP	C,L,P band dielectrics	7/21
YJP	Tree geometry	7/22
RAN	Plot sampling	7/22
YJP	Tree geometry	7/23
OJP	C,L,P dielectrics	7/23
YJP	Tree geometry	7/24
RAN	Plot sampling	7/24
YJP	Tree geometry	7/25
YJP	P band dielectrics	7/25
RAN	Plot sampling	7/25
RAN	Plot sampling	7/26
OA	C,P band dielectrics	7/26
OJP	Tree geometry	7/26
RAN	Plot sampling	7/27
OJP	Tree geometry	7/27
OJP	Tree geometry	7/27
RAN	Plot sampling	7/28
RAN	Plot sampling	7/29
RAN	Plot sampling	7/30

RAN	randomized plot locations in Nipawan Area with TE-20.
OJP(E)	mature jack pine stand 3.5 km east of OJP.
YJP(E)	mature jack pine stand 0.5 km east of YJP.
YJP(ALLG)	alligator shaped mature jack pine stand 1.2 km south of YJP.
YJP (W)	regenerating stand of jack pine 0.8 km west of YJP.
YJP (SE)	regenerating jack pine stand 0.7 km southeast of YJP site.

1994 Shuttle Imaging Radar - C/ X-band Synthetic Aperture Radar (SIR-C/XSAR) BOREAS data takes.

A) Space Radar Laboratory -1 Mission (April 9-19, 1994)

Orbit/Data Take No.	Ascending/ Descending Pass	Date	Local Time (MST)	Look Angle (degrees)
SSA, Prince Albert				
20.1	A	April 10	9:27	29.45
36.3	A	April 11	9:09	33.48
52.3	A	April 12	8:51	36.8
68.2	A	April 13	8:31	39.46
84.2	A	April 14	8:11	41.65
100.2	A	April 15	7:51	43.4
116.3	A	April 16	7:31	44.82
117.1	D	April 16	9:00	33
132.4	A	April 17	7:10	45.94
133.1	D	April 18	8:38	55.53
148.2	A	April 18	6:48	46.8
NSA, Nelson House				
21.1	D	April 10	11:57	25.21
37.1	D	April 11	11:37	23.58
53.1	D	April 12	11:22	21.86
69.1	D	April 13	10:59	20.05
70	D	April 13	12:35	57.84
85.1	D	April 14	10:39	18.32

B) Space Radar Laboratory -2 Mission (September 30 - October 10, 1994)

Orbit/Data Take No.	Ascending/ Descending Pass	Date	Local Time (MST)	Look Angle (degrees)
SSA, Prince Albert				
20.12	A	Oct. 1	9:39	29.14
36.3	A	Oct. 2	9:21	33.18
52.3	A	Oct. 3	9:02	36.52
68.2	A	Oct. 4	8:43	39.32
84.2	A	Oct. 5	8:24	41.69
100.2	A	Oct. 6	8:04	43.61
101.1	D	Oct. 6	9:36	55.41
116.3	A	Oct. 7	7:44	45.27
NSA, Nelson House				
21.1	D	Oct. 1	12:13	25.42
37.1	D	Oct. 2	11:54	23.79
53.1	D	Oct. 3	11:35	21.99
69.1	D	Oct. 4	11:16	20.08
70	D	Oct. 4	12:48	57.71
85.1	D	Oct. 5	10:57	18.12

5.3.1.16 RSS-16

P.I.(s): S.S. Saatchi — NASA JPL
CO-I(s): J. VanZyl, M. Mogaddam — NASA JPL; T. Engman — NASA GSFC

Title: Estimation of Hydrological Parameters in Boreal Forest Using SAR Data

Objectives: To estimate the water content of the top layer of the forest canopy and the moisture of the forest floor and to map the snow and permafrost cover by using SAR imagery and possibly synergism between microwave and optical data. We propose to use AIRSAR, ERS-1, JERS-1, and AVIRIS data (SIR-c/X-SAR if available) in conjunction with classification techniques, forest modeling and retrieval algorithms to provide these parameters as quantitative inputs to hydrological models. In order to make the algorithms operational, we will validate the models used in SAR data analysis by working closely with other investigators for parameterizing the boreal forest surface cover and acquiring in situ measurements. In addition, we will also focus on the scaling problem to adjust the parameter estimation algorithms suitable for local and mesoscale hydrological modeling. We will participate in summer, fall and winter field campaigns to collect biometry data and characterizing the forest surface (snow depth, soil moisture, freeze and thaw in vegetation and soil, and understory).

5.3.1.17 RSS-17

PI: JoBea Way — NASA et Propulsion Laboratory
CoIs: Reiner Zimmermann, Kyle McDonald, Eric Rignot — NASA JPL

Title: Winter/Spring Thaw Transitions at the BOREAS Sites as Observed with ERS-1 Imaging Radar

Objectives: Measurements of the length of the growing season may significantly improve current estimates of net annual CO_2 flux in the boreal regions. For coniferous forest species, the summer frost free period bounds the growing season length. Both coniferous and deciduous tree types are driven in their growth potential by active mineral and water uptake through the soil. Estimating the duration of favorable soil temperature regimes is therefore of equal ecological significance as the temperature regime of the above-ground biomass. Based on AIRSAR and ERS-1 measurements collected in Alaska, freezing results in a significant drop in radar backscatter. This change is due to a decrease in soil and canopy dielectric constant as the in situ water, which is highly polar in the liquid state, freezes.

In addressing the use of imaging radar data for estimating growing season length, there are two questions to be addressed. First, the relationship between canopy, bole and soil freezing, and the beginning and end of seasonal photosynthetic activity must be ascertained. Secondly, the sensitivity of spaceborne imaging radar backscatter to freeze/thaw processes must be assessed. In particular, is backscatter sensitive to canopy or soil freezing, or both?

To address these questions, in situ soil, stem and root temperatures, and stem xylem flux were measured over a complete annual cycle in 1994 at the BOREAS test sites. ERS-1 data were also acquired throughout 1994; in the winter Ice Phase of the ERS-1 mission, three day repeat image transect data provided detailed and regional sampling of the BOREAS sites. During the spring, summer and fall Geodetic Phase of the mission, data over a particular site were available approximately every two weeks.

The temperature data at the southern BOREAS sites show clear transitions from frozen to thawed soil on DOY 61, and frozen to thawed stems on DOY 100. The xylem flux begins to be active as early as DOY 61 and is fully active by DOY 135. The ERS-1 data show a significant rise in backscatter between DOY 60 and DOY 63. The image backscatter does not drop back to its winter value after this date even though the stem temperatures drop down to 0°C. A second rise in backscatter also occurs in the spring, however, the temporal resolution of the ERS-1 data analyzed so far do not allow us to correlate this second rise with stem thaw. Data for the end of the growing season are still being analyzed.

In summary our results show that imaging radar provides a unique ability to observe thaw transitions at the beginning of the growing season. The first spring thaw of the upper soil layer is clearly observable in the radar data. Based on the results of other BOREAS investigators, this early soil thaw appears to trigger the beginning of respiration; although the fluxes are small in this March through June period, the duration is long and therefore the contribution is significant to the net annual carbon flux.

Equipment Used and Data Collected:
Five sites were selected for continuous measurement of canopy micrometeorology, tree and soil temperature and tree xylem water flow during one full annual cycle. Data were collected automatically by a datalogger at each site. During summer, the data storage rate was between 10 and 30 minutes; during winter the data take rate has been slowed to 1 hour to conserve memory. Power supply to the system was buffered by 12 Volt lead batteries which allows continuation of all external power dependent measurements (xylem flux and some micromet. sensors) for five to ten days and of temperature measurements for at least one month if the power supply is down. Memory storage was buffered separately.

Summary of Places and Times of Measurements:

Study Area	Start Date	End Date
NSA-OBS	21 October 1993	30 October 1994
SSA-OBS	5 October 1993	April 1995
SSA-OA	16 February 1994	April 1995
SSA-OJP	17 February 1994	April 1995
SSA-YJP	15 July 1994	April 1995

Known Problems and Caveats:
On the northern site, data from January 10, 1994 to April 12, 1994 are missing due to frequent power off status of the line power. Power was also shut off by a crew at the southern Black Spruce site for several days in end of September 1994 but reinstated by the National Park Service. Old Aspen South, Old Jack Pine South and Young Jack Pine South had no data loss up to October 30, 1994. Soil temperature data are partly missing for Old Black Spruce sites due to degradation of soil temperature sensors during freeze/thaw. Micrometeorological sensor data and xylem data were only in a few instances affected by damage to sensor cables by rodents which was corrected during the following maintenance operation.

5.3.1.18 RSS-18

P.I.: R.O. Green — NASA Jet Propulsion Laboratory

Title: Surface and Atmosphere Measurements for Calibration and Validation of AVIRIS for Quantitative Data Analysis at BOREAS

Objectives: A spectral and radiometric calibration of radiance-measuring sensors such as AVIRIS is required for physically based analysis of the measured data and for quantitative comparison of data acquired from different sites, times and instruments. The data measured in this experiment support this calibration and validation requirement for AVIRIS during the BOREAS experiment. Ground based surface and atmospheric measurements with calibrated field instruments were acquired simultaneously with the AVIRIS overflights.

Data Collected:

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DATA SET 1: AVIRIS IMAGE DATA (400 to 2500 nm)
            940419 BOREAS Southern Study Area
            940420 BOREAS Northern Study Area
            940428 BOREAS Northern Study Area
            940608 BOREAS Northern Study Area
            940721 BOREAS Southern Study Area
            940804 BOREAS Northern Study Area
            940808 BOREAS Northern Study Area
            940916 BOREAS Southern Study Area
            940917 BOREAS Northern Study Area

            WWW Quicklook Image Site
            ftp://ophelia.jpl.nasa.gov/README.htm
            Also BORIS


DATA SET 2:   FIELD SPECTROMETER SPECTRA (400 to 2500 nm)
        940608 100   Spectra of AVIRIS Calibration Site
        940611 300   Spectra of AVIRIS Calibration Site
        940721 200   Spectra of AVIRIS Calibration Site
        940723 200   Spectra of AVIRIS Calibration Site
        940724 80    Spectra of AVIRIS Calibration Site
        940802 200   Spectra of AVIRIS Calibration Site
        940807 105   Spectra of AVIRIS Calibration Site
        940808 194   Spectra of AVIRIS Calibration Site
        940916 140   Spectra of AVIRIS Calibration Site
        940601 30    Spectra of AVIRIS Calibration Site

        Aspen               10
        Jackpine Bark       10
        Jackpine Needles    10
        Healthy Grass       10
        Shallow Water       10
        Tarps               10
        Wet Soil            10
        Spruce              10
```

DATA SET 3: SUNPHOTOMETER DATA (Aerosols, Water Vapor)

940529A AVIRIS Calibration Site
940529C Old Jack Pine Site
940531A AVIRIS Calibration Site
940531B Old Jack Pine Site
940531C Old Jack Pine Site
940601A AVIRIS Calibration Site
940601B Old Jack Pine Site
940601C Old Jack Pine Site
940604B Old Jack Pine Site
940604C Old Jack Pine Site
940606B Old Black Spruce Site
940606C Old Black Spruce Site
940611A AVIRIS Calibration Site
940611B Old Aspen Site
940912B Old Black Spruce Site
940912C Old Black Spruce Site
940913A AVIRIS Calibration Site
940913B Old Black Spruce Site
940913C Old Black Spruce Site
940915A AVIRIS Calibration Site
940915B AVIRIS Calibration Site
940915C AVIRIS Calibration Site
940916A AVIRIS Calibration Site
940916B Old Black Spruce Site
940916C Old Black Spruce Site
940917A AVIRIS Calibration Site
940917B Old Aspen Site

5.3.1.19 RSS-19

PI: John Miller — York University
CoIs: E. LeDrew — Univ. of Waterloo; N. O'Neill & A. Royer — Univ. de Sherbrooke; P. Teillet, K. Staenz, R. Gauthier & R. Neville — CCRS; A. Hollinger — Canadian Space Agency

Title: Variation in Radiometric Properties of the Boreal Forest Landscape as a Function of the Ecosystem Dynamics

Objectives: CASI Airborne Data Collection:
• Compact Airborne Spectrographic Imager (CASI) data collection for all five 1994 field campaigns - 36 flight days, 228.1 image collection hours.
• 4 CASI operating modes and 12 different mission plans to meet the scientific objectives of the RSS-19 group and collaborators - 459 mission flights (i.e. image acquisitions over a specific target with a specific sensor configuration).

Summary of Places and Times of Measurements:

CASI Missions	Location	Duration	Number of Flights	Processing Status	Access Status
1. Multiview Canopy Bi-directional Reflectance	10 flux towers NSA & SSA	all FFCs&IFCs	57	0	BG
2. Canopy biochemistry - spectrometer mode	10 flux towers NSA & SSA	all FFCs&IFCs	37	0 1	BG
3a. Site Mapping @ 1675 m AGL - spatial mode	10 flux towers NSA & SSA	all FFCs&IFCs	48	0 1	BG BG,BO*
3b. Site Mapping @ 600 m AGL - spatial mode	10 flux towers NSA & SSA	all FFCs&IFCs	48	0 1	BG
4. Stem Mapping @ 150 or 300m AGL - CIR spatial mode	10 flux towers NSA & SSA	all FFCs&IFCs	28	0 1	BG
5. PAR and Spectral Albedo @ 150 m AGL-from up & down spectral irradiance	10 flux towers NSA & SSA	all FFCs&IFCs	53	N	-
6. Lake transects @ 1675 m	Wask & Candl Lake SSA	IFC 1, 2, & 3	10	0 1	BG
7. Beaver ponds	NSA	IFC 1, 2 & 3	9	0 1	BG
8. Auxiliary sites @ 1675 m AGL - spatial mode	NSA & SSA	all FFCs&IFCs	135	0 1	BG
9. ET transects @ 2.5 km AGL	SSA <-> NSA	all FFCs&IFCs	5	N	-
10. Snow Course lines	SSA & NSA • FFC-W	FFC-W	37	0 1	BG
11. Agriculture Lines	PA to SSA	FFC-T and IFC 1,2& 3	4	0 1	BG
12. Atmospheric Correction Methodology study - multi-altitude & flights over characterized ground targets	SSA	IFC-2	40	0 1	BG

N- not yet processed
0- quick-look gifs
1- at-sensor radiance
2- at-sensor reflectance
3- surface reflectance
BO -BORIS
BG -ISTS (RSS-19 WWW site at URL: http://www.eol.ists.ca)

Field Data Collection Completed (analysis status as indicated):
Scientists associated with RSS-19 were at the BOREAS sites at all FFCs and IFCs. The field activities carried out are outlined in detail below.

1. Canopy Radiative Transfer input parameters:

(i) canopy architecture

(a) vectorization - to obtain the 3-D distribution of canopy elements and tree form i.e. branching structure, age, DBH, Ht, length of live crown:
- where: YJP - 4 trees; OJP: 3 trees; OA: 2 trees + $1m^2$ hazel
- data status: data processed for YJP (4 trees) and OJP (3 trees), ready for submission to BORIS.

Documentation in progress. (Contact R. Landry, CCRS)

(b) site characterization - on detailed referenced grid (normally 50 x 60 m)
- X-Y location of trees, DBH,, Ht, live crown Ht & radius in cardinal directions, dominance class, understory cover (in 10 m x 10m subplots)
- where: - SSA: OA, OBS, OJP, YJP, 4 mixed OA/white spruce
  - NSA: OA, OBS, OJP, YJP, YA aux site
- data status: submitted to BORIS (Contact R. Fournier, TE-23)

(ii) branch BRF: bidirectional spectral reflectance using spectrometer & goniometer (JPL)
- where: adjacent to sites OBS, OJP, OA
- data status: data processing in progress (but data not yet reached level suitable for submission)

(iii) needle reflectance and transmittance (r,t) spectral properties, and shoot bi-directional reflectance
- where: YJP, OJP, OBS tower sites at the NSA & samples from SSA at each IFC
- data status: NSA needle r,t data processing completed, documentation in progress.

(iv) understory mean spectral reflectance: seasonal variation from all 5 campaigns
- where: flux tower sites at both SSA and NSA
- data status: analysis complete, submitted to BORIS

(v) BRF of selected understory dominant components:
- IFC-2:- where: SSA: OJP, OBS (moss & lichen) - some vis/NIR; some vis to SWIR
- IFC-3: - where: SSA & NSA (vis/NIR)
- data status: data processing in progress (but data not yet reached level suitable for submission)

(vi) Tower-based canopy spectroradiometric signatures
- FFC-W: where - SSA-OJP - (sunlit & shadowed) component signatures 400 to 850 nm
- FFC-T & IFC-3: where - SSA & NSA - canopy BRF & endmember spectra
- data status: FFC-W data analysis complete

2. Atmospheric Correction Methodology Evaluation:

(i) BRF characterization of standard ground targets:

- where airport tarmac & canvas panels
- status: analysis in progress

(ii) optical depth data collection

- IFC-2: - where - Prince Albert airport
- data status: analysis complete and rationalized through interchanges with OD data by Markham RSS- & Wrigley

(iii) airborne spatial variability characterization

- airborne zenith sky, global irradiance Spectron data SSA (collaboration with Wathall
- Status: analysis in progress

(iv) Atmospheric Correction Model Validation Intercomparison

status: - internal report prepared on benchmark results for standard McClatchey atmosphere for 10 altitudes, including typical C-130, Chieftain & ER-2 altitudes

5.3.1.20 RSS-20

P.I.(s): V.C. Vanderbilt — NASA ARC

Title: stimation of Photosynthetic Capacity using Polder Polarization

Title: stimation of Photosynthetic Capacity using Polder Polarization The overall hypothesis of this study is that the ecosystem-dependent variability in the various vegetation indices is in part attributable to the effects of specular reflection. The polarization channels on the French sensor POLDER provide the potential to estimate this specularly reflected light and allow the modification of the vegetation indices to better measure the photosynthetic process in plant canopies. In addition these polarization channels potentially provide additional ecologically important information about the plant canopy. The expected result from this research is a series of map products providing seasonal estimates of 'minus specular' vegetation indices for flightlines at the two BOREAS test sites. This is a companion effort to TF-6.

5.4 Terrestrial Ecology (TE)

A primary focus of the terrestrial ecology group in BOREAS is to quantify the major C pools and fluxes for the dominant forest ecosystems of the boreal forest and how they vary over a climatic gradient. Productivity, carbon (C) storage, and CO_2 fluxes are being studied at sites that reach from the southern boundary of the boreal forest, represented by a drought-prone aspen parkland 60 km south of Prince Albert, Saskatchewan, to near the northern boreal forest - Arctic woodland ecotone of the boreal forest, represented by cool, moist forests in the Northern Study Area (NSA) near Thompson, Manitoba. The climatic gradient will provide a spatial analog of climate change for investigating the effects of global warming on the structure and function of terrestrial ecosystems and their interaction with the atmosphere. Measurements made at each of the forested tower flux sites included C distribution in the soil, lichens or mosses, understory shrubs and overstory trees; leaf photosynthesis by the moss or lichens, understory shrubs and overstory trees; leaf, branch, stem and root net primary production and respiration; and soil surface CO_2 flux. Preliminary data provided by Gower (pers. comm.) of TE-6 indicate that the carbon content in wood and foliage tissue and soil surface CO_2 fluxes differ among similar-aged forests types at each study site and between study sites for a similar vegetation type and that maintenance respiration rates for boreal tree species are positively correlated to tissue nitrogen concentration. Collectively, the C flux measurements will be used to determine if the terrestrial ecosystems are a net C sink or source. In addition they will be compared to net ecosystem CO_2 flux as determined by eddy correlation for the same forest ecosystems to test different scaling approaches. Stable isotope analyses are also being conducted to determine the extent of recycling of CO_2 within terrestrial ecosystems and their interaction with the atmosphere, as well as reconstruct past temporal patterns of leaf gas exchange.

5.4.1 TE Team Science Activities

5.4.1.1 TE-1

P.I.(s): D.W. Anderson — University of Saskatchewan
CO-I(s): J.J. Schoenau, E.G. Nisbet — Univ. of Saskatchewan; D. Pluth — Univ. of Alberta

Title: Stores and Dynamics of Organic Matter in Boreal Ecosystems

Objectives: The objective of this research is to characterize the various soil-plant systems along a transect in one of the ecosystems selected for study at the Southern Study Area. Particular emphasis is on nutrient biochemistry, the stores and transfers of organic carbon and on soil properties and pedogenesis, and how the characteristics are related to measured methane fluxes. The transect in Prince Albert National Park included the major plant communities and related soils that occur in that section of the boreal forest. Soil physical, chemical and biological measurements along the transect are being used to characterize the static environment, which will then be related to methane fluxes. Chamber techniques were used to provide a measure of methane production/uptake. Chamber measurements coupled with flask sampling were used to determine the seasonality of methane fluxes.

5.4.1.2 TE-2

PI: Michael Ryan — USDA
Collaborator: Michael B. Lavigne — Forestry Canada

Title: Autotrophic Respiration in Boreal Ecosystems

Objectives: (1) to measure CO_2 efflux from autotrophic respiration from foliage, stems, branches, coarse roots, and fine roots in the major forest ecosystem types of the boreal forest; (2) to develop relationships between autotrophic respiration, tissue characteristics (N, P, C, growth), and environment (temperature) to scale cuvette measurements to the ecosystem; (3) to estimate instantaneous and annual fluxes of CO_2 from autotrophic respiration for the footprint of tower flux measurements; (4) to use paired species comparisons at the two locations to determine whether respiration rates acclimate to different climates; and (5) to estimate an annual carbon budget for these sites (in cooperation with other scientists) to determine whether the ratio of respiration to photosynthesis differs among species and for different climates.

Types of Data Collected:
(1) CO_2 efflux from tree stems and stem and air temperature (continuous diurnal measurements, 3-6 days per IFC) and wood growth, sapwood volume, and N, P, C, and starch and sugar content of sapwood after IFC-3. (2) CO_2 efflux from fine roots (< 2mm diameter) and foliage (at night), and tissue temperature, N, P, C, starch, sugar, mass, area (foliage) for each sample. (3) CO_2 efflux from branches and coarse roots and stem and air temperature and wood growth, sapwood volume, and N, P, C, and starch and sugar content of sapwood after IFC-3. (4) CO_2 efflux from foliage and foliage growth, C, N, P, starch, sugar, temperature. (5) Estimates of bole photosynthesis for aspen using shaded and unshaded chambers.

Summary of Places and Times of Measurements:
Stem, foliage, and fine root respiration were collected at OBS, OA, OJP, YJP in NSA and OBS, OA, OJP, YJP, YA in SSA each IFC and also after IFC-3. Stem respiration was also collected at OBS, OA, OJP, YJP in NSA approximately every two weeks from 6/1 - 9/30. Stem respiration was also collected continuously at SSA-OBS between IFC-2 and IFC-3. Branch and coarse root respiration were measured only at NSA and only during IFC-3. Foliage respiration and foliage expansion was measured every 5-14 days from 5/28- 9/16 (depending on expansion rates) near NSA-Fen on aspen, black spruce, jack pine, alder, and birch.

5.4.1.4 TE-4

P.I.(s): J.A. Berry — Carnegie Institution of Washington
CO-I(s): G.J. Collatz — Carnegie Inst. of Washington; J. Gamon — Calif. State Univ., Los Angeles

Title: Measurement and Prediction of CO2 and H2O Exchange from Boreal Forest Tree Species

Objectives: To measure steady-state gas exchange and spectral reflectance responses to temperature, light, CO2 and humidity in leaves of aspen, jack pine, and black spruce. Some of these measurements were made within canopies of these species in the 1994 IFC's and some will be made under more controlled laboratory conditions. Effects of leaf age, and conditions (temperature, light, nitrogen, water) will be measured. Specialized chambers and portable field instruments are being developed for use with broad leaf and conifer tissue. This data will be used to develop algorithms for predicting photosynthesis and transpiration from bidirectional reflectance and to parameterize our mechanistic leaf and canopy models of CO2 and exchange for the boreal forest.

5.4.1.5 TE-5

PI's: J. R. Ehleringer — Univ. of Utah; L. B. Flanagan — Carleton University
Collaborator: J. Renee Brooks

Title: Vegetation-Atmosphere CO2 and H2O Exchange Processes: Stable Isotope Analyses

Objectives:
1) to determine the influence of vegetation on changes in the carbon and oxygen isotopic composition of atmospheric CO_2.
2) to determine the extent of recycling of CO_2 within forest canopies.
3) to determine the water sources used by different tree species within a growing season.
4) to reconstruct past temporal patterns of leaf gas exchange (ratio of assimilation to stomatal conductance) using cellulose from tree rings.

Summary of Places and Times of Measurements:
Sites visited: SSA-OJP, SSA-OA, SSA-OBS, NSA-OJP, NSA-TEBS, NSA-OA.

Types of Data Collected:
1) d13C & d18O of Atmospheric CO_2 was collected over a diurnal period for each site during each IFC.
2) Water Source Data: stem, leaf, soil and atmospheric water was collected at each site for each IFC.
3) Leaf d13C was measured for the 10 most dominant species at each site.
4) Meteorological and continuous CO_2 data
Meteorological: 9m and 1m PPFD, 9m and 1m air Temperature, RH, 10 cm and 20 cm soil temperature. [CO_2] at 9m, 3 m, 1 m, 0.5m, 0.25m, and 0.05m, over at least 24 hrs., usually more.
Note: No RH data for NSA-OA IFC3, due to rodent problems.
5) Soil Data

a. Soil Respiration Rates
b. d13C & d18O of Respired Carbon
c. d13C of Soil Carbon
d. d18O of Soil Water

6) Photosynthesis Data

a. IFC-1, Daytime Diurnal data were collected at SSA-OBS, SSA-OJP, NSA-OJP and NSA-TEBS.

b. IFC-2, Daytime Diurnal data were collected at SSA-OJP, SSA-OBS, SSA-OA, NSA-OJP, NSA-TEBS, and NSA-OA.

7) Disks for Tree Ring analysis and d13C of Cellulose to accomplish objective 4. d13C of Cellulose will only be measured for trees at NSA-OJP and SSA-OJP.

5.4.1.6 TE-6

P.I.(s): S.T. Gower — University of Wisconsin
CO-I(s): J.M. Norman — University of Wisconsin

Title: Measurement and Scaling of Carbon Budgets for Contrasting Boreal Forest Sites

Objectives: To examine the influence of vegetation, climate and their interaction on the major carbon fluxes for aspen, jack pine and black spruce forest ecosystems at the Southern Study Area and Northern Study Area. Four, 15 x 15 m plots were established at each site during the fall 1993 IFC. We measured above- and below-ground net primary production and are using leaf respiration, autotrophic respiration and soil surface CO2 flux data from other PI's to construct stand-level carbon budgets. Above-ground net primary production will be calculated annually for a 10-year period (1985-1994) from annual stemwood radial increment cores and site-specific allometric equations which will be developed in conjunction with M. Apps (TE-13). Below-ground net primary production will be estimated using sequential coring and carbon balance methods. Soil surface CO2 flux will be measured weekly for the northern aspen stand during the IFC's using a LI-COR 6200 and soil respiration chamber. Soil surface CO2 flux estimates obtained by this method will be compared to estimates obtained by PI's measuring soil surface CO2 flux (using similar or different methods) at all mature forested sites at least once during 1994. We will develop a method to scale leaf-level photosynthesis measurements to the canopy level using measurements of canopy architecture and models of radiative transfer. The scaled canopy-level CO2 fluxes will be compared to tower fluxes that are based on micrometeorological methods. We will develop and explore the utility of a new multi-band vegetation imager for indirectly determining forest canopy architecture in aspen and jack pine sites.

5.4.1.7 TE-7

PI: E.H. (Ted) Hogg — Forestry Canada
CoI: P.A. (Rick) Hurdle — Forestry Canada

Title: Climate Change Effects on Net Primary Productivity of Productivity of Aspen and Jack Pine at the Southern Limit of the Boreal Forest

Objective: To compare ecophysiological responses of aspen to environmental conditions across a climatic moisture gradient from the aspen parkland to the southern boreal forest.

Data Collected:
1. Sap flow by the heat pulse velocity method, every 3 hours, estimated transpiration based on sap flow and stand sapwood area
   a) Batoche aspen, 12 trees (4 sites x 3 trees) 23 May-19 Oct 1994
   b) PANP old aspen, 6 trees (2 clones x 3 trees) 26 May-20 Oct 1994
   c) Candle Lake Mixedwood, 8 trees (4 aspen, 2 white spruce, 2 black spruce) 21 Jun-20 Oct 1994
2. Meteorological data
   a) Batoche, continuous hourly since Sept. 1992, air and soil temperatures, RH, wind, PAR, global solar, etc.
   b) At HPV sites, every 3 hours (3 m height), air and soil temperatures, RH, wind
3. Litter fall by species, estimated LAI, stand basal and sapwood area, Batoche (1992-1994), PANP old aspen (1994)
4. Other (Batoche)
   a) Aspen dendrochronology (12 trees processed to date)
   b) Aspen leaf P/S, LWP, conductance, 23 Jul, 24 Aug, 8 Sep 1994, (also 5 dates in 1993)

Known Problems and Caveats:
Interruption of sap flow by the heater and sensors causes a consistent underestimation from theoretically calculated values (by 45-55% based on heat transfer modeling and published analyses).

Other Information:
Comparison of sap flow at mixedwood with those made by Saugier have been completed. Comparison of sap flow and canopy transpiration at PANP OA will be made once Zimmerman and Black send us their data. We are planning to present our HPV work at 1995 ESA meeting in Utah. Main result is that midday sap flow increases linearly with VPD up to ca. 1 kPa, then remains remarkably constant over VPDs from 1-2.8 kPa. There was no evidence that sap flow was limited by soil moisture, but 1994 was wetter than average. Significant night-time sap flow in aspen occurred on warm, dry nights, especially in June. Sap flow in aspen was almost negligible after Sep 27 at both PANP and mixedwood, but in spruce continued through at least Oct. 20.

Team: TE-7

PI: Ted Hogg
Co-Is: Ian Campbell, Thierry Varem-Sanders

Objectives: Tree-ring density and width measurements on biometry and allometry material.

Data Collected:
Cores were collected by various teams including Tom Gower and the biometry crew. Cores have also been submitted by D. Lawrence (H. Shugart). Total involves an estimated 2000 cores (biometry and D. Lawrence) and 1500 disks (allometry). Material is being analyzed by x-ray densitometry for ring width and density using a system developed at the Northern Forestry Center of CFS (DendroScan). Resolution is in most cases 0.005 mm.

Places and Times of Measurements:
Most tower sites, allometry sites, and biometry sites. Additional sites collected by D. Lawrence. Collection during 1993 and 1994.

Known Problems and Caveats:
Some cores/disks mislabeled in the field; some incomplete; some breakage during transport or analysis. Problems are noted with each sample individually. Percentage latewood calculated as percentage of ring formed after (max. density + min. density)/2.

Other Information:
Data to be supplied to BORIS from biometry and allometry sets: mean (of two radii per tree where available) ring widths, mean maximum density, mean minimum density, mean percentage latewood. Submission is expected after the completion of quality control, in late summer 1995. Other data will be available from Ian Campbell and Thierry Varem-Sanders; this includes the entire density traces, but will be readable only with DendroScan software (expected available for purchase in fall 1995). Data for material from D. Lawrence will be submitted to BORIS by D. Lawrence.

Tree-ring studies using x-ray densitometry, examining all the tree cores and cross-sections collected by the various biometry and allometry teams, totaling approximately 3,000 pieces of wood, most of which have now been processed. We expect to have a series of reports ready starting around January. All ring data will also be contributed to the International Tree-Ring Data Bank in Tucson,

<u>5.4.1.8 TE-8</u>

P.I.(s): V.I. Kharuk — Russian Academy of Sciences

Title: The Tree's Bark Input in Tree-Atmosphere Interactions

Objective: To evaluate the input of tree bark into tree-atmosphere interactions (i.e., the photosynthetic process). Tree-atmosphere interaction is considered usually as "leaf" interaction with the atmosphere. But the input of tree bark is not negligible, especially during "leafless" periods (e.g., spring, fall, as well as after defoliation caused by insects or pollution), when the bark is the single source of hydrocarbons. The comparative analysis of biophysical properties of bark versus those of leaves must be done.

The studies should include:

• Comparative analysis of optical properties (transmittance, reflectance, polarization) of bark and leaves
• Comparative analysis of bark versus leaf pigment content
Estimation of LAI versus "BAI" ("bark area index")
• Comparative analysis of bark photosynthesis/evapotranspiration versus leaf photosynthesis/evapotranspiration.
• Comparative analysis of deciduous (Populus tremuloides) versus coniferous species

<u>5.4.1.9 TE-9</u>

PI: Hank Margolis — Universit`eacute Laval
Collaborators: Geoffrey Edwards, Keith Thomson, Alain Viau — Universit`eacute Laval

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

Objectives: There are five main components to this study:
1) Measure the response of branches, for all foliage age-classes, to light, CO_2 concentration, temperature and vapor pressure deficit for jack pine, black spruce and trembling aspen.
2) Determine diurnal photosynthesis of intact branches.
3) Produce profiles of %PAR versus nitrogen concentration for each IFC.
4) Measure concentrations of chlorophyll, nitrogen, starch, lignin, cellulose, and sugars.
5) Make measurements of angular and nadir reflectance of the understory.

Data Collection and Equipment:
1) Response of branches to light, CO_2 concentration, temperature and vapor pressure deficit. All foliage age-classes combined for jack pine, black spruce and trembling aspen in the Northern Study Area were measured. A cut branch technique was used. A laboratory-based open photosynthetic system was used.
2) Diurnal photosynthesis of intact branches was measured with LiCor-6200 from canopy access towers in the Northern Study Area.
3) Profiles of %PAR versus nitrogen concentration used PAR data taken with LiCor quantum sensors from the canopy access towers on overcast days. Nitrogen measured in the lab using kjeldahl procedure.

4) Concentrations of chlorophyll, nitrogen, starch, lignin, cellulose, and sugars were measured using branches harvested in the field and analyzed using standard laboratory procedures (refer to Data Documentation for details).
5) Measurements of angular and nadir reflectance of the understory in the NSA. An Analytical Spectral Devices Personal Spectrometer II, a 35 mm photographic camera and a LiCor Integrating Sphere were used.

Measurement Sites and Periods:
1) Response of branches to light, CO_2 concentration, temperature and vapor pressure deficit for jack pine, black spruce and trembling aspen. Data were collected for each of the three IFC's.
2) Diurnal photosynthesis of intact branch branches was collected for selected days for each IFC for NSA -OJP, -YJP, -OBS, -TE-BS, and -OA.
3) Profiles of %PAR versus nitrogen concentration were collected for each IFC for NSA -YJP, -OJP, -OBS, -TE-BS, -OA and -YA.
4) Concentrations of chlorophyll, nitrogen, starch, lignin, cellulose, and sugars were collected for NSA -OBS, -OJP and -OA for all three IFC's and the two FFC's.
5) Measurements of angular and nadir reflectance of the understory . Measurements were made in the NSA -YJP, -OJP, -YA and -OA sites. Measurements were taken on 23 different days between May 27 and July 31, 1994.

Known Problems and Caveats:
Measurements of angular and nadir reflectance of the understory, the solar plane orientation was generally random in respect to the angular plane but was known in most cases. Some of the data were normalized to the white reference panel when the panel was in shade.

5.4.1.10 TE-10

PI: E.M. Middleton — NASA GSFC
Co-I(s): J.H. Sullivan — Univ. of Maryland; Robert G. Knox — NASA GSFC

Title: CO_2 and Water Fluxes in the Boreal Forest Overstory: Relationship to f_{APAR} and Vegetation Indices for Needles/Leaves

Objectives: In this study we will correlate physiological processes at the leaf/needle level with and optical measurements amenable to remote sensing. Specifically, in situ measurements

Approach:
For gas exchange fluxes for CO_2 and water, plant stress as indicated by chlorophyll-a fluorescence, and other supporting measurements will be acquired for dominant species of the boreal forest overstory at the BOREAS Southern sites (mature aspen, mature jack pine, young jack pine, black spruce, and mixed aspen/white spruce). In the laboratory, further measurements of photosynthetic capacity will be made in conjunction with continuous visible/near-infrared spectral optical properties and pigment analyses. Nitrogen will be determined from dry foliar material. This data set will be utilized to estimate the vertical gradients of carbon assimilation, nitrogen use efficiency, and photosynthetic efficiency for different species as a function of phenology and environmental conditions, especially available water, nitrogen, and PAR. These data will be used to examine the relationships

between the physiological parameters, especially photosynthetic and conductance rates, and the optical parameters (Fapar and spectral vegetation indices, or SVIs). Ultimately, these data will be used to test hypotheses relating leaf physiology to canopy physiology and remotely acquired SVIs. They will also be used to parameterize the canopy level radiative transfer and physiological models utilized in landscape analyses by other investigators.

Study Objectives:

- Examine the vertical and seasonal dynamics for net photosynthesis and transpiration, PAR, (absorbed, reflected, transmitted), spectral vegetation indices, and leaf characters for the primary overstory species of the major boreal forests (aspen, jack pine, and black spruce) of north-central Canada.
- Evaluate the relationships among net photosynthesis and vegetation indices and f_{APAR}.
- Evaluate "PAR Canopy Use Efficiency Parameter" Hypothesis (Sellers et al).
- Input to Canopy Models
    - Radiative Transfer Model (BRDF, R. Myneni);
    - Middleton is also Co-I on BOREAS RSS-1 (Deering et al.)
    - Canopy Physiological Processes
    - Canopy Carbon Uptake and Dynamics (Sib)

1994 Field & Lab Measurements:

PI: Betsy Middleton (NASA/GSFC)
Co-I: Joe Sullivan (U MD)
Participant: Stephen Chan (SSAI)
Students: Brian Bovard (Duke U), Andrea DeLuca (U MD), Takisha Cannon (U VA)

SSA Sites:
Old Aspen (aspen, hazelnut), Young Aspen (aspen, hazelnut), Old Jack Pine (jack pine, understory), Young Jack Pine (jack pine), Black Spruce, White spruce @ "Young Aspen"

Measurements Acquired During 1994 IFC's:
I. Gas Exchange

- In Situ (light-saturated): Photosynthesis, Conductance, Transpiration etc.
- Lab: Photosynthetic Capacity (25°C < T <29°C), with light curves

II. Leaf/Shoot Characters

Broadleaf (Aspen, Hazelnut, Misc.)	**Conifers** (Jack Pine, Black spruce, White Spruce)
Fresh Weight	Fresh Wt., needles + stem
Dry Weight	Dry Weight/ needles, stem separately
Projected Area	Projected Area (by age class)
L, W	L, W, H (needle sample) # needles per age class
Munsell Color (both sides)	Munsell Color (both sides)
Pigments: Chl a, Chl b, Total Carotenoids	Pigments: Chl a, Chl b, Total Carotenoids

III. Spectral Optical Properties (By Age Class)
• Reflectance and Transmittance of abaxial and adaxial surfaces at 5 nm sampling rate (400-1000 nm). Spectral Absorbance (400-1000 nm) determined.

IV. Fluorescence (By Age Class):
• Spectra (360-800 nm), with excitation at 340 nm (IFCs 2-3).

V. Chemistry (By Age Class) from Dried Material: Nitrogen, Carbon (TBD).
• Terrestrial Ecology Group 10 (TE-10)
• CO_2 and Water Fluxes in the Boreal Forest Overstory:

TE-10 again

PI: Dr. Elizabeth Middleton (NASA/GSFC)
Co-I: Dr. Joe Sullivan (U MD)
Analyst/Technologist: Mr. Stephen Chan (SSAI @NASA/GSFC)
Technician: Ms.Andrea DeLuca (U MD)
Graduate Student: Mr. Brian Bovard (Duke University)
Student: Ms. Takisha Cannon (U VA)

SSA Site	Species	1994 IFC	Field Dates
Old Aspen (SSA-OA)	aspen	1	5/25 &29
	poplar	1	6/10
	hazelnut	2	7/21
		2	8/03
		3	9/02
		3	9/15
Young Aspen (SSA-YA)	aspen	1	5/24 & 26
	hazelnut	1	6/04
		2	7/28
		3	9/02
		3	9/12
Old Jack Pine (SSA-OJP)	jack pine	1	5/31
	understory	1	6/03
		2	7/25
		3	9/07
Young Jack Pine (SSA-YJP)	jack pine	1	5/26
		1	6/07
		2	7/22
		3	9/07
Black Spruce (SSA-OBS)	black spruce	1	6/01
		1	6/05
		2	7/28
		3	9/09
Young Aspen [Snow Castle]	white spruce	2	7/30
		3	9/08

5.4.1.11 TE-11

PI: Bernard Saugier — Universite Paris
Collaborators: Andre Granier, Eric Dufrene, Jean-Yves Pontailler, Anne Ruimy

Title: Seasonal Variations of Net Photosynthesis and Transpiration at the Tree Level

Objectives: To monitor transpiration and CO_2 exchanges of a forest stand over the whole growing season

Type of Data Collected:
- Sapflow measurements by a thermal method on 5 trees from day 121 to 258 (half-hourly measurements).
- CO_2/H_2O exchanges of two branches using branch bags as cuvettes: nearly continuous measurements from day 206 to day 222 (half-hourly measurements)
- sporadic measurements of CO_2 exchanges of the lichen layer using a small chamber (0.3 m by 0.3 m)

Equipment Used:
- Sap flow sensors (made by A. Granier) + CR21X data logger and power supply
- 2 branch bags (with fans, temperature and relative humidity and PAR sensors) + IRGA for CO_2 (CID) + CR21X data logger
- One lichen chamber (closed circuit) with temperature and PAR sensors, with a portable IRGA for CO_2 (PP systems)

Place of Measurement:
SSA-OJP site in Nippawin (near TF5)

Times of Measurement:
Sapflow days: 121 to 258, 1994
Branch bags: days 206 to 222, 1994
Lichens: scattered data from July 24 to August 10, 1994

Known Problems:
Good functioning of sap flow sensors, with encouraging comparisons with micromet technique on a daily basis. For work on a half-hourly basis, sap flow lags about one hour to one hour and a half behind transpiration (likely variations in plant water storage). Branch bags gave also a good data set, but measured transpiration appears too small. We do not yet have a good scheme for deriving CO_2 exchange of the stand from both (sap flow and branch bags) datasets.

The data collected on lichens by Anne RUIMY have not been placed in BORIS but Anne made a small report that can be sent on request.

5.4.1.12 TE-12

PIs: Elizabeth A. Walter-Shea and Timothy J. Arkebauer — University of Nebraska

Title: Radiation and gas exchange of canopy elements in a boreal forest

Objectives: The goal of our coordinated research program is to gain an understanding of radiation and gas exchanges of canopy elements within a boreal forest and the coupling between radiation and gas exchange. The three objectives identified to achieve our goal are:
1. Characterization of boreal forest canopy optical properties during critical periods of the year. Leaf, needle, twig, and substrate optical properties were measured at the BOREAS Southern Study Area (SSA) as well as in the laboratory using various combinations of spectroradiometer and integrating sphere. Conifer shoot geometry was also characterized. Models will be used to enhance the understanding of key variables influencing canopy element reflectances and transmittances.
2. Characterization of gas exchange of boreal forest canopy elements during critical periods of the growing season. Responses of CO_2 exchange and stomatal conductance of canopy elements to environmental factors and diurnal courses of photosynthesis, respiration and stomatal conductance of canopy elements will be determined. Models will be used to describe the influence of relevant controlling variables on CO_2 and water vapor fluxes of boreal forest canopy elements.
3. Integration of foliage optical properties and gas exchange characteristics. Models will be used to couple radiation and gas exchange of canopy elements under diffuse and total radiation conditions via absorbed photosynthetically active radiation.

Data Collection and Equipment:

Group	Data Type	Equipment
I	Optical properties	SE-590, integrating sphere,
	Leaf and conifer	imaging system
	Twig	
	Substrate leaf and bark	
	Leaf and conifer shoot geometry	Digital calipers, balance
	Shoot water potential	Pressure chamber
II	Leaf and conifer shoot geometry & needle surface area	Digital calipers, balance
	light response	LI 6200 photosynthesis system, screens
	A/Ci	LI 6200
	Ambient photosynthesis	LI 6200
	respiration	LI 6200, film developing bag
III	Substrate reflectance	Exotech, calibrated reference, camera

Places and Times of Measurements:
Group I: FFC-T and FFC-W: SSA OBS and OJP. Jack pine and black spruce optical properties were measured on samples collected from the sites and sent to Lincoln, Nebraska for analysis. IFC-1: SSA OBS, YJP and OA; IFC-2 and IFC-3: SSA OBS, YJP and YA. Jack pine and black spruce optical properties and shoot geometry were characterized on samples collected in the field and taken to the SSA laboratory for analysis, two visits per IFC, sampling from the top and bottom parts of the canopy. Aspen samples were collected and analyzed in the field. Water potential was collected on surrounding samples in the field and in the laboratory at the time of analysis. Substrate element properties were measured once per IFC.
Group II: May 29-Aug. 9 and Sept. 7-9: SSA YA and YJP with occasional measurements at OA, OBS and the Mixed site. Properties were measured at various times during this period. For canopy element gas exchange properties our primary emphasis was on aspen at SSA YA and jack pine at SSA YJP sites. Other species included were aspen at SSA OA, black spruce at SSA OBS and mixed sites and hazelnut and balsam poplar at SSA YA site.
Group III: IFCs: SSA OJP and YJP. Measured once per IFC.

Problems and Caveats:
Calculations of needle transmittance in the visible portion of the spectrum occasionally yield negative numbers. The equation used in the calculation requires a measure of the non-intercepted fraction of the illumination beam (i.e., the fraction of light which passes between the mounted needle samples). The calculated transmittance is sensitive to any error in the fraction; our methods yield a fraction within 5% of the
true value.

Accurate determination of conifer needle surface area by the volume displacement method required image analysis of needle cross sections to quantify the ratio of the perimeter to the square root of the cross sectional area.

5.4.1.13 TE-13

PI: M. Apps — Canadian Forest Service
Collaborators: D. Price, W. Kurz, D. Halliwell— Canadian Forest Service

Title: Annual Carbon Budget and Climate-induced Changes in Boreal Forest Ecosystems at the Landscape Level

Objectives: Examination of annual carbon cycling, carbon storage.

Data Collected:
Basic forest mensuration, providing samples of overstory composition (species, diameters, heights, and crown dimensions), understory vegetation (percent cover by species), detritus (detrital mass), and soil conditions. In cooperation with TE-6, detailed allometry was also carried out at selected sites.

Methods Used:
For overstory, a combination of point sampling methods and fixed area plots provide the sample of trees used in the analysis. This sample allows estimation of stand basal area, stem density, DBH distributions, stem volume, and above-ground biomass. Selected trees were

cored, for dendrochronology work. Understory vegetation was measured using fixed- area plots, providing information on species presence and abundance. Detritus on the forest floor was measured using the line intersect method, allowing estimates of total detrital mass (and carbon storage) in a range of diameter classes. Soil pits were excavated to depths of up to 1 m at each site, and samples collected for particle size, organic matter, and nutrient analysis.

Places and Times of Measurement:
Sampling was carried out at all auxiliary sites, and all sites with Terrestrial Ecology (canopy access) towers, plus a few flux tower sites. These sites include transect sites, in between the NSA and SSA. In total, nearly 100 sites were visited, with three sampling points within each site. Each site was visited once in either 1993 or 1994. Slightly less than half of the sites were visited in July-September 1993, with the remaining site being visited in the period May-October 1994. Allometry harvesting was carried out in August 1994, in cooperation with TE-6. These measurements were done at a subset of the auxiliary sites (listed as carbon evaluation sites in the Experimental Plan).

Known Problems or Caveats:
Possible inconsistencies between 1993 and 1994 measurements. Some of the variables (e.g. understory vegetation cover) are time-dependent, and comparison between sites must take this into account. Most of the variables are fairly constant in time and the period over which measurements were taken should not be a problem.

Other Information:
The dataset provides an extensive survey of general forest characteristics over nearly all the BOREAS sites (plus a few not included in the Experimental Plan).

5.4.1.14 TE-14

P.I.(s): G.B. Bonan — NCAR

Title: Estimating Regional Biosphere-Atmosphere Exchange of Carbon Dioxide and Water in Boreal Forests with Ecosystem Models

Objectives: Models provide a means to extrapolate processes to large spatial and long temporal scales. I will conduct simulation analyses with coupled ecosystem and land surface process model to:
• identify key physiological processes and ecological variables needed for a general predictive model of biosphere CO2 and water fluxes
• quantify errors produced by parameter uncertainty
• derive seasonal and annual CO2 and water budgets for several BOREAS tower sites and the two regional sites

Global extrapolation will proceed by coupling the land surface process model to the NCAR Community Climate Model. Regional estimates of CO2, water, and energy exchange obtained from the off-line modeling will be used to test the representation of sub-grid scale land surface heterogeneity for the land surface process model.

5.4.1.15 TE-15

P.I.(s) & CO-I(s): R.P. Bukata, J.H. Jerome — NWRI; J.R. Miller — York Univ.; M.S. Evans — NHRI; R.A. Armstrong, R.C. Wrigley — NASA ARC; E.J. Fee — FI Winnipeg; Gallie — Laurentian Univ.

Title: Utilizing Remotely Sensed Data to Model Limnological Carbon Budgets and Primary Production in Boreal Ecosystems

Objectives: Remotely-sensed data will be acquired by the Compact Airborne Spectrographic Imager (CASI) and the Airborne Ocean Color Imager (AOCI) from NASA/Ames Research Center, to determine the co-existing concentrations of aquatic chlorophyll, dissolved organic matter, and suspended inorganic matter. The chlorophyll estimates will be used to model primary production through calculable transfer coefficients, and the dissolved organic matter estimates will be used to model the carbon content of selected lakes within the BOREAS test area. Targetted study sites include Crean and Waskesiu Lakes in the Prince Albert National Park. These two lakes are the only lakes in which direct optical measurements can be complemented with direct biological measurements. Coordination of direct optical measurements, remote sensing overflights, and water sample collection for off-site laboratory analyses, however, is possible for several other Prince Albert lake sites accessible to boat launchings (e.g., Anglin, Halkett, Emma, Christopher, Whiteswan, and Candle Lakes). Whether or not the intensive hydrology test site at Gull Lake can be accessible for the required optical studies is to be determined.

The inherent optical properties of aquatic chlorophyll, dissolved organic matter, and suspended inorganic matter will be determined by direct sampling and in situ mid-lake measurements using the WATERS instrument. The water samples will be analyzed at laboratory facilities at NWRI, NHRI, and CIMMER.

5.4.1.16 TE-16

P.I.(s): J. Cihlar — CCRS
CO-I(s): Z. Li, Y.M. Chen — CCRS; R. Desjardins — Agriculture Canada

Title: Land Cover and Primary Productivity in the Boreal Forest

Objectives: The study is aimed at addressing the use of satellite data in ecological monitoring with emphasis on two parameters, land cover and ecosystem productivity. For land cover, the objective of the research is to determine improvements in land cover type identification with data from future sensors (simulated MODIS, Radarsat SAR), compared to research presently underway which emphasizes AVHRR. For productivity, the principal objective is to assess the feasibility of estimating forest primary productivity and net primary productivity using models that can be realistically applied over large areas yet have high spatial resolution. To be practical, the models should require a minimum of data that:

- can be obtained from satellites, or
- can be cost-effectively obtained over large areas

Such models have been formulated and tested in recent years, and will be included among those models studied in other BOREAS investigations. The intention in this study is to focus on the contribution of remote sensing data at the landscape and regional levels, and to collaborate with modelers in validating remote sensing inputs and model performance. Specific tasks to be carried out include: improvement in land cover determination and information on seasonal dynamics from simulated MODIS and RADARSAT SAR data; derivation of site and landscape ecosystem parameters (bidirectional surface reflectance, vegetation indices, vegetation density) from optical data in relation to the sensor spatial resolution (102m to > 103m); feasibility of direct APAR estimation from AVHRR and similar data; the relationship of instantaneous gas (CO2, H2O) exchange to satellite-derived reflectance and emission quantities; and derivation of the above and related quantities for testing ecosystem productivity models at the regional level.

5.4.1.17 TE-17

P.I.(s): S.N. Goward — University of Maryland
CO.I.(s): S.D. Prince, R. Dubayah, J. Townshend — Univ. of Maryland; C.J. Tucker — NASA GSFC

Title: Biospheric Dynamics in the Boreal Forest Ecotone

Objectives: A study of primary production in the boreal forest ecotone using regional scale models driven by coarse-resolution satellite data. The primary scale of interest is the BOREAS inter-site transect and the entire N. American Boreal Forest biome. Net primary production (NPP) will be modelled using production efficiency models (PEM), parameterized using the detailed field site measurements planned at the Intensive Study site scale (400km2). A multi-scale analysis will be used to address the problem of scaling of information from the ISS to the regional scales.

5.4.1.18 TE-18

P.I.(s): F.G. Hall, P.J. Sellers — NASA GSFC

Title: Regional-Scale Carbon Flux from Modeling and Remote Sensing

Objectives: To use long-term satellite remote sensing to characterize the successional and disturbance dynamics at a regional scale and to associate, via the use of carbon flux models, these dynamics with carbon flux.

Landsat MSS and TM, SPOT and AVHRR data will be acquired for the BOREAS region, including the Southern and Northern Study Area and the intervening transect for the period of record of each satellite (Landsat back to 1972). Key successional stages will be identified using pattern recognition and image analysis. The rates of changes between successional stages will then be quantified using change analyses. These results will be combined with ecophysiological models that relate carbon flux to the successional state and climate history to estimate regional carbon flux.

5.4.1.19 TE-19

P.I.(s): R.C. Harriss — University of New Hampshire
CO-I(s): J. Aber, S.E. Frolking — University of New Hampshire

Title: Modeling Climate-Biosphere Interactions in the Boreal Forest

Objectives: We propose a research program which integrates and advances two separate models we have recently developed for understanding carbon and nitrogen cycling in soil and vegetation. The primary product of this model integration will be a capability for assessing and understanding the sensitivity of boreal ecosystem carbon and nitrogen pools and fluxes to climate variability. The proposed modelling research program will be coordinated with the BOREAS field measurements program. Field measurement at BOREAS sites will be used to test and validate our model. Our model will provide conceptual framework for testing which components of the boreal ecosystem especially sensitive to climate change. The results of the combined field and studies will provide a sound rationale for the design and implementation of a measurement program in the boreal forest ecosystem using the Earth Observing System (EOS).

5.4.1.20 TE-20

PI: R.G. Knox, — NASA GSFC
Co-I's: E.R. Levine, K.J. Ranson, S.M. Goltz — NASA GSFC

Objectives: Investigators from TE-20 and RSS-15, with support from the FED and SIR-C projects and TE-8, sampled an extensive series of sites in the SSA modeling subarea. Data from these new field sites are intended to complement process studies and more intensive continuous or multi-visit data from regular auxiliary sites and tower sites. When combined with data from the regular auxiliary sites they will provide adequate sample size for developing and testing remote sensing algorithms for characterizing biomass and surface cover in the SSA modeling subarea. They will also help place results from tower sites and auxiliary sites in context by sampling regional patterns of structural and compositional variation; in conjunction with remote sensing these will facilitate scaling studies and surface flux modeling for aircraft flux data and large-fetch tower sites. Each new site was sampled in a single visit, without extensive prior screening, and the data collected address the sort of slowly varying soil and vegetation structural features that could be compared with imagery covering a wide time-span. In the same field effort, we also sampled four sites of particular interest for SAR studies and four of the regular auxiliary sites for methods inter-comparison, using the same field methods.

Data Collected:
Site locations, soil profiles, tree species, DBH, crown position, understory vegetation cover, tree height, crown depth, tree age

Methods Used:
Location Data: To assist in precise registration to high resolution imagery, distances from easily recognized landmarks were measured along roads with a surveying wheel. Most sites were reached by stopping at fixed 2 km intervals along major roads. Distances from road

centers were measured with fiberglass tapes and selected randomly between 150 and 250 m. The bearings selected were perpendicular to the road (or its tangent line) and randomly assigned to either side. [Differential GPS reading for the landmarks selected would be widely useful for aircraft image registration.] Similar randomization was used for exact site locations in purposive sampling of four sites, but with median distances from a starting point adjusted to fall within the stand of interest.

Soil Data: A soil scientist (E. Levine) recorded profile descriptions suitable for soil classification and comparison with broad-scale soil maps. Separate descriptions span the variation noted in a roughly 100x100 m area.

Vegetation Data: Sites were sampled with five plots. In each, all trees at least 5 cm dbh in a 3.99 m radius plot (i.e. 50 m2) were measured at 1.4 m and assigned a species code and a live crown position code. In 1x10 m belt transects, living woody stems 1-5 cm were counted, by species and 1 cm diameter class. In two 1x1 m subplots, cover of vegetation less than 1 cm dbh, and of litter, open water, and bare soil, was visually estimated using a 100-point 10x10 cm grid counting technique. Cover percentages over 3% were rounded to the nearest 5%. Data from a site consist of 5 circular plots for trees, 5 belt transects for saplings and large shrubs, and 10 1x1 m surface cover subplots. Circular plots were centered on the randomly selected location and on points 30 m N, E, S, and W of that point. Belt transects were aligned to one side of the tape used to measure it to the center point, for 5 m either side of the plot center. Surface cover subplots were within the belt transect, 2 to 3 m from the plot center. For each circular plot with sufficient live tress, two living trees were randomly selected for height measurements and increment boring at breast height, totaling up to 10 trees per site with height, crown depth, and age information.

Places and Times of Measurement:
Data were collected July 18-30, 1994. Systematic, randomized sampling at 2 km intervals along Rt. 120, between 265 and Rt. 106, and along Rt. 106 between 120 and Harding Road: 35 sites. Purposive sampling related to radar signatures, along Harding Road and on the Fen Site peripheral road (road loops around N end of fen with tower site): 4 sites. Regular auxiliary sites sampled for methods cross-comparison: 4 sites (F7J0P, G9I4S, G1K9P, G4K8P)

5.4.1.21 TE-21

P.I.(s): S. Running — University of Montana
CO-I(s): R. Nemani — Univ. of Montana; D. Peterson, J. Dungan, J. Coughlan — NASA ARC; D. Harding — NASA GSFC; E. Wood — Princeton Univ.; L. Scuderi — Boston Univ.; A. Price, T. Carleton — Univ. of Toronto

Title: Simulation of Boreal Ecosystem Carbon and Water Budgets: Scaling from Local to Regional Extents

Objectives: To simulate boreal landscape/atmosphere exchange processes and the scaling behavior of these processes from local to regional extents. Our emphasis is boreal ecosystem water and carbon flux processes, which will be simulated using a suite of models based on the processes of photosynthesis, respiration, evapotranspiration and surface and subsurface hydrologic flow. The implications of model and data generalization on the agreement between simulated and measured flux rates will be explored by constructing a hierarchy of modeling and surface parameterization methods. Each level in the hierarchy will vary in the degree of complexity of process and surface representation. The set of computed surface flux rates in combination with flux rates measured by other science groups will be used to quantify the impact of process and parameter generalization in terms of model bias at each level of the hierarchy, and the scaling behavior of flux processes computed over the range of parameter resolutions we will sample. We hypothesize that the spatial patterns of surface/atmosphere flux is strongly influenced by the distribution of available soil moisture and inundation areas in the study sites, which, in conjunction with disturbance regime, may provide a key organizing framework for scaling stand to regional simulations. We will develop surface parameter sets for the models with a combination of field measurement of hydrologic processes, remotely sensed canopy information and laser and radar altimetry. This effort will collaborate with HYD-7.

5.4.1.22 TE-22

P.I.(s): H.H. Shugart — University of Virginia
CO-I(s): T.M. Smith — University of Virginia

Title: Multidiscipline Integrative Models of Forest Ecosystem Dynamics for the Boreal Forest Biome

Objectives: The development of a model-based synthesis of the influence of water and nutrients on forest community composition, and of evaluating the feedback from community composition to surface biophysical characteristics for the BOREAS project. The models involved in this synthesis are:

- ZELIG, a spatial individual tree model. ZELIG is currently part of the FED model
- FED, a model shell allowing the interfacing of several different models of forest ecosystem dynamics and, hence, several different ecosystem processes
- HYBRID, a combination model including ZELIG, a photosynthesis model and a coupling with a canopy biophysical model (GBC, Running and Coughlan 1990)

The ZELIG and HYBRID models will be parameterized and implemented for the BOREAS test sites, and will be used to project the composition and canopy structure of forests over relatively long time spans for different regions. This will also provide a capability to predict CO2 and H2O fluxes from the forests. Several of the data sets being developed in conjunction with the BOREAS project will be used to test these model implementations.

5.4.1.23 TE-23

PI: Paul Rich — University of Kansas
Collaborators: Richard Fournier, Jing Chen

Title: Canopy architecture of boreal forests: using hemispherical photography for study of radiative transport and leaf area index.

Objectives:
A) To acquire and analyze a catalog of upward looking hemispherical (fisheye) photography from beneath the forest canopy to provide BOREAS investigators with extensive estimates of canopy architecture (LAI...) and radiative transfer (FPAR...) properties for most major BOREAS study sites.
B) To set up mapped forest plots (typical dimensions 50 m x 60 m) to characterize canopy architecture and understory cover. The mapped plots serve two general functions: 1) to provide comprehensive canopy architecture measurements for a site representative of a specific type of forest; and 2) to provide a study area for field measurements, such as studies of light regime, leaf area index, and tree population dynamics. More specifically, the mapped plots serve as the location for 1) intercomparison and calibration of techniques; and 2) testing geometric models concerning radiative transport in canopies.

Types of Data Collected:
A) A comprehensive catalog of hemispherical photographs were acquired using to calculate 1) gap fraction as a function of zenith angle, 2) canopy architecture indices (effective LAI, extinction coefficient, and LAI), and 3) radiative transfer indices (daily direct FIPAR at monthly, intervals, and diffuse FIPAR).
B) Mapped plot characterization: stand density, basal area, average height, average crown radius; Measurements for all trees (> 2 m height) in mapped plot: X-Y location, diameter at breast (DBH), dominance class (dominant, codominant, suppressed, juvenile, dead standing, dead leaning); Measurements for a subset of trees: height, height to base of first branches, height to base of green crown, crown radius in four azimuth directions; and Understory Cover for 10 m x 10 m Subplots: hand-drawn maps of major cover classes, description of dominant species and features, catalog of photographs.

Summary of Places and Times of Measurements:
Hemispherical photographs were acquired at all forested tower sites during IFC1 and IFC2, at all auxiliary sites, and at aspen tower sites at intervals of 2-4 weeks throughout the growing season. Trees within mapped plots were measured as possible through the summer.

5.5 Tower Flux (TF)

Nine semi-permanent towers were installed in large (~1 km^2) patches of homogeneous vegetation cover with the goal of measuring fluxes from the most important surface types to be found in the region. The surface attributes considered for sampling were vegetation type (Aspen, Black Spruce, Jack Pine, Fen); vegetation age (old and young) and surface wetness. Given the limited resources available, it was not possible to instrument every combination of these attributes. In addition to these nine towers, a temporary tower was erected at a Young Aspen site in the SSA during IFC-2 and IFC-3.

Data collected at the TF towere show some surprisingly low evaporative fractions (corresponding to high Bowen ratios) over most of the sites most of the time. These are associated with much lower CO_2 fluxes than are commonly observed by temperate forests, see for example Verma et al. 1986. The exception to this generalization is the Old Aspen site in the SSA which after a rapid leaf-out in IFC-1 maintained the highest evaporation and carbon drawdown rates of all the sites. By contrast, the SSA Old Jack Pine site (TF-5: Baldocchi) and the SSA Old Black Spruce site (TF-9: Jarvis) reported mean growing season evapotranspiration rates of around 1.3 to 2.0 mm/day, respectively. These two sites more or less bracket the range of wet (black spruce) and dry (jack pine) conditions over most of the BOREAS sites and present us with a new and unexpected picture of the partitioning of energy at the surface in this region. These findings are consistent with those of the AFM group summarized in the previous section.

5.5.1 TF Team Science Activities

5.5.1.1 TF-1

P.I.: T.A. Black — Univ. of B.C.; G.W. Thurtell — Univ. of Guelph
Collaborators: K.M. King, P.M. Voroney, G.E. Kidd — Univ. of Guelph; M.D. Novak — Univ. of B.C.
Location: Southern Study Area, Old Aspen (SSA-OA)

Objectives: To measure the fluxes of heat, momentum, water vapor, CO_2, CH_4 and N_2O above the hazel understory and above the old aspen forest in Prince Albert National Park, and to investigate the processes controlling these fluxes.

Types of Data Collected and Equipment Used:
An eddy correction system mounted at a height of 4 meters was used to measure the three wind velocity components u, v, w, air temperature (Solent anemometer/ thermometer), CO_2 concentration (LI-COR infrared gas analyzer 6262) and water vapor density. Water vapor density was measured in two ways: closed-path (LI-COR 6262) and open-path (CSI krypton K20). The above measurements were used to calculate half-hourly fluxes of momentum, sensible heat, latent heat and CO_2.

Radiation measurements were made using a tram at the 4-m height. They are: net radiation (Swissteco S-1 and S-14 (miniature) net radiometers); incoming solar radiation and diffuse radiation (shaded and unshaded Kipp and Zonen CM-5 pyranometers); incoming PAR and outgoing PAR (LI-COR quantum sensor).

Soil heat flux at a depth of 3 cm (G3, soil heat flux plates, Middleton Inst., Model F) and rate of heat storage change in the top 3 cm soil layer (M, nickel resistance wire integrating thermometer) were measured. Soil heat flux at soil surface (G0) was calculated using G0 = G3 + M.

Soil water content in the following surface soil layers: 0-3 cm, 3-6 cm and 6-10 cm, was measured gravimetrically every 2 days. Time domain reflectometry systems (Tektronix 1502B cable tester + Gabel & Associates moisture point) were also used to measure soil moisture to a depth of 4 feet, and mini-lysimeters were used to measured soil evaporation.

A LI-COR LAI-2000 plant canopy analyzer was used to determine separately aspen plant area index and hazel plant area index throughout the growing season.

CH_4 and N_2O fluxes above and below the aspen canopy were determined using the gradient method with a tunable diode laser (CSI Trace Gas Analysis System).

A static chamber was used to measure soil CO_2 efflux throughout the growing season.

Also measured were aspen bole and hazel stem temperature, snow profile temperature and surface temperature of the snow and forest floor.

Place and Time of Measurements:
Old Aspen Tower Site, Prince Albert National Park, Southern Study Area. Oct. 13 - Nov. 13, 1993 & Apr.8 - Sep.20, 1994. For CH_4 and N_2O: Oct. 16 - Nov. 12, 1993 & Apr. 16 - Sep. 20 1993.

Known Problem or Caveats:
Soil temperature data missing (DOY 250-253); daytime CH_4 and N_2O data missing (DOY 106-109); Krypton replacement (DOY 144-146), data are questionable; some nighttime CO_2 fluxes were strongly negative, users should be careful in interpreting the measurements.

Other Information:
General climate and above-aspen flux data can be found in the TF-2 BOREAS data submission.

<u>5.5.12 TF-2</u>

P.I.(s): G. den Hartog — AES
CO-I(s): R.E. Mickie, H.H. Neumann, N.B.A. Trivett — AES
Location: Southern Study Area, Old Aspen (SSA-OA)

Title: AES Flux Tower Measurements for BOREAS: Exchange of Energy, Water vapor and Trace Gases Project

Objectives: To quantify and examine the controlling factors for CO2, O3, CH4, N2O exchange at the SSA-OA site in PANP and to determine diurnal and seasonal surface energy fluxes at the same site. This study complements TF-1. The broader objectives of the combined proposals include determination of the annual cycle for carbon and nitrogen at the site, with trace gas measurements now also including CO, NO, NO2, NH3, and possibly terpenes. Four types of measurements were done:

1. eddy correlation flux measurements of momentum, sensible heat, latent heat, CO2, O3, CH4 and N2O above the canopy
2. within and above canopy profiles of temperature, CO2 and O3
3. half-hour means of wind speed, wind direction, incoming solar radiation, net

radiation, PAR, temperature, relative humidity, wet precipitation, CO2, O3, CH4 and N2O above the canopy, IR canopy temperature, and soil heat flux and temperature
4. tethersonde profiles including O3

5.5.1.3 TF-3

PI: Steven C. Wofsy — Harvard University
Co-I: Michael L. Goulden — Harvard University
Collaborators: B.C. Daube, S.M. Fan, D.J. Sutton, A.M. Bazzaz, J.W. Munger — Harvard University
Location: Northern Study Area, Old Black Spruce (NSA-OBS)

Title: Eddy Correlation Flux Measurements of CO2, and H2O for BOREAS

Objectives: Eddy correlation flux measurements of CO_2 and H_2O are made at the northern black spruce site from December 1993 to present. Our objective is to directly determine the net ecosystem exchange of CO_2 and the surface energy budget over diurnal, seasonal, and annual time scales. We also aim to couple these observations with a comprehensive characterization of the physical environment (temperature, precipitation, PAR, etc.).

Types of Data Collected:
All data is recorded in half-hour periods.
• Flux measurements of momentum, heat, latent heat, and CO_2 at an elevation of 30m.(ATI sonic anemometer and LiCor 6262 gas analyzer).
• wind direction and wind speed.(ATI sonic anemometer)
• storage measurement of CO_2 and H_2O from 0-30m.(LiCor 6262 gas analyzer).
• net radiation above canopy.
• PAR above and below canopy.
• temperature profile from 0-30m.
• soil temperatures from 0-100 cm.
• precipitation

Summary of Site:
The measurements are made continuously at a remote (50 km from the nearest town and 5 km from the nearest road) old (70-90 years) black spruce site. The coverage is relatively homogeneous and the trees reach a height of approximately 10m. The ground cover is primarily feather moss mixed with some lower level areas of sphagnum bog.

Known Problems:
There are some gaps in the data set resulting from a number of technical problems. Also, the data is still preliminary. Some changes will occur when further quality control is implemented and the data is reprocessed.

5.5.1.4 TF-4

P.I.'s: Dean E. Anderson, Robert G. Striegl — U.S. Geological Survey
Co-I. David I. Stannard — U.S. Geological Survey
Location: Southern Study Area, Young Jack Pine (SSA-YJP)

Title: Exchange of Trace Gases, Water and Energy in Disturbed and Undisturbed Boreal Forests

Objectives: Measurements of above and within canopy fluxes of CO_2, latent and sensible heats will be made during a growing season. Combined with soil gas effluxes of CO_2 and CH_4 the data will be used to determine daily and seasonal patterns in carbon fluxes, evapotranspiration, and in environmental controls regulating the partitioning of available energy and net ecosystem productivity (NEP). Comparisons will be made between young and mature jack pine stands in relatively close proximity of one another in terms of NEP and water use.

Types of Data Collected:
- Above canopy fluxes: CO_2, Latent heat, Sensible heat, Momentum
- Forest floor fluxes: CO_2, CH_4, (Sensible heat and latent heat)*, soil heat flux
- Radiation: Net, PAR, Short wave, canopy temperature (IRT based)
- Profiles: Canopy: Temperature, rH, CO_2, (delC13, occasional sampling)
- Soil: Temperature, CO_2, CH_4, (delC13, occasional sampling)
- Tree: Tree bole temperatures
- Other Mean variables:
  Above canopy: Wind direction & speed, air temperature, relative humidity.
  Below canopy: Temperature, relative humidity, soil moisture, water table depth & dissolved carbon, soil air pressure fluctuations, precipitation, bear sightings.

Period of Measurement:
Measurements began during IFC-1 and ended a day after IFC-3. Equipment operated almost continuously. Notable is lack of CO_2 data following a lightning strike and malfunction of CO_2 sensor June 16-20, July 10-19. CO_2 profile was not operational until IFC-2. Forest floor sensible and latent heat fluxes record has numerous lapses due to equipment problems. Considering all measurements, IFC-3 has the most complete record.

5.5.1.5 TF-5

PIs: Dennis Baldocchi and Christoph Vogel — NOAA Atmospheric Turbulence and Diffusion Division
Location: Southern Study Area, Old Jack Pine (SSA-OJP)

Title: Experimental and Modeling Studies of Water Vapor, Sensible Heat, and CO2 Exchange Over and Under a Boreal Forest

Objectives: Our objective was to measure and model air-surface exchange rates of water vapor, sensible heat and CO_2 over and under a boreal forest and to study the abiotic and biotic factors that control the fluxes of scalars in this landscape. Scalar flux densities were measured with tower-mounted measurement systems. Tower-mounted flux measurement systems were installed above and below an old jack pine forest canopy. This configuration allows us to investigate the relative roles of vegetation and the forest floor on the net canopy exchange of mass and energy. We also used the tower-mounted flux measurement system to study temporal patterns (diurnal/seasonal) of mass and energy exchange at a point in the landscape.

Types of Data Collected, Equipment Used:
Key measured flux variables were net radiation, quantum, latent heat, sensible heat, soil heat and CO_2 flux densities above and below the canopy. Key measured meteorological variables included wind speed, wind direction, air temperature, relative humidity, soil temperature, CO_2concentration, ozone concentration.

Summary of Places and Times of Measurements:
Old jack pine, Southern Study Area. Data were acquired on a nearly continuous basis. Data of 30 minute average fluxes and meteorological variables have been submitted to BORIS.

Known Problems or Caveats:
The radiation and flux data should be used with caution when the wetness sensor detects moisture. There are some problems with the stability of the ambient CO_2concentration measurements. We experienced appreciable zero drift at times.

Other Information:
Daily average fluxes are being computed and analyzed and will soon be submitted.

5.5.1.6 TF-6

PI: Pierre Bessemoulin — CNRM/GMEI
Collaborators: Gilles Bouhours, Emmanuel Gizard, Guy Lachaud, Jacques Marcel, Dominique Puech — METEO FRANCE, Centre National de Recherches Meteorologiques (CNRM)
Location: Southern Study Area, Young Aspen (SSA-YA)

Title: Study of the Boreal Forest Effects on Surface/Atmosphere Fluxes

Objectives: Document the atmospheric forcing and the resulting fluxes of heat, evaporation and momentum over a representative ecosystem of the boreal forest.

Types of Data Collected:
Meteorological measurements: Wind speed and direction at 10m, temperature and humidity above and in canopy, rainfall, pressure, upward and downward solar and total radiation, soil temperature at -1 and -5 cm, soil heat flux; Sensible, latent and momentum fluxes using Eddy correlation

Place and Times of Measurements:
• SSA/ Young Aspen (53 deg 39' N; 105 deg 20' W)
• Continuously from 18th July to 20 September (IOP 2 and 3)

Known Problems:
• Krypton Hygrometer (Campbell KH20) fails when wet: corresponding data have been removed
• Power supply destroyed by big game, resulting in: missing fluxes on the 30 August and missing met data from 23rd to 26th August (outside IFC's)

5.5.1.7 TF-7

PI's: Ray L. Desjardins, Elizabeth Pattey — Agriculture and Agri-Food Canada; Ian J MacPherson — NRC
Co-I's: Peter H. Schuepp — McGill University; Gerry St-Amour — Agriculture and Agri-Food Canada
Location: Southern Study Area, Old Black Spruce (SSA-OBS)

Title: Areal Estimates of Mass and Energy Exchange from a Boreal Forest Biome

Objectives: Surface flux measurements were carried out during the three intensive field campaigns (IFCs) of the BOReal Ecosystem Atmosphere Study (BOREAS) in 1994 at the old black spruce stand in the southern site. The objective was to quantify the energy and carbon exchange for key periods of the growing season. Some of the limitations associated with nighttime CO_2 flux measurements by eddy-correlation are also addressed. Another objective was to scale-up aircraft- and tower-based flux measurements to a regional scale.

Types of Data Collected and Equipment Used:
Momentum, CO_2, sensible and latent heat fluxes were measured using the eddy-correlation technique (EC), while methane and nitrous oxide fluxes were measured using either the

aerodynamic-gradient technique (AG) or EC. The measurements were made at 20 m above the ground (about 12 m above the displacement plane). Incoming solar radiation was measured with a LI-COR pyranometer (LI-200S). Wind velocities and temperature were measured with a sonic anemometer-thermometer (Kaijo-Denki DAT-310). The sonic anemometer and the intake tubes of the closed-path analyzers were located on a boom, approximately 1.65 m long, parallel to the soil surface. The boom was mounted on a rotating table to orient the sensors in the prevalent wind direction, and on a sliding carriage to access both ends of the south side of the tower. CO_2 and H_2O concentrations were measured in fast-response absolute mode with an infrared gas analyzer (LI-COR 6262) equipped with a 4-m sampling tube. Methane and nitrous oxide gradients between 16 and 24 m above the ground were measured with tunable diode lasers (Campbell Scientific, TGA). The eddy diffusivity coefficient, K, was calculated based on the measurements from a sonic anemometer. Isoprene fluxes were measured by the relaxed eddy-accumulation technique. Isoprene concentrations were analyzed by TGB-10. All the fluxes were calculated on 30-min. basis. Measurements were carried out during the three IFCs between calendar days 144-155 (May-June), 200-210 (July) and 251-260 (September).

Known Problems:
No methane and nitrous oxide data were available for IFC-1 due to a problem with the pumps. Flux measurements for methane and nitrous oxide during IFC-2 and -3 are intermittent because three different measuring techniques were used (AG, EC and REA), and tunable diode lasers are very sensitive to vibrations. No data were collected on CD 148 because of rain. Flux data for day 209 were lost because of lightning. Night eddy CO_2 flux data are not representative of CO_2 respiration processes when wind speeds are low.

Other Information:
Isoprene flux were recorded on day 205, 207, 208, 251, 252.

5.5.1.8 TF-8

PI: David R. Fitzjarrald — Atmospheric Sciences Research Center, University at Albany, SUNY
Collaborator: Kathleen E. Moore — University at Albany, SUNY
Associated Groups: Crill (TGB-1), Roulet (TGB-4)
Location: Northern Study Area, Old Jack Pine(NSA-OJP)

Title: Surface Exchange Observations in the Canadian Boreal Forest Region

Objectives:
a) Obtain the time series of the elements in the surface energy and water balance during the growing season 1994 at the BOREAS Old Jack Pine Site at the Northern Study Area preliminary to investigations aimed to determine the minimally complex vegetation-atmosphere model required for models;
b) To relate the vertical wind profile to the frequency and type of coherent turbulent eddies in the canopy layer.
c) To relate components of radiation budget the observed cloud fraction, type, and height preliminary to developing feedback relationships between surface heat and water vapor fluxes and convective cloud cover.

Types of Data Collected:
Heat, water vapor, momentum fluxes using the eddy correlation method at two levels, components of radiation budget and related to the observed cloud fraction, type, and height, observed rainfall above and inside the canopy and soil moisture.

Equipment Used:
Most instruments were mounted on a 30 m Roln 30G triangular cross-section tower. Turbulent fluxes were obtained using ATI, Inc. 3-D sonic anemometers (w',u',v',Tv') and a Gill propeller anemometer (U', direction') along with krypton hygrometers (q'), Li-Cor CO_2 and H_2O IRGA (q',CO_2), and an A.I.R. Inc. fine-wire thermocouple (T'). The sonic was rotated regularly to face the wind, minimizing obstacle effects. The mean wind profile was made using cup anemometers. Automatic rain gauges were operated at one level above the canopy and two places in the canopy (one with a collecting trough). Four manual rain gauges were placed below the canopy. -Upwelling and downwelling long- and short-wave radiative flux components (Kipp & Zonen, Inc) were operated above the canopy. At one level above the canopy and two levels within the canopy Swissteco net radiometers were operated. At three sites, 3 levels of soil temperature and 1 level of soil heat flux were operated. The CSU ceilometer was used to determine cloud base up to 25000 ft. A partial-sky video camera was used to make digital images of the sky. The McGill University TDR probe sampled soil moisture at 3 levels at an open lichen site and at a moss-covered site. An automatic GC from U. of New Hampshire was used to obtain the methane gradient on the tower.

Summary of Places and Times of Measurements.
All observations were made at the NSA Old Jack Pine site. Observations began 5/25/94 (Day 145) for mean gradient and radiation instruments. Flux observations were done between 5/30/94 and 9/21/94 (Day 264). All turbulence data were archived at 10 Hz; fluxes, moments, and spectra were calculated in real time.

Known Problems or Caveats:
Power problems between 7/5 and 7/13 lead to data gaps then. Intermittent problems with the second level sonic anemometer led to sporadic periods of bad data. There is noise in some soil temperature channels in mid-summer. Much of the missing flux data is being reinstated using post-processing.

Other Information:
We had a good time.

5.5.1.9 TF-9

P.I.s: Prof. Paul Jarvis and Dr. John Moncrieff — University of Edinburgh
Co.I.s: Jonathan Massheder, Mark Rayment, Sophie Hale, Steve Scott — Univ. of Edinburgh
Location: Southern Study Area, Old Black Spruce (SSA-OBS)

Title: The CO2 Exchanges of Boreal Black Spruce Forest

Objectives: To measure and model the CO_2 exchanges of boreal black spruce forest to determine whether the soils and vegetation are significant global sinks for atmospheric CO_2. Stand CO2 fluxes were measured using eddy covariance and the CO_2 concentration profile was also measured to allow estimation of the atmospheric storage of CO_2 within the canopy. These measurements will be used to verify scaling up procedures from leaf level measurements and may be scaled up to regional scales.

Types of Data Collected and Equipment Used:
• Stand fluxes (sensible and latent heat, momentum and CO_2 fluxes) by eddy covariance using Solent 3 axis sonic anemometer, LI COR LI 6262 IRGA (infrared gas analyzer) and the University of Edinburgh's EddySol software.
• CO_2 storage in the canopy by measuring CO_2 concentration profiles using solenoid switched sampling from five heights to an ADC 225 IRGA.
• Soil CO_2 efflux using open chambers multiplexed to a LI COR LI 6252 IRGA.
• Stem CO_2 efflux using open chambers and an ADC LCA3 IRGA.

Supporting Environmental Variables

Variable	Sensor
Net radiation	2 REBS Q6 net radiometers
Total solar radiation	LiCor pyranometer, Kipp solarimeter
Photosynthetic Photon Flux Density	LiCor quantum sensor
Wind direction	Vector instruments windvane
Wind speed	Vector instruments cup anemometer
Air temperature	Psychrometer developed at Edinburgh Univ.
Wet bulb temperature	Psychrometer developed at Edinburgh Univ.
Soil temperatures	Probe developed at Edinburgh Univ.
Soil heat flux	7 REBS heat flux plates
Precipitation	Cassella tipping bucket rain gauge

Measurement Sites and Periods:
All measurements were made at the Southern Study Area Old Black Spruce site. The measurements were made almost continuously from 23 May until 19 September 1994 except the soil and stem CO_2 efflux, which were made at sub intervals of the above period.

Known Problems and Caveats:
Eddy covariance is used to measure the flux through a horizontal plane, placed above the canopy. In very stable conditions, i.e. cloudless nights with little wind, there is almost no such flux. In such conditions the storage of CO_2 in the canopy is measured to estimate the flux in and out of the biological system. However, in extremely stable conditions this storage of CO_2 also appears to be underestimated. Simple modeling can be used to circumvent this problem.

5.5.1.10 TF-10

PI's: J. Harry McCaughey — Queen's University; Dennis E. Jelinski — State Univ. of New York at Buffalo
Collaborators: Peter M. Lafleur and Jim Buttle — Trent Univ.
Location: Northern Study Area, Fen (NSA-Fen) and Young Jack Pine (NSA-YJP)

Title: Surface Energy and Water Balances of Forest and Wetland Subsystems in the Boreal Forest: Surface-Atmosphere Links and Ecological Controls

Objectives: The primary objective of the team was to measure the surface radiation and energy balances of a northern fen and a Young Jack Pine (YJP) site at Thompson, Manitoba. At the YJP site the stomatal conductance of the jack pine was studied. The work at the fen included a study of spring runoff and unsaturated zone hydrology of the small basin located north of the fen site proper. This basin is the principal water source region for the fen. The diverse surface vegetation of the fen was sampled and its spatial distribution mapped in order to examine its relation to surface-boundary interaction.

Data Collection and Equipment:
At both sites the primary instruments were deployed on a centrally located meteorological tower to collect the following data: net radiation, incoming and reflected solar radiation, incoming and reflected PAR (photosynthetically active radiation), outgoing longwave radiation, profiles of air temperature, humidity, and windspeed, wind direction, rainfall, latent and sensible heat flux, net carbon dioxide flux (net ecosystem exchange), soil heat flux, heat storage in surface soil and vegetation, soil temperature profile, and biomass temperature. The instrument packages deployed at both towers were practically identical and with a few exceptions (noted) it can be assumed that the measurement instruments and the measurement protocols were identical at each site.

Some minor difference are as follows: i) at the fen site, the soil temperature profile went to a depth of 2 m in the peat, whereas the deepest soil temperature profile at the YJP site reached a depth of 1 m; ii) there was no biomass temperature measurement at the fen. At the YJP, a series of stomatal conductance measurements were taken throughout the season to characterize the physiological control on evaporation.

The flux data were collected with eddy correlation systems that consisted of a single-axis sonic anemometer, a Krypton hygrometer, and an infrared gas analyzer. All data were sampled at 10 Hz and averaged over thirty minutes. As well a Reversing Temperature Difference Measurement System (RTDMS) provided dry- and wet-bulb temperature difference data from which the Bowen ratio could be calculated to give a gradient solution for the latent and sensible heat fluxes. Soil heat flux was measured with a soil heat flux plate, replicated twice on each site, and buried at 10 cm. Heat storage above the plates, including in the soil and vegetation (YJP site only), was found from soil and biomass temperature data. Stomatal conductance was measured with a ventilated porometer at the YJP site.

Data Collection Periods:
The data collection period was from April 8 to September 19 at the fen, and from May 22 to September 20 at the YJP site. For both sites, surface flux data collection was continuous except for short periods when some data records were missed through instrument failure.

Noncontinuous data consisted of canopy characterization information including tree density, tree height, and leaf area index at YJP site, and plant species and location at the fen. At the YJP site, the primary sample transects radiated out from the tower on five bearings, every 60 degrees, to the edge of the WAB (500 m), and intermediate transects were sampled on intermediate bearings towards the outer perimeter.

At the fen, a total of seventy-three vascular plant species and twenty-nine bryophytes were identified within fifty-four sampled plots. Each plot was 3m x 3m and was positioned in a selected patch of homogeneous vegetation, with the exact location of the plot being determined by random. The analysis of the vegetation data using TWINSPAN produced a classification scheme with he following six stand groups: (1) Extremely wet, medium-rich fens; (2) Sedge fens; (3) Moss/shrub rich fens; (4) Wooded fens; (5) Bog/poor fens; and (6) Peat plateaus.

Semi-continuous data at the YJP consisted of the stomatal conductance of the jack pine. These data were collected on chosen sample days in each of the three IFC's in order to build up a dataset that could characterize both the diurnal and seasonal behaviors of the conductance. Two different sample locations were used: on the dry sandy soil near the tower where the understory was principally lichen, and at a moister location with a deeper organic horizon and a better developed understory of spruce seedlings along the access path, approximately 300 m east of the tower.

The distributed hydrological measurements included runoff, soil moisture, precipitation, snow depth, snowmelt, air and snow temperature. All of these data were recorded starting in April before snowmelt and all, excepting the snow-related data, continued until September. Net radiation, windspeed, relative humidity, and temperature were recorded for the snowmelt period only at a small tower located in the forest. Extensive surveying was done in the basin to support development of a digital elevation model. Also, species groupings of the primary forest types were compiled along with sample transects of gap fraction to aid in the development of a snowmelt model.

Known Problems and Caveats:

The hydrological experiment was repeated in the spring of 1995 (April to mid-June) with the same suite of measurements as in 1994. Also, extra sampling of fen vegetation was completed in the summer of 1995.

5.5.1.11 TF-11

PI: S. B. Verma — University of Nebraska-Lincoln
Co-PIs: T. J. Arkebauer, F. G. Ullman, D. W. Valentine, W. J. Parton, and D. S. Schimel
Location: Southern Study Area, Fen (SSA-Fen)

Title: Field Micrometeorological Measurements, Process-Level Studies and Modeling of Methane and Carbon Dioxide Fluxes in a Boreal Wetland Ecosystem

Objectives:
1) Quantify, employing the micrometeorological eddy correlation technique, the surface exchange rates of methane and carbon dioxide at a boreal wetland site.
2) Evaluate the soil surface carbon dioxide flux and characterize its response to controlling variables (such as temperature, water content, water table depth).
3) Conduct process-level studies (field experimental manipulations) to quantify the degree of substrate quantity and quality limitations on methane production, oxidation and emission. Quantify the responses of leaf photosynthesis, plant respiration and stomatal conductance of dominant plant species to relevant controlling variables.
4) Integrate the first three components to test and improve a model of decomposition and methane emission responsive to variability in moisture, temperature and plant productivity in northern wetland ecosystems. (This effort has been substantially reduced due to the budget reduction, and will be undertaken in the fourth year of the project using other resources.)

Data Collection and Equipment:
The main emphasis during 1994-1995 was to conduct detailed field measurements at the BOREAS SSA (Southern Study Area) fen site. Installation of the micrometeorological flux instrumentation started in early May, 1994. After completion of the installation and checkout of the equipment in mid-May, collection of flux data began and continued through early October. Data analysis is presently in progress. Some preliminary results, based on real-time raw observations, are included in this report. The magnitude of midday methane efflux was negligible until May 25. It then increased approximately linearly to 6.3 mg m-2 h-1 on July 19. A heavy precipitation (87 mm) on July 18-19 raised the water table by 10 cm which inundated almost all of the hummocks (microhills). The magnitude of the methane flux began to rise dramatically about this time and reached a seasonal peak of 16.7 mg m-2 h-1 on August 3. The flux then began decreasing and was 2.5 mg m-2 h-1 at the end of the measurement period (October 7). The midday (atmospheric) CO_2 flux was negligible until about May 20. A significant increase in the (midday) atmospheric CO_2 flux began around May 30, and a seasonal peak of 0.45 mg m-2 s-1 was measured on July 7. The midday flux then decreased approximately linearly to about zero on September 27. Nighttime CO_2 flux ranged from -0.07 to -0.10 mg m-2 s-1 during the midseason.

Surface CO_2 flux was measured using a chamber, from late May through September. Surface CO_2 flux was small early in the season (-0.05 mg m-2 s-1 on 27 May). Midseason values averaged about -0.1 mg m-2 s-1. The flux decreased to around -0.05 mg m-2 s-1 by late September. A good fit to the data was obtained with an exponential relationship with a Q10 2.

Leaf gas exchange properties were quantified in detail for Betula pumila (bog birch) and Menyanthes trifoliata (buckbean). Selected measurements were made on the dominant Carex (sedge) species. Peak midseason net CO_2 assimilation rates for both Betula and Menyanthes were near 20 μmol CO_2 m-2 s-1, while Carex typically exhibited smaller peak rates, closer to 11 μmol CO_2m-2 s-1. Full sunlight rates obtained earlier and later in the season tended to be smaller than these.

Process-level (experimental manipulation) studies were conducted to develop information on the controls of methane production and emission. These studies involved manipulation of substrate quantity and quality. The experimental carbon additions appeared to decrease methane emissions slightly, relative to controls. Collars with nitrogen treatments generally emitted more methane than the others (the control collars or the collars with only carbon additions). The carbon and nitrogen additions decreased CO_2 uptake, suggesting that these additions enhanced system respiration.

5.6 Trace Gas Biogeochemistry (TGB)

The role of the boreal forest as a carbon source or sink for atmospheric CO_2 is poorly understood but is critical to understanding both the global carbon cycle and the biophysical feedbacks on the physical climate system. There is some indication that there may be a large terrestrial sink for anthropogenic carbon in the mid-latitudes of the northern hemisphere (Tans et al., 1990) and work by Harden et al. (1992) shows that many soils in the boreal forest have been net sinks for carbon since the retreat of the Laurentide ice sheet. However, soils and wetlands of the boreal forest biome are probably the stores of terrestrial carbon most sensitive to human-induced climate change. The trace gas biogeochemistry program within BOREAS is largely a ground-based study of the magnitude, processes and controls of trace gas exchange between the boreal forest and the atmosphere. The studies are mainly tied to the established tower flux sites but, because of the observational rather than experimental nature of this experiment, auxiliary sites across various gradients were developed to test long-term effects of environmental forcing factors. Sampling matrices across soil types, moisture, dominant vegetation, fire disturbance and beaver pond age were established in 1993 and were examined closely throughout the 1994 season. The results from these small-scale studies will be integrated and compared with the tower flux and airborne eddy correlation measurements using remote sensing data to provide area-weighting information.

BOREAS investigators have been directly quantifying the fluxes of radiatively important trace gases (e.g. CO_2 and CH_4) and those gases which could affect the oxidant balance of the troposphere (e.g. NMHC, CO). The principal emphasis will be on carbon dynamics, particularly the role of environmental controls on carbon storage and fluxes. This work was coordinated with studies of moisture and energy fluxes and with studies of the rates of carbon turnover and accumulation in soils using radiocarbon (^{14}C). Measurements of ^{14}C in accumulating soil organic matter, together with measures of bulk density and carbon content, will provide longer term rates of carbon burial into boreal soils. For decadal and shorter time scales, the amount of carbon labeled with excess ^{14}C produced during atmospheric weapons testing in the late 1950's and early 1960's will enable us to compare more recent carbon accumulation with longer term averages. Both of these estimates may be used as context in which to interpret the net ecosystem fluxes measured during the main BOREAS field season. This work is being carried out in close cooperation with field groups who are determining the primary controls on trace gas emissions. We hypothesize that the same factors (e.g., soil drainage, flooding by beaver activity, time since fire disturbance, etc.) will determine both trace gas biogeochemistry and net carbon burial.

Moisture (time-domain reflectometry, TDR) temperature (thermistor) and gas probe arrays were established at a number of upland sites in both the NSA and SSA in 1993.

5.6.1 TGB Team Science Activities

5.6.1.1 TGB-1

PI: Patrick Crill — University of New Hampshire
Collaborators: Dean Moosavi, Monique Simone, Tim Finnegan, Carey Lewis, Nigel Roulet (TGB-4), Niel Comer (TGB-4), Dave Fitzjarrald (TF-8), Tim Moore (TGB-3), Jill Bubier (TGB-3), Kathleen Savage (TGB-3), Sue Trumbore (TGB-12), Jennifer Harden (TGB-12)

Title: Magnitude and Control of Trace Gas Exchange in Boreal Ecosystems

Objectives: To quantify and determine the controls on the exchange of trace gases, especially methane (CH_4) and carbon dioxide (CO_2), between boreal upland environments and beaver ponds with the atmosphere.

CH_4 and Respiratory CO_2 Fluxes
Types of Data and Equipment:
Fluxes were measured with a dark chamber technique in which a chamber was fit to the collars (or floated on the water surface) to begin the flux and aliquots of headspace air were removed at four to five minute intervals for 20 minutes with 60 ml polypropylene syringes. CH_4 and CO_2 concentrations in the syringes were measured at the Hayes Rd lab within 12 hours of collection using gas chromatography (flame ionization detection for CH_4 and thermal conductivity detection for CO_2). Fluxes were quantified by regressing the concentration changes against time; n=5 for CH_4 and n=3 (ambient then first two syringe samples) for CO_2. Temperature was measured in each chamber. Temperature was also measured at 0-2 cm, 10 cm and 20 cm at thermocouple arrays installed with each group of collars.

Summary of Places and Times of Measurements:
- OJP-NSA; Lichen, Moss and Aspen sites (12 collars)
- YJP-NSA; 4 collars over lichen/vaccinium groundcover
- OBS-NSA: moisture gradient from upland black spruce/feather moss to Sphagnum/Carex fen (28 collars)
- Beaver Pond Tower site, NSA: moisture gradient from dry feather moss ground cover to flooded pond edge (16 collars).
- beaver pond regional survey, NSA: with TGB-4; six ponds in the NSA (6-8 chambers in each)
- Duration/Frequency: each collar measured at 7-10 day intervals from early May to mid-September

CH_4 and CO_2 Soil Concentrations
Summary of Places and Times of Measurements:
- NSA OJP; NSA OBS
- Duration/Frequency: 7-10 day intervals from early May to mid-September

Types of Data and Equipment:
CH_4 and CO_2 depth profiles to ca. 90 cm were also taken weekly from tubes installed during

August 1993 at OJP Moss and Lichen sites. Temperature (thermocouple) and TDR moisture profiles (w/ TGB-4) were continuously monitored at these sites during the same period. At the other sites, samples were taken by inserting a 1/8" stainless steel tube to depth and pulling gas. CH_4 and CO_2 concentrations in the syringes were measured at the Hayes Rd lab using gas chromatography.

Continuous CH_4 Concentration and Flux by Gradient Methods
Summary of Places and Times of Measurements:
- NSA OJP (w/ TF-8) and Beaver Pond towers (w/ TGB-4)
- Duration/Frequency: semi-continuous from early May to mid-September

Types of Data and Equipment:
Ambient air samples were analyzed from two heights on the NSA-OJP (30m and 16.5m) and the beaver pond tower (1.75m and 0.25 m). A continuous stream of air pumped from each height was automatically sampled and injected at approximately 6 minute intervals onto gc-fid s that were kept in continuous operations at the sites; one in the instrument shack, the other in a tent). A standard was run between each ambient injection. Precision (as coefficient of variation of a half hour running average of the standard) was about 0.18%. Five discrete determinations of the gradient were then combined into half hourly averages and the gradients were multiplied by transfer coefficients determined by heat, moisture and turbulent fluxes in order to calculate mass flux of CH_4.

5.6.1.3 TGB-3

PI's: Tim Moore, Roger Knowles — McGill University
Co-I's: John Amaral, Lianne Bellisario, Jill Bubier, Kathleen Savage

Title: Carbon Dioxide and Methane Exchanges Between Wetland and Upland Soils and the Atmosphere

Objectives: The objective of the study was to measure the flux of carbon dioxide and methane between the atmosphere and upland forest and peatland soils in the NSA, Thompson and to relate these fluxes to environmental variables which will allow spatial extrapolation and modeling of the fluxes.

Types of Data and Equipment:
Measurements of CO_2 and CH_4 were made with small static chambers placed over the soil surface, enclosing the ground layer of vegetation. In the upland soils, these were comprised of dark chambers ca. 30 cm diameter and 40 cm height. In the peatland soils, the dark chambers were supplemented at some sites with clear chambers in which net ecosystem exchange (NEE) was also measured, along with CH_4 flux. Measurements were conducted over periods up to 30 min. and calculated as mass of gas fluxed m-2 h-1 or d-1.

Summary of Places and Times of Measurements:
Measurements were made at approximately weekly intervals at 11 upland and 15 peatland sites, each with 6 replicate chambers, from early June to mid September, 1994. Upland sites included stands of black spruce (Old Black Spruce trail and Gillam Road), aspen (Old Black

Spruce trail and Gillam Road), pine (Young Jack Pine tower), palsa moss and birch (palsa near Fen Tower site) and three regenerating burn sites (aspen and spruce-pine along Gillam Road and spruce near Footprint River). Peatland sites were selected near the Fen Tower to represent the gradients of wet-dry and rich-poor. NEE measurements concentrated on the wet, rich end of this gradient.

Ancillary measurements included soil temperature and water regimes and available N contents (upland soils) and water table depth and soil thermal regime (peatland soils).

Laboratory analyses were also conducted of soils to establish the location of CH_4 consumption in the upland soil profiles and to identify the controls on this microbial consumption.

Known Problems or Caveats:
Caveats on the quality of the data are that only short periods were used for measurement of fluxes, and the constants of the static chamber technique in determining gas fluxes.

5.6.1.4 TGB-4

P.I.(s): N.T. Roulet — York University

Title: The Fluxes of Energy and Trace Gases from Beaver Ponds and Dry Upland Forest Floor in the NSA

Objectives: To quantify the exchange of heat, water, and CH_4 between boreal forest beaver ponds and the atmosphere for the ice free period of BOREAS. The fluxes of heat, water and CO_2 from one beaver pond was measured continuously using the energy balance Bowen ratio approach. The diffuse and bubble flux CH_4 was measured several times a week using chambers. The chamber approach was used to sample CO_2 and CH_4 flux from 4 to 5 additional beaver ponds, once every two weeks, and regional survey of the surface concentrations of CO_2, CH_4 , and DOC were carried out on accessible beaver ponds. The results of this work will be extrapolated from the local to regional scale in collaboration with the remote sensing project of J. Miller (RSS-19).

The secondary objective of this research is to study the soil climate and soil characteristics at a forest site in conjunction with the flux studies of P. Crill (TGB-1). Soil moisture and temperatures were measured continuously, and soil porosity will be determined.

5.6.1.5 TGB-5

P.I.s: R. G. Zepp — Environmental Research Laboratory (AERL), U.S. Environmental Protection Agency
Co. I's: R. A. Burke, Jr. — AERL; J. S. Levine and W. R. Cofer — NASA Langley Research Center; D. S. Ojima and W. J. Parton — Colorado State Univ.; B. J. Stocks — Forestry Canada; R. A. Bourbonniere — Environment Canada; M.A. Moran and R. E. Hodson — Univ. of Georgia.

Title: Trace Gas Exchange in the Boreal Forest Biome: Effects of Fire and Beaver Activity

Objectives: Both fire and beaver activity are natural disturbances in boreal forests. This project examined the effects of these disturbances on trace gas fluxes and biogeochemical processes in the BOREAS Northern Study Area (NSA) near Thompson, Manitoba. Post-burning effects on soil fluxes of trace gases (CH_4, CO, CO_2. N_2O, and NO) were determined in upland jack pine and black spruce sites located in this area. The results of the fire-related field studies are being used to refine and validate the CENTURY model. In addition to the fire studies, we also obtained a set of CO flux measurements and other data (e.g., chemical characterization, ammonification, and microbial degradability of DOM) in beaver ponds and other wetlands for input into process models that describe carbon cycling in these systems.

Types of Data and Equipment:
Data were obtained throughout the summer of 1994 (May through September). Gas fluxes were determined using the closed chamber techniques with gas chromatography to measure carbon gas and N_2O concentrations. A chemiluminescent procedure was used to determine nitric oxide fluxes. Data on soil temperature, moisture, and nutrient content also were obtained.

Summary of Places and Times of Measurements:
Studies of the trace gas exchange in fire scars were conducted at 5 upland black spruce sites and 2 jack pine sites. Most of the black spruce sites were located on the road to Gillam, Manitoba about 100 km from Thompson where 4 sites of varying ages were studied. The jack pine sites were located in a large burn (135000 ha) on the road to Leaf Rapids, Manitoba. Data for nearby stands that had not been burned for over 70 years are provided for comparison to the recently burned sites.

The beaver pond site was one of the BOREAS tower sites located about 18 km from Thompson. Studies were conducted throughout the summer, with most CO flux studies conducted during IFC-1 in June.

5.6.1.6 TGB-6

PIs: Martin Wahlen, Bruce Deck — Scripps Institution of Oceanography, Univ. of California, San Diego

Title: Isotopic Composition of Methane Produced and Consumed in Boreal Ecosystems

Objectives: To measure oxidation of methane in forest soils and aquatic sediments, Isotopic Fractionation.

Types of Data Collected, Equipment Used:
2 liter gas samples were slowly withdrawn from soil probes at several depths in the forest soil. The depths were chosen to approximate 25% depletion and 50% depletion of soil methane. Several ambient surface air samples were taken. In addition, 2 liter samples were taken from flux chambers on the soil surface equilibrated over a period of several hours to monitor the isotopic changes in methane during direct soil consumption. All samples were returned to the lab for analysis of 13/12 C in methane.

Gas from inverted funnels at the water surface, and from water samples by He equilibrated headspace techniques were made on the NSA Tower beaver pond site. High concentration of methane in some of these samples allows the determination of H/D in addition to 13/12 C in the methane.

Summary of Places and Times of Measurements:
Soil gas samples SSA 8/3-7/94, NSA 8/23-27/94. Soil probes and flux chambers. Beaver pond sediments and waters NSA 8/25+31/94. Surface funnels and water column/sediment water samples.

NSA and SSA, Young and Old Jack Pine sites in conjunction with other TGB sampling.

NSA Tower Beaver Pond site utilizing TGB-4 sampling equipment.

5.6.1.7 TGB-7

P.I.(s): D.T. Waite — Environment Canada

Title: Atmospheric Transport of Agricultural Pesticides into the Boreal Ecosystem

Objectives: To measure the deposition in the boreal forest of seven herbicides (2, 4-D, bromoxynil, dicamba, MCPA, triallate, trifluralin and diclop-methyl) known to appear in the atmosphere of the Canadian prairies, three herbicides (atrazine, alaclor and metlaclor) commonly used in the central United States and known to be deposited in precipitation in the forest and three groups of insecticides (toxaphene, lindane and breakdown products and DDT and breakdown products) reported from the literature and from unpublished data to occur in boreal and arctic food chains.

Sampling locations were:

- Regina atmospheric study site (source of herbicides originating in prairie Canada)
- BOREAS site in Saskatchewan (southern boreal forest)
- Yellowknife NWT Env. Can. site (northern boreal forest)
- Inuvik AES meteorological station (northernmost boreal forest site)

• Iqaluit (a remote site on the eastern arctic).

Sediment core samples were collected from Great Slave Lake (Yellowknife) in the winter of 1992 and from both Montreal L. or Waskesiu L. (BOREAS) in the winter of 1993. The cores will be sectioned and analyzed for the same pesticides as the atmospheric samples. The result will be a measurement of yearly deposition rate of pesticides.

5.6.1.8 TGB-8

PIs: M. Lerdau and R. Monson — University of Colorado
Collaborator: M. Litvak

Title: The Relationship Between Non-Methane Hydrocarbon Emission and Leaf Carbon Balance in the Boreal Forest: An Approach for Mechanistic Ecosystem Modeling

Objectives: To determine ecological controls over leaf-level fluxes on monoterpenes from black spruce and jack pine

Types of Data Collected, Equipment Used:
Photosynthetic rates, monoterpene flux rates, monoterpene tissue concentrations, leaf tissue nitrogen concentrations, infra-red gas analysis, gas chromatography-mass spectroscopy

Summary of Places and Times of Measurements:
All four intensives in SSA at OJP and OBS, in addition, 6 black spruce bogs along east/west transect from SSA-OJP to PANP

Known Problems or Caveats:
Our humidity sensor worked only intermittently, so out transpiration numbers are sketchy

Other Information:
Happy to discuss Ps numbers with other groups

5.6.1.9 TGB-9

PI: Hiromi Niki — York University, Ontario

Title: Ambient Measurements of Ozone, Nitrogen Oxides and Non-Methane Hydrocarbons

Objectives:
1. To identify and quantify the trace hydrocarbons present in the boreal forest, with a view towards discovering what pollutant sources impact upon the forest, and what oxidative processes are important in the boreal atmosphere.
2. To collect ambient samples in a manner that allows calculation of the flux of biogenic emissions using the gradient method.

Types of Data Collected:
Ambient samples were collected in stainless steel canisters from two different heights above the forest canopy. Samples were returned to our laboratory in Toronto for analysis by GC-FID. Concentrations, in ppbV, are reported in BORIS for many nonmethane hydrocarbons. Other NMHC concentrations are available; contact TGB-9 directly for more information.

Summary of Places and Times of Measurements:
Old Black Spruce Site, Southern Study Area
May 31 - June 5, 1994
July 20 - July 24, 1994
September 1 - September 7, 1994

Old Jack Pine Site, Southern Study Area
June 7 - June 12
July 27 - August 2
September 9, 11, 15

Old Aspen Site, Southern Study Area
August 4 - August 8
September 12 - 14

Known Problems and Caveats:
Of the biogenic data, isoprene is absolutely the most reliable, alpha-Pinene is also fairly reliable. Other monoterpenes we continue to check, but we guess we are in the correct order of magnitude. Data for anthropogenic NMHCs reported we are quite confident in.

5.6.1.10 TGB-10

P.I.(s): H. Westberg — Washington State University
CO-I(s): N. Hewitt — Lancaster University

Title: Measurement of Biogenic Hydrocarbon Fluxes and Surface Exchange Processes in a Boreal Forest

Objectives: The following variables were measured:
- biogenic hydrocarbon emission fluxes
- oxidant deposition rates (ozone & hydrogen peroxide)
- boundary layer exchange rates (via concentration gradient measurements and tracer studies)
- diurnal ambient concentration patterns of VOC's and oxidants

These data will be used to determine the role of biogenic hydrocarbon emissions with respect to carbon cycles in the boreal forest and to examine the atmospheric chemical fate of boreal biogenic emissions. Measurements of oxidant deposition rates will be used to investigate feedback mechanisms between atmospheric chemical cycles and forest dynamics.

Hydrogen peroxide and organic peroxides in ambient air at the southern Prince Albert field site were measured during the July 19-August 8, 1994 second IFC. We plan to examine the hypothesis that VOC emissions from the biosphere contribute to peroxide formation in the atmosphere. We will collaborate closely with Dr. Hal Westburg, Washington State University, in this.

5.6.1.12 TGB-12

PI's: S. Trumbore — University of California, Irvine; J. Harden, E. Sundquist — USGS; E. Davidson — Woods Hole Research Center

Title: Input, Accumulation, and Turnover of Carbon in Boreal Forest Soils: Integrating ^{14}C Isotopic Analyses with Ecosystem Dynamics

Objectives: We are determining rates of C accumulation and turnover of soils in the range of conditions found in the BOREAS NSA (wetlands to dry jack pine sites). In addition, TGB-12 (Sundquist and Winston) has collected non-growing season CO_2 flux data. Selected results to date:

1) Fall and winter flux measurements by Sundquist and Winston have shown that significant net loss of carbon dioxide, especially during the fall and early winter. Preliminary calculations based on our data, combined with those of Wofsy et al. (TF-3), suggest that this non-growing efflux amounts to the equivalent of about 1/3 to 1/2 of the net CO_2 uptake during the growing season. The good agreement demonstrated between our chamber measurements and Wofsy's OBS tower flux measurements of CO2 suggests that our winter measurements at other sites (OJP and YJP) should also provide useful estimates of winter C efflux. Concurrent measurements of soil moisture and temperature, soil gas concentrations, as well as winter snowpack properties and CO_2 isotopes are the only data available to determine the sources (and causes of variation) of winter CO_2 efflux. Preliminary data for the winter of 94-95 show warmer soil temperatures associated with generally higher CO_2 flux.

2) Soil C inventory and accumulation rates vary widely, with lowest values for both occurring in sandy, dry jack pine sites, and highest values in Sphagnum-moss-dominated upland clay soils. Long-term accumulation of C appears tied to variables such as moss C inventory, fire frequency and fire intensity.

3) Short-term (decadal) rates of C sequestration are determined from moss C inventory changes following stand-killing fire events, and, for Sphagnum mosses, from ^{14}C data. Values for annual average C accumulation in feather mosses show NEE of these mosses is of similar order to those estimated for trees at the OBS site. We are also collecting data for wetland sites.

Types of Data Collected, Equipment Used:

We stratified soil sampling using a series of sites on clay and sand soils representing times varying from several years to nearly a century since the last stand-killing fire. At each site, we laid out a transect with 10 soil pits to gather data on intra-site variability of organic matter. (Biomass data along these transects were collected by Brian Stocks' group from Forestry Canada). We sampled the organic layers of each pit to determine the total gC m-2 in moss and decomposed organic layers. In all, a total of about 400 samples were collected from upland sites for moisture, density, carbon and nitrogen analyses. ^{14}C will be measured on a subset of these to determine C turnover and accumulation rates.

To answer the second question, we had to develop a freeze- coring method to sample the upper meter of wetland sediment/soil without compressing the sample (not an easy task in standing water). We sampled the wetland sites being measured by TGB3 (Bubier), and will work with TGB3 to tie together net ecosystem exchange, C flux measurements and C accumulation rates (from ^{14}C) at fen, collapse bog and collapse fen sites in the NSA.

TGB-12 measurements of winter fluxes of CO_2, CH_4, as well as soil gas and temperature profiles have been made at four NSA sites. We have also measured C isotopes in soil gases to determine the turnover time of C decomposing to produce CO_2.

Known Problems or Caveats:

Care must be taken in scaling C accumulation data beyond the sites where we have measured them, without reference to maps of relevant soil properties. C accumulation rates we have measured in mosses (the top of the soil profile) are offset by decomposition deeper in the profile - thus these rates are greater than the net C sequestered in soils. We are working with other TGB and TE groups to work out the balance of C accumulation and decay in soils.

5.7 Integrative Efforts

5.7.1 Parameter Evaluation From Remote Sensing

In 1994, image classifications from TM imagery were produced for the NSA and SSA using 1988 and 1990 imagery respectively. These images include classes such as: wet conifer, dry conifer, mixed, deciduous, fen, water, burned, and various regeneration classes. Training fields of known land cover were selected and a maximum likelihood technique was used to produce the classification image.

A new technique is now being used to produce new classifications of the NSA and SSA. This technique involves the use of end member reflectances of land cover components including sunlit canopy (C), sunlit background (B), and shadow (S). Field measurements of the various types of sunlit canopy and background were collected and used in a geometric canopy model. This model computes the amount of C, B, and S that will be produced depending on the amount of canopy and the sun angle conditions at the time of image acquisition. This model output was used to produce signature trajectories for many of the same classes mentioned previously.

The classification of the SSA has already been done using this technique and is available. The classification of the NSA will begin soon. This technique will also be extended to produce a map of biomass, using the classification map in conjunction with the geometric canopy model.

5.7.2 Climate Modeling

The Surface Meteorological Data Set contains actual and 'derived' fifteen-minute meteorological and radiation data for an entire year from four BOREAS sites. This continuous data set (no data gaps) is provided for the use of BOREAS modelers for their climate models. There are modeling datasets for 1994 and 1995. At the end of 1996, a modeling data set will be created for that year. Each data set was based on AFM-7 SRC data. When this data was missing, similar parameters from flux towers (TF) were substituted for the 1994 data set. When these data were missing, analytical methods were used to derive values.

6.0 BOREAS Information System (BORIS)

The functions of BORIS include:
1) Capture, store, and track the large volume and diverse set of BOREAS data;
2) Function as a data cooperative for experiment design, execution, and analysis;
3) Provide data and communication support to investigators;
4) Coordinate formatting and organization of data sets;
5) Lead experiment level data quality checking, integration, and documentation;
6) Prepare data and documentation for long term archive.

The BORIS approach for fulfilling these functions is based on the heritage and lessons from the FIFE (First ISLSCP Field Experiment) Information System (FIS).

As an integral part of BOREAS activities, the development and data handling efforts of BORIS are prioritized by project management and the six science groups in order to meet goals specified during science workshops. Realizing that the needs of the project and science teams are likely to change as BOREAS progresses, BORIS is designed to be flexible enough to accommodate the changes, yet rigorous enough to meet the general scientific needs.

This chapter is divided into seven sections. The first section describes the BORIS organization and provides information to assist you in contacting the BORIS staff member assigned to handle your particular concerns. The second section describes how BORIS is providing access to data and software and information on obtaining user support as needed. Section 6.3 presents information about submitting data and documentation. Section 6.4, provides information of the current data and documentation status. Section 6.5 provides information about the BOREAS grid system for colocation of data. Section 6.6 reviews current issues and plans for various data sets and related processing. The final section describes the nature and status of ongoing interactions between BORIS and the ORNL DAAC related to archiving of the BOREAS data.

6.1 Organization and General Information

This table provides names and contact information for various staff members.

Information Needed	Contact Person	Phone (301) 286-	Email Address
Data Availability and General User Support	Beth McCowan	-4005	beth@ltpmail.gsfc.nasa.gov
System Connection or Account Problems	Anthony Young	-1272	young@boreas.gsfc.nasa.gov
AFM Data status or submission	Don Rinker	-0544	drinker@pop900.gsfc.nasa.gov
HYD Data status or submission	David Knapp	-1424	knapp@ltpmail.gsfc.nasa.gov
RSS Data status or submission	Jaime Nickeson	-3373	jaime@ltpmail.gsfc.nasa.gov
TE Data status or submission	Shelaine Curd	-2447	shelaine@ltpmail.gsfc.nasa.gov
TF Data status or submission	Fred Huemmrich	-4862	fred@ltpmail.gsfc.nasa.gov
TGB Data status or submission	Sara Golightley	-2624	sgolight@pop900.gsfc.nasa.gov
Image/Off-line Data Access	Beth McCowan	-4005	beth@ltpmail.gsfc.nasa.gov
Site Location Information/Coordinates	David Knapp	-1424	knapp@ltpmail.gsfc.nasa.gov
General BORIS Information or if all else fails	Jeffrey Newcomer	-7858	newcomer@ltpmail.gsfc.nasa.gov
	Fred Huemmrich	-4862	fred@ltpmail.gsfc.nasa.gov

6.2 Data and Software Access and User Support

BORIS divides its handling of the data sets based on their size. Those that are too large to easily store on-line (i.e., image data) are kept off-line on 8 mm tapes and those that are small enough to be kept on-line are being placed in a structured set of directories on a disk on the BOREAS.GSFC.NASA.GOV system. The data are accessible by all BOREAS investigators and concerted efforts are made to provide rapid responses to questions and requests for available data. Information about the experiment and data (for authorized users) can be accessed through the World-Wide Web at http://boreas.gsfc.nasa.gov/. For the image data stored off-line, BORIS is adding data base inventory listings of the current holdings in the specific directories. These inventory listings are updated monthly as part of the regular data base reporting. If you cannot find the data for which you are looking, please contact Beth McCowan.

The current organization and storage of the on-line data follow the experiment plan. The two top directories of DATA and SOFTWARE divide the data holdings from available software. Under the main DATA directory are a series of sub-directories for the various science groups, teams, and data sets. In a similar fashion, the STAFF sub-directory is broken into the various staff data components.

In order to access the on-line data and inventory information, BORIS has established user accounts on the BOREAS.GSFC.NASA.GOV system and implemented access via the World-Wide Web (WWW). When users log into their accounts on the BOREAS system, a menu is displayed that provides an introductory way of getting to the data directories. Once a user has a working knowledge of where the various data and software are stored they can exit from the menu and more directly access the data and documentation files.

The WWW provides open access to general project information for everyone, but access to the data and inventory listings is password protected. BOREAS project personnel are informed of the periodic password changes by email. The password is posted on the electronic bulletin board of the BOREAS.GSFC.NASA.GOV system for access by those with system accounts.

User support personnel are available to answer questions during normal working hours (0900 - 1700 Eastern Standard or Daylight Time). Answers to project and data related questions and help in finding needed information can be obtained by contacting Beth McCowan.

6.3 Data and Documentation Submission and Distribution

6.3.1 General Information

BORIS anticipates approximately 300 different data sets from the staff and science team data collection efforts. The current estimate for the approximate volume of all the raw and processed data volume for BORIS is 500 gigabyte. A primary BORIS function is to store, integrate, quality check, and document each of the data sets to make a coherent and useful data set for research activities. To facilitate this, a BORIS staff member has been assigned to interact with each of the six science groups to coordinate data set delivery, formatting, and loading. Any questions regarding these issues should be presented to the science group representatives identified above.

BORIS encourages the submission of preliminary data and later submission of data that has been further processed, reviewed, and quality checked. All science teams who collected field data are expected to deliver their data products and documentation to BORIS for further distribution versus distributing the data themselves to other BOREAS groups. This centralized distribution helps assure that everyone has access to and is using the same data and fosters improved interdisciplinary research. The most recent version of a given data set is being kept on-line along with available documentation. When new data versions are added, the 0_README.TXT files in the data directories are updated accordingly.

6.3.2 Data Formats

The detailed contents of data files are expected to vary by data type; however, if the files have some common attributes, it makes the BORIS data handling a bit easier. For the point source measurements, the most common file format is a tabular ASCII text file containing a series of measurement records with the measured parameters as columns across the records separated by commas. This is preferred over spreadsheet or word processing package specific formats. Files in this form can be quickly placed on-line for access to all BOREAS personnel and are the easiest to use with available spreadsheet, word processing, and data base software utilities.

For image data, BORIS is using the template of separate band sequential (BSQ) files. In each BSQ file, a single tape record corresponds to one image scanline. For some image data types where this BSQ format does not make good storage or use sense, BORIS is working with data providers to use other reasonable formats (e.g., multiple image records in a physical tape record but still in BSQ form or band interleaved by line (BIL)). BORIS is also encouraging data suppliers to place data and information of different types into separate files (i.e., image spectral data versus calibration data versus geographic location coordinates). An example of this is the level-3a Landsat TM image data. CCRS and BORIS staff have processed the level-3s products delivered bu CCRS to level-3a products with the following file structure and contents:

```
FILE 1 (90 byte ASCII text records)

-  Description of level-3a product files

-  Original image header information (tape values are decoded based on the
   conventions outlined in the User's Guide for Landsat Thematic Mapper
   Computer-Compatible Tapes, 1985; EOSAT).

-  Level-3a image coordinates

-  Calibration information summary (gain and offset per band)

-  Georeferencing information summary (minimum and maximum latitude/longitude)

-  Coordinates (pixel,line and longitude,latitude) of the control points used
   to provide improved georeferencing information.

FILES 2 - 8 (A band sequential set of files containing image bands 1 to 7,
             respectively.)

-  Each of the 5728 records in each file contains 6920 bytes.

-  Each of the 6920 byte records contains 6920 8-bit/one-byte pixel values

-  Each pixel value is in units of digital counts

-  Each image is oriented so that pixel 1, line 1 is in the upper left-hand
   (i.e., northwest) corner of the screen display.  Pixels and lines progress
   left to right, and top to bottom so that pixel n, line n is in the lower
   right-hand corner.
```

6.3.3 Measurement Units

A significant help to BORIS is having the science teams submit date, time, and measurement fields in the proper form and measurement units. Certain reporting formats and measurement unit standards have been adopted which pertain to both tabular and image sorts of data. These include:

Dates in the form of dd-mon-yy (e.g., 06-Jul-94)

Time in the form of hh:mm:ss.s specified in reference to GMT (e.g., 13:01:35.4)

All values in solar and instrument view zenith and azimuth files should be spherical polar coordinates in relation to the observed point on the ground. The source-target-sensor geometry is thus specified consistently, and in the reference system required by formal definitions of the bidirectional reflectance distribution function (BRDF). Instrument view and solar azimuth angles are relative to north (as 0 degrees) and increase in a clockwise direction. Instrument view and solar zenith angles are relative to nadir (looking straight down on the target at 0 degrees) increasing to 90 degrees looking from the horizon and increasing to 180 degrees looking up at the target.

Mass flux values in units of micromoles/(m2 * second)

Radiometric measurements in units of Watts/(m2 * steradian * micrometer) except those for Photosynthetically Active Radiation (PAR) which should be expressed as microEinsteins/(m2 * second)

6.3.4 Documentation

As noted under section 6.3.1, BORIS anticipates a total of 300 data sets from the BOREAS data collection efforts. For these data to be useful to other groups within and outside BOREAS, each of these must be sufficiently documented. The BOREAS-96 Experiment Plan Version 2.0, Volume II, Appendix C contains an outline of the current documentation outline and some overall guidelines.

All science teams must make their best effort to fill in the provided sections and are encouraged to contact their BORIS representative for questions and additional information.

6.4 Data and Documentation Status

The status of the various data sets are presented in the following tables.

Aircraft Flux & Meteorology (AFM)

Group	Data Set	Dates Available
AFM-1	Preliminary Aircraft Flux	IFC-1, IFC-2, IFC-3
AFM-2	Preliminary Aircraft Flux	IFC-1, IFC-2, IFC-3
	Sounding	IFC-1, IFC-2, IFC-3
AFM-3	Preliminary Aircraft Flux	IFC-1, IFC-2, IFC-3
	Sounding	No Data Received
AFM-4	Preliminary Aircraft Flux	IFC-1, IFC-2, IFC-3
	Moving Window	No Data Received
	Sounding	IFC-1, IFC-2, IFC-3
AFM-5	AES Upper Air	IFC93, FFC-T, IFC-1, IFC-2, IFC-3
AFM-6 Profiler	Mean Wind and Temperature Profiles	May --> Sep 94
	Boundary Layer Heights	May --> Sep 94
AFM-6 Radar	Vertical Doppler Radar	16-Jul-94 --> 8-Aug-94
	Conical Scan Doppler Radar	No Data Received
AFM-7	SRC Met Data	15-Dec-93 --> Present
AFM12/Staff	Regional AVHRR Classification	1994
AES Autostations	Cambell Scientific (continuous)	01-Aug-93 --> Present
	Readac (IFC only)	IFC-1, IFC-2, IFC-3
	MARSII (IFC only)	IFC-1, IFC-2, IFC-3

Hydrology (HYD)

Group	Data Set	Dates Available
HYD-1	Soil Moisture	IFC-1, IFC-2, IFC-3
	Hydraulic Conductivity	No Data Received
	Soil Water Retention	No Data Received
	Under Canopy Precipitation	IFC-1, IFC-2, IFC-3
HYD-2	Microwave & Gamma Measurements	Feb-94
	Snow Water Equivalent	No Data Received
HYD-3	Sub-canopy Radiation from SSA OJP	Feb-94
	Canopy Wind Speed (2 meters SSA-OJP)	06-Feb-94 --> 10-Feb-94
	Snow Temperature Profiles	FFC-W, FFC-T
	Canopy Density	Feb, Apr-94
	Snow Water Equivalent	FFC-T in SSA
	Snow Depth	FFC-W, FFC-T
HYD-4	Microwave & /o Gamma Measurements	No Data Received
	Snow Water Equivalent	15-Nov-93 --> 15-Apr-94 Nov 95 --> Apr 96
	Snow Depth	15-Nov-93 --> 15-Apr-94 Nov 95 --> Apr 96
HYD-6	Microwave & /o Gamma Measurements	IFC-1, IFC-2, IFC-3

Hydrology (HYD) cont.

Group	Data Set	Dates Available
HYD-8	Moss Monitoring Data (NSA Joey Lake)	Jun --> Sep 94
	Digital Elevation Model	Circa 1978
HYD-9	Rain Gauge	94 IFC-1, IFC-2, IFC-3 95 Apr --> Nov
	Stream Gauging	IFC-1, IFC-2, IFC-3
	Radar Precipitation	IFC-1, IFC-2, IFC-3
	Standpipe Observation	No Data Received
Soil SSA (TE-1)	Soil Lab Data	Circa 1994
Soil NSA (Levine)	Soil Lab Data	Circa 1994

Remote Sensing Science (RSS)

Group	Data Set	Dates Available
RSS-1	fPAR	No Data Received
	fAPAR	No Data Received
	Albedo	No Data Received
	PARABOLA Data	94 FFC-T, IFC-1, IFC-2
RSS-2	PAR	No Data Received
	BRDF	No Data Received
	ASAS Level-1b images	SSA 7-Jun, 21-Jul, 13-Sep NSA 7-Jun
	Vegetation Index	No Data Received
	Radiance/Reflectance	No Data Received
RSS-3	Radiance/Reflectance/Surface Temp	Cat. 1 sites (IFC-1, IFC-2, IFC-3)
	Video	Being Copied
	Aerial Photography (Helo)	No Data Received
	Optical Thickness	No Data Received
RSS-4	fAPAR	25-Jul-94 --> 05-Aug-94
	Leaf Chemistry	No Data Received
	LAI	25-Jul-94 --> 05-Aug-94
	DBH	No Data Received
	% Canopy cover	No Data Received
RSS-7	fAPAR	IFC-1
	LAI	IFC-1
RSS-8	BRDF	IFC-3
	Vegetation Index	No Data Received
	Radiance/Reflectance	No Data Received
	Canopy Photography	IFC-3
	Surface Temperature	No Data Received
	Land Cover	No Data Received
	Snow Cover	No Data Received
RSS-11	Optical Thickness	IFC-1, IFC-2, IFC-3
RSS-12	Optical Thickness	IFC-1, IFC-2, IFC-3
RSS-13	Scatterometer Data	No Data Received

Remote Sensing Science (RSS) cont.

Group	Data Set	Dates Available
RSS-14	GOES-7 Level-1 images	1994, 1995
	GOES-7 Level-1a images	1994, 1995
	GOES-7 Level-2 (Surface Rad ASCII)	1994
	GOES-7 Level-2a (Surface Rad Images)	1994
RSS-15	Biomass	No Data Received
RSS-16	AirSAR CM Level-3b	IFC-93, FFC-T, IFC-1, IFC-2
	AirSAR SY Level-3b	IFC-93, IFC-2
	AirSAR Parameter Maps	No Data Received
	Land Cover	1994
	Snow Cover	No Data Received
	Surface Moisture	No Data Received
RSS-17	Sub-surface and bole Temp.	SSA, NSA 1994
	Land Cover	No Data Received
	Surface Moisture	No Data Received
	ERS-1 Level-? Images	No Data Received
	Freeze/Thaw maps	No Data Received
RSS-18	Radiance/Reflectance	No Data Received
	Optical Thickness	IFC-1, IFC-3
	AVIRIS Level-1b Images	FFC-T, IFC-1, IFC-2, IFC-3
	AVIRIS Parameter Maps	No Data Received
RSS-19	Radiance/Reflectance	FFC-T, IFC-1, IFC-2, IFC-3
	CASI Level-1b images	FFC-T, IFC-1, IFC-2, IFC-3
	CASI Level-2 images	Sample Data
RSS-20	BRDF	No Data Received

Staff

Group	Data Set	Dates Available
Staff Sat. Images	AVHRR Level-3b	FFC-T, IFC-1, IFC-2, IFC-3
	AVHRR Level-4b	FFC-T, IFC-1, IFC-2, IFC-3
	AVHRR Level-4c	FFC-T, IFC-1, IFC-2, IFC-3
	JERS Level-0	April --> Dec 94
	Landsat TM Level-3s (CCRS systematic)	1984 --> 1995
	Landsat TM Level-3p (CCRS precision)	1988, 1989, 1991, 1994
	Landsat TM Level-3a (BORIS BSQ DN)	1984 --> 1995
	Landsat TM Level-3b (BORIS BSQ Rad)	1984 --> 1994
	Landsat TM Level-3c	Not Yet Available
	Landsat TM Level-3g	Not Yet Available
	Landsat MSS Level-1	1972 --> 1978
	Landsat MSS Level-1a	Not Yet Available
	Landsat MSS Level-1b	Not Yet Available
	Landsat MSS Level-2	Not Yet Available
	Landsat MSS Level-3	Not Yet Available
	SPOT Level-3s (CCRS systematic)	1993 --> 1994
	SPOT Level-3a	Not Yet Available
	SPOT Level-3b	Not Yet Available
	SPOT Level-3c	Not Yet Available
	SPOT Level-3g	Not Yet Available
Staff Aircraft Images	AOCI Level-0	94 IFC-2
	Daedalus TMS Level-0	94 IFC-3
	C130 Navigation Data	FFC-T, IFC-1, IFC-2, IFC-3
	MAS Level-0 BSQ	21-Jul-94 SSA
	MAS Level-1b (HDF)	21-Jul-94 SSA
	MAS Level-1b (BSQ)	21-Jul-94 SSA
	MAS Level-2	Not Yet Available
	MAS Parameter Maps	Not Yet Available
	NS001 Level-0	FFC-T, IFC-1, IFC-2, IFC-3
	NS001Level-1a	Not Yet Available
	NS001 Level-1b	Not Yet Available
	NS001 Level-2	Not Yet Available
	NS001 Level-3	Not Yet Available
	TIMS Level-0	94 FFC-T, IFC-3
	TIMS Level-1b	94 FFC-T, IFC-3
	ER2 Navigation Data	FFC-T, IFC-1, IFC-2, IFC-3
Staff Meteorological Data	ECMWF Data	
	TOGA Advanced Operational Analysis Surface and Diagnostic Fields	1994, 1995
	TOGA Supplementary Fields	1994, 1995
	TOGA Extension Fields	1994, 1995
	Saskatchewan Forestry Weather Stations	05-May-94 --> 30-Sep-94

Staff cont.

Group	Data Set	Dates Available
Staff Sat. Image Extract	AVHRR-LAC	Not Yet Available
	GOES	Not Yet Available
	Landsat TM	Not Yet Available
	SPOT	Not Yet Available
Staff AC Image Extract	AOCI	Not Yet Available
	MAS	Not Yet Available
	NS001	Not Yet Available
	TIMS	Not Yet Available
PI AC Image Extract	ASAS	Not Yet Available
	AVIRIS	Not Yet Available
	CASI	Not Yet Available
Staff Analog Data	C130 Photography	FFC-T, IFC-1, IFC-2, IFC-3
	C130 Flight Logs	FFC-T, IFC-1, IFC-2, IFC-3
	C130 Videos Tapes	IFC-3
	ER2 Photography	FFC-t, IFC-1, IFC-2, IFC-3
	ER2 Flight Logs	FFC-t, IFC-1, IFC-2, IFC-3
	Hardcopy Maps	1971 --> 1993
	PI Reports	Miscellaneous
	Publications	Miscellaneous
Staff/CanSIS GIS	Region ARCINFO Soils (1:1M)	circa 1984
Staff GIS	Region Raster Soils (1:1M)	circa 1984
Staff/CanSIS GIS	SSA ARCINFO Soils (1:125K)	28-Aug-87 --> 14-Feb-89
Staff GIS	SSA Raster Soils (1:125K)	28-Aug-87 --> 14-Feb-89
Staff/MNR GIS	NSA ARCINFO ForCover (1:15840)	circa 1988
Staff GIS	NSA-MSA Raster ForCover (1:15840)	circa 1988
Staff/SERM GIS	SSA ARCINFO ForCover (1:12500)	circa 1988
Staff GIS	SSA-MSA Raster ForCover (1:12500)	circa 1988
Staff/PANP GIS	PANP ARCINFO ForCover (1:50K)	circa 1978
Staff/SERM GIS	SASK ARCINFO ForCover (1:1M)	circa 1988
Staff/Geomatics GIS	NSA Vector Contours Topo (1:250K)	Preliminary
Staff/Geomatics GIS	SSA Vector Contours Topo (1:250K)	Preliminary
Staff/Geomatics GIS	NSA Vector Contours Topo (1:50K)	circa 1978
Staff/Geomatics GIS	SSA Vector Contours Topo (1:50K)	circa 1978
Staff/HYD08 GIS	MSAs Raster UTM DTM (1:50K)	circa 1978
Staff GIS	MSAs Raster BORGRID DTM (1:50K)	circa 1978
Staff/EDC GIS	Region Raster Lat/Long DTM (1:1M)	Available
Staff GIS	Region Raster BORGRID DTM (1:1M)	Available
Staff/TGB05	MANI ARCINFO FireHist (1:125K)	1980 --> 1992
Staff/TGB05	SASK ARCINFO FireHist (1:125K)	Preliminary
Staff/SERM	SASK ARCINFO FireHist (1:125K)	1943 --> 1989

Terrestrial Ecology (TE)

Group	Data Set	Dates Available
TE-1		
Gas Flux	CH4	SSA 1994
Soil Profiles	CH4	No Data Received
	CO2	No Data Received
Substrate (SSA)	soil C	SSA 1994
	soil N	SSA 1994
	soil pH	SSA 1994
	elec. conduct.	SSA 1994
	soil H2O	SSA 1994
Tower Trace Gas	Other Soils Data	No Data Received
	SSA soils map	No Data Received
TE-2	Leaf Respiration	NSA 1994
	Leaf Conductance	NSA 1994
	Bole Respiration	NSA 1994
	Leaf Nitrogen	No Data Received
	Wood Nitrogen	No Data Received
	Phenology	No Data Received
TE-4	Leaf Photosynthesis	1994
	Leaf Conductance	1994
	Leaf Conductance	1994
	Leaf Optical Properties	1994
TE-5	Air Stable Isotope	NSA/SSA 1994
	CO2 Profile	NSA/SSA 1994
	Gas Exchange	NSA/SSA 1994
	Leaf carbon isotope	NSA/SSA 1994
	Meteorological data	NSA/SSA 1994
	Tree Ring Data	NSA/SSA 1994
TE-6	Soil CO2 flux	No Data Received
	Sapwood	NSA/SSA/Aux 1994
	Biometry	No Data Received
	Allometry	No Data Received
	Soil Carbon	No Data Received
	Soil Nitrogen	No Data Received
	Biomass(leaf,wood,root)	NSA/SSA/Aux 1994
	Leaf Area Index	NSA/SSA/Aux 1994
	Litterfall	No Data Received
	Net Primary Production	NSA/SSA/Aux 1994
	Predawn leaf water potential	NSA/SSA/Aux 1994
	Canopy Architecture	SSA 1994
	Site Characteristics	NSA/SSA/Aux 1994

Terrestrial Ecology (TE) cont.

Group	Data Set	Dates Available
TE-7	Leaf Photosynthesis	No Data Received
	Leaf Conductance	No Data Received
	Litterfall	No Data Received
	Net Primary Production	No Data Received
	Sap flow	SSA 1994
TE-8	Bark Chlorophyll	No Data Received
	Bark optical properties	SSA 1994
TE-9	Photosynthesis CO2 Response	NSA 1994
	Photosynthesis Temperature Response	NSA 1994
	Photosynthesis Light Response	NSA 1994
	Photosynthesis VPD Response	NSA 1994
	Photosynthesis Water Potential Response	NSA 1994
	Leaf biochemistry	NSA 1994
	Leaf Optical Properties	NSA 1994
	N vs PAR Profile	NSA 1994
	N vs Photosynthesis	NSA 1994
	Diurnal Gas Exchange	No Data Received
TE-10	Leaf Optical Properties (Broadleaf)	SSA 1994
	Leaf Optical Properties (Conifer)	No Data Received
	Leaf Physical Characteristics	No Data Received
	Gas Exchange	No Data Received
	Leaf Biochemistry	No Data Received
TE-11	Leaf Photosynthesis	SSA 1994
	Leaf Conductance	No Data Received
	Leaf Nitrogen	No Data Received
	Sap flow	SSA 1994
	Lichen and Moss Photosynthesis	No Data Received
TE-12	Branch Angle	SSA 1994
	Leaf Gas Exchange	No Data Received
	Shoot bidirectional data	No Data Received
	Leaf Nitrogen	No Data Received
	Leaf Optical Properties	SSA 1994
	Leaf water potential	No Data Received
TE-13	Biometry	SSA 1994
	Allometry	1994
TE-16	Leaf area index	No Data Received
TE-18/Staff	Landsat TM Classifications	NSA/SSA 1994
TE-20	Biometry	SSA 1994
	Leaf area index	No Data Received
	Stem Maps	No Data Received

Terrestrial Ecology (TE) cont.

Group	Data Set	Dates Available
TE-23	Hemispherical Photos	NSA/SSA 1994
	LAI from hemis photos	NSA/SSA 1994
	Gap Fraction from hemis photos	NSA/SSA 1994
	fPAR from hemis photos	NSA/SSA 1994
	Stem Maps	Mapped Plot Summary 1994

Tower Flux (TF)

Group	Data Set	Dates Available
TF-1	SSA-OA Flux Data	1993 --> 1994
	SSA-OA Met Data	1993 --> 1994
TF-2	SSA-OA Flux Data	No Data Received
	SSA-OA Met Data	1994 Golden Days
TF-3	NSA-OBS Flux Data	1993 --> 1994
	NSA-OBS Met Data	1993 --> 1994
TF-4	SSA-YJP Flux Data	26-May --> 20-Sep-94
	SSA-YJP Met Data	IFC93, 15-May-94 --> 20-Sep-94
TF-5	SSA-OJP Flux Data	IFC93, 23-May-94 --> 16-Sep-94
	SSA-OJP Met Data	IFC93, 23-May-94 --> 16-Sep-94
TF-6	SSA-YA Flux Data	19-Jul-94 --> 19-Sep-94
	SSA-YA Met Data	19-Jul-94 --> 19-Sep-94
TF-7	SSA-OBS Flux Data	24-May-94 --> 04-Jun-94 19-Jul-94 --> 28-Jul-94 08-Sep-94 --> 18-Sep-94
	SSA-OBS Met Data	24-May-94 --> 04-Jun-94 19-Jul-94 --> 28-Jul-94 08-Sep-94 --> 18-Sep-94
TF-8	NSA-OJP Flux Data	24-May-94 --> 21-Sep-94
	NSA-OJP Met Data	24-May-94 --> 21-Sep-94
TF-9	SSA-OBS Flux Data	23-May-94 --> 21-Sep-94
	SSA-OBS Met Data	23-May-94 --> 21-Sep-94
TF-10	NSA-YJP Flux Data	IFC93, 24-May-94 --> 20-Sep-94
	NSA-YJP Met Data	IFC93, 24-May-94 --> 20-Sep-94
	NSA-Fen Flux Data	IFC93, 08-Apr-94 --> 21-Sep-94
	NSA-Fen Met Data	IFC93, 08-Apr-94 --> 21-Sep-94
TF-11	SSA-Fen Flux Data	19-May-94 --> 07-Oct-94
	SSA-Fen Met Data	19-May-94 --> 07-Oct-94

Trace Gas Biogechemistry (TGB)

Group	Data Set	Dates Available
TGB-1		
Gas Flux	CH_4	IFC-1, IFC-2, IFC-3
	CO_2	IFC-1, IFC-2, IFC-3
	CO	No Data Received
	N_2O	No Data Received
Tracers	SF_6	No Data Received
	Rn	No Data Received
Soil Profiles	CH_4	IFC-1, IFC-2, IFC-3
	CO_2	IFC-1, IFC-2, IFC-3
TGB-3		
Gas Flux	CH_4	IFC-1, IFC-2, IFC-3
	CO_2	IFC-1, IFC-2, IFC-3
Soil Profiles	CH_4	IFC-1, IFC-2, IFC-3
	CO_2	IFC-1, IFC-2, IFC-3
	Water table	IFC-1, IFC-2, IFC-3
	Peat Temperature	IFC-1, IFC-2, IFC-3
Substrate	DOC fract'n	94 IFC-1, IFC-2, IFC-3
	DOC	94 IFC-1, IFC-2, IFC-3
TGB-4		
Gas Flux	CH_4	No Data Received
	CO_2	IFC-1, IFC-2, IFC-3
	N_2O	No Data Received
Soil Profiles	CH_4	No Data Received
	CO_2	No Data Received
Substrate	Water Table	IFC-1, IFC-2, IFC-3
	Sediment Temperature	IFC-1, IFC-2, IFC-3
TGB-5		
Gas Flux	CH_4	IFC-2 Golden Days
	CO_2	IFC-2 Golden Days
	CO	May --> Sep 94
	NO-burn	No Data Received
	N_2O	No Data Received
Tracers	SF_6	No Data Received
Soil Profiles	CH_4	No Data Received
	CO_2	No Data Received
Substrate	DOC fract'n	No Data Received
	DIC	No Data Received
	DOC	No Data Received
Tower Trace Gas	Water Chemistry	No Data Received

Trace Gas Biogechemistry (TGB) cont.

Group	Data Set	Dates Available
TGB-6		
Isotopes Flux	d13CH4	No Data Received
	D/H	No Data Received
	d13CO2	No Data Received
Isotopes Soil Gas	d13CO2	No Data Received
	d13CH4	No Data Received
Substrate	DH2O	No Data Received
TGB-7		
Tower Trace Gas	Herbicides	No Data Received
	Organic Chlorine	No Data Received
TGB-8		
Tower Trace Gas	NMHC	No Data Received
	Foliar Chemistry	No Data Received
	Photosynthesis	No Data Received
TGB-9		
Tower Trace Gas	NMHC Mixing Ratio	94 IFC-1, IFC-2, IFC-3
TGB-10		
Tower Trace Gas	NMHC	IFC-1, IFC-2, IFC-3
	O3/H2O2	IFC-1, IFC-2, IFC-3
TGB-12		
Gas Flux	Winter Flux	14-Nov-93 --> 27-Apr-94
Tracers	Rn?	No Data Received
Isotopes Soil Gas	d13CO2	No Data Received
	14CO2	No Data Received
Substrate	13C(dom)	No Data Received
	14C(dom)	21-Aug-93 --> 26-Aug-93
	mass (dom)	No Data Received
	soil C	No Data Received
	soil N	21-Aug-93 --> 26-Aug-93
Tower Trace Gas	Soil Temp	14-Nov-93 --> 20-Nov-93
	Other Soils Data	Aug 94, Aug 95

6.5 The BOREAS Grid System

A key element of the information system effort is to consistently track and locate the data collected over the BOREAS region. This includes satellite and aircraft imagery, biophysical measurements collected along transects, and other measurements of all sorts at specific points in the 189A of longitude (93° W to 111° W) and 99A of latitude (51° N to 60° N) area. Based on the experience with FIFE, it was felt that an (x,y) grid system would provide a means of performing the requisite data location function needed in organizing and retrieving the data in a consistent manner The grid system had to satisfy certain criteria which included:
1) grid cells whose area was the same across the region (important for not requiring use of weighted statistics calculations),
2) identification of grid cells at different scales (i.e., hierarchical in nature),
3) ability to identify any spot in the area from 1 by 1 km down to 10 by 10 m in a meaningful fashion.

With these criteria in mind, several methods were considered and map projections of different sorts were reviewed. After reviewing these needs and discussions with USGS personnel, the ellipsoidal form of the Albers Equal-Area Conic (AEAC) projection under the NAD83 datum was selected. The advantages of the AEAC projection include: 1) easily derived grid cells of equal area, 2) extremely small distortion over the BOREAS region using the established rules of standard parallel selection, and 3) if desired, the ability to essentially perform circumpolar mapping/location of data in the boreal forest region (potentially valuable for long term boreal region research). The origin (000.00, 000.00) of the grid is located at the lower left (southwest) corner of the area using 51.00=9A N and 111.00=9A W as its physical location. The x and y coordinate values increase as you proceed east and north, respectively.

The next step was to determine how to identify grid cells of different spatial sizes. With the maximum width and height of the region as 1000 km, a base grid matrix of 1000 columns and 1000 rows with 1 km resolution for each cell would cover the area. Dividing each 1 km cell into a matrix of 10 by 10 100 m cells, and then dividing each 100 m cell into a matrix of 10 by 10 m cells provides a hierarchical gridding/location scheme. It also provides a means of referencing the grid at each level, as shown in the following examples:

(000.00, 000.00) is the whole region
(121., 237.) is the whole specific 1 km cell
(121.5, 237.3) is the whole specific 100 m cell
(121.53, 237.39) is the whole specific 10 m cell.

A program, named BOR_CORD, was developed to perform conversion of geographic latitude, longitude and UTM northing, easting coordinates in the NAD27 and NAD83 datums to the BOREAS x,y grid values. BOR_CORD has been successfully used on IBM PC, Macintosh, VAX, and various Unix workstations. Written in C, BOR_CORD is available on-line in the SOFTWARE directory. In addition to the source code file, a datum shift file is needed for BOR_CORD to handle datum conversions.

6.6 Issues and Plans

The majority of current BORIS issues center around getting the diverse data set integrated, documented, and assembled for publication and release to the ORNL DAAC. Staff and science team representatives are compiling schedules to guide data processing and documentation through December 1997. Open communication and cooperation from the science teams is greatly needed to accomplish the data publication goals. BORIS plans to publish the best of the BOREAS data on a set of CD-ROMs with the type of CD-ROM dependent on how quickly the new Digital Video Disk (DVD) technology becomes stable.

6.7 Interactions with ORNL DAAC

As part of the functions outlined at the beginning of section 6, BORIS will handle and distribute the BOREAS data to project personnel through the duration of the BOREAS project. However, as BOREAS staff and science teams complete needed data manipulations, quality checks, and documentation, the data will be handed off to a long term archive center. Part of preparing the BOREAS data and documentation for long term use and archive includes interacting with the long term archive center; currently the Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (DAAC). The current ORNL DAAC representative for BORIS is Ms. Merilyn Gentry. Merilyn's contact information is as follows:

Merilyn Gentry, User Services / Data Coordinator
EOSDIS ORNL DAAC
Oak Ridge National Laboratory
P.O. Box 2008
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Oak Ridge, TN 37830-6407
phone: 615-241-5926
fax: 615-574-4665
internet: mjg@ornl.gov

Communications with the ORNL DAAC have been ongoing since the start of BOREAS. The result of this communication is the compilation of the BORIS/ORNL Transition Plan, modifications to the original BOREAS documentation outline to make more comparable to the DAAC documentation requirements, and some data exchanges and discussions. The BORIS/ORNL Transition Plan discusses how BORIS and ORNL will interact regarding data transfer, outlines the BORIS and ORNL DAAC data handling plans, describes the data documentation process, issues on data with copyright concerns, and several appendices giving the status of all known data sets. The overall purpose of the document is to set a framework under which BORIS and ORNL will interact to successfully archive the BOREAS data and provide ongoing data processing status information.