BOREAS Operations 1996

Version 1.0 (August 12, 1997)

Executive Summary

The design of the BOREAS-96 field experiment is described in the BOREAS Experiment plan (EXPLAN-96); preliminary results and a summary of field operations and weather conditions may be found in Hall et al. (1997).

This document describes what was actually achieved in BOREAS-96. 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 BOREAS-94 Preliminary Results

1.1 Preliminary Science Results from BOREAS-94

The beginnings of BOREAS-96 grew out of the preliminary results from the BOREAS-94 field season. Sellers et al. (1995) cover some preliminary science results from BOREAS-94, key findings were:

(i) The surface energy and heat balance: In terms of albedo, the boreal forest is one of the darkest ecosystems on Earth; the snow-free albedo of areas covered by coniferous species was observed to be less than 10% in BOREAS-94. This, combined with long daylengths during the growing season, ensures that a large amount of solar energy is absorbed by the surface when time-integrated over a day. However, a surprisingly small fraction of the intercepted energy is used to evaporate water from the system, as compared with the temperate forests and grasslands to the south. Results reproduced in Sellers et al. (1995) show that less than half of the available energy is typically used for evapotranspiration, which is estimated to average less than 2 mm/day over the area during the growing season. Because such a small fraction of the available energy is used in evapotranspiration, large sensible heat fluxes are generated which often lead to the development of very deep dry turbulent atmospheric boundary layers (ABL) over the region. From a preliminary inspection of the ECMWF and NMC forecasts provided to BOREAS during 1994, it seems that these two numerical weather prediction models, thought to be the best of their kind in the world, are calculating excessive evapotranspiration rates for this region during the growing season, with subsequent overprediction of cloudiness and precipitation.

(ii) Physiological controls on the surface heat and carbon fluxes: During the early part of the growing season, the roots of many of the trees are frozen which inhibits photosynthesis and transpiration. Later in the growing season (at least, the 1994 growing season), the high daytime temperatures lead to large vapor pressure deficits which in turn initiate strong stomatal closure responses from all of the coniferous vegetation. This stomatal closure effect is so strong that for the bulk of the summer, the coniferous evapotranspiration rates appeared to be relatively insensitive to changes in radiation and other meteorological conditions.

Photosynthetic uptake was observed to continue at at least one TF site (NSA-OBS) long after the end of IFC-3, which ended in late September. Presumably, the soils and root systems remain warm for some time into the fall allowing active physiological processes to continue in the canopy. Similarly, significant CO_2 effluxes were measured throughout the winter. Other measurements and modeling studies indicate that the moss layer may also play a significant role in the carbon cycle of the region.

Why is the boreal vegetation so sparing with water which is so abundant in the region? (No direct soil water stress limitations on evapotranspiration were observed during the 1994 growing season if the effects of frozen roots are discounted). The obvious explanation is that the photosynthetic capacity of the vegetation is very low, presumably an adaptation to the nutrient-poor environment, leading directly to low transpiration rates. Still, it is puzzling why the stomatal response function seems tuned to such a low risk-low benefit strategy; one reason may be that 1994 was so warm and dry that we are seeing an atypical 'mean' growing season physiological response. During cooler, more humid years, the stomatal function may serve the vegetation more efficiently.

(iii) Remote sensing results: Preliminary results from the remote sensing component of BOREAS indicate that many of the hypotheses relating optical satellite data to surface conditions developed for other ecosystems, e.g. grasslands in FIFE, may transfer to the boreal forest, albeit with some significant additional effort. The first cut at doing this on a large scale is encouraging, see Sellers et al. (1995).

A number of BOREAS workshops have defined the initial interfaces required between regional-scale energy/water/carbon models and remote sensing parameters. These workshops have shown the need for parametrically homogeneous classes to initialize and evaluate the models.

In BOREAS, regional scale remote sensing is used to map community composition, i.e., wetland conifer, upland conifer, deciduous, fens, conifer/deciduous mixed communities, and several classes of disturbance by approximate age. Within these classes, the models need other characteristics such as biomass density (for respiration loss), leaf area index (precipitation interception and roughness length), height and basal area fraction (roughness length) and the fraction of photosynthetically active radiation intercepted by the green portion of the canopy (FPAR) to compute transpiration and photosynthetic rates. Preliminary studies of the relationships between reflectance and the biophysical properties of boreal forest communities indicate that remote sensing can be used to map landcover characteristics. To obtain these regional-scale parameter maps, BOREAS investigators and staff develop and apply optical and microwave algorithms to the aircraft and satellite data. The first versions of these maps, at the study area and regional scales, are now ready for evaluation in conjunction with the energy-water-carbon models.

AVHRR data have been used to develop a 1 km spatial resolution community composition map of the 1000x1000 km BOREAS regional study area. The technique used is very similar, if not identical, to that used on the 1 km AVHRR Pathfinder land cover data set. TM data have been used to develop a 30 m resolution map of the BOREAS Northern and Southern study areas. Both maps are of the model-required classes discussed above. The TM classifications show that the NSA and the SSA are similar in composition with respect to conifers, about 50% of both study areas, and mixed deciduous/conifers, roughly 20% in both areas, but somewhat different with respect to deciduous covers; 10% in the SSA and 4% in the NSA. Fens contribute only about 3 to 4% of each study area and open water about 10% of both areas. The remainder of the study areas are disturbed and regenerating in mixes of conifer and aspen (<30 yrs. old) comprising roughly 5% of the SSA and NSA.

Comparisons of the TM map to the 30 m auxiliary site data show an overall classification accuracy of about 80%. The TM and AVHRR maps have also been compared, showing 70 to 80% agreement between the 1km AVHRR and the 30m TM for aggregated classes such as conifer, mixed deciduous, regeneration and water. At the more detailed class breakout level, agreement decreases because of the difference in spatial resolution between TM and AVHRR. Other preliminary results from studies using optical and radar data indicate that biomass densities, LAI and FPAR can be estimated to about 5 levels, or roughly to 20% relative accuracy.

Microwave sensors on aircraft (DC-8, CV-580) and satellites (ERS-1) were used to monitor soil and canopy thaw, which relates to the start of photosynthesis. The ERS-1 C-band radar data showed an increase in backscatter between days 60 and 63, correlated to the soil thaw, and another increase around day 78 related to canopy thaw.

1.2 Shortcomings of the 1994 Data Set and Open Issues

Examination of the 1994 data set identified the following weaknesses:

(i) **Beginning and end of the growing season**: The first field campaign of 1994 started in May, at which time many of the coniferous species had started photosynthesis. We did not have a clear picture of how the system emerges from winter dormancy. Similarly, the last field campaign ended in late September 1994; measurements by a team who stayed in place (TF-3) indicated that significant photosynthetic uptake was maintained through November 1994, while significant respiration fluxes were measured in the NSA throughout the winter of 1994-1995. The bulk of the 1994 measurements did not extend through the thaw and freeze-up periods, leaving a significant gap in our understanding of the processes controlling carbon and energy fluxes as these times.

(ii) **Role of Moss**: Analysis of some field measurements and some preliminary modeling studies indicated that the moss layer may play an important role in carbon assimilation, particularly in the wet coniferous sites. The data gathered in 1994 was not sufficient to construct a credible model of moss photosynthesis and water relations. This indicated that more detailed measurements which extend over the growing season were needed.

(iii) **Smoke in IFC-2**: Heavy smoke from forest fires alternating with patchy cloud cover severely reduced optical remote sensing opportunities in IFC-2, the 1994 mid-growing season field campaign. All of the airborne remote sensing data collection work was compromised to some extent: the C-130 (MAS, ASAS, TMS); the ER-2 (AVIRIS); the Chieftain (CASI); and the helicopter (SE-590, POLDER). Of the data gaps, perhaps the most serious is the suite of C-130 measurements, particularly the incomplete MAS and ASAS data acquisitions over the NSA. The result was that we did not have a complete remote sensing record of the growing season to match up with our surface flux observations and other data sets. This seriously compromised the development of algorithms for growing season (maximum) Fpar and LAI.

(iv) **Snow cover and the radiation balance**: Some preliminary modeling work indicated that the effects of the forest canopy on albedo may be highly significant in determining the winter climatology of the northern mid- and high-latitudes, see Bonan et al. (1992, 1995). This work suggests that replacement of the boreal forest by a low-lying vegetation cover, such as could happen with a northward migration of biomes following continental warming and drying, would result in a large increase in the wintertime albedo over the northern high latitudes and dramatic changes in the climate there. The increase in albedo would give rise to decreased winter and summer temperatures at these latitudes which may partially counteract the classical 'greenhouse effect' which is predicted to generate a significant warming for the same area. Bonan et al. (1992) go on to suggest that the current correlation of climate indices and biome boundaries in the boreal zone is a result of a two-way interaction between the biota and the physical climate system there rather than solely a consequence of (one-way) atmospheric forcing. These simulations were performed using a land surface parameterization coupled with an atmospheric generation circulation model (AGCM) which incorporated a fairly basic description of snow-vegetation-albedo effects. The uncertainty attached to this result is large, mainly because we did not have enough information about the physics of radiative transfer within snow-covered boreal vegetation and also because we did not know how to spatially assign albedo fields for the region from satellite data.

We had little useful surface and airborne data to help us understand how the snow-covered forest intercepts and reflects/emits incoming solar and longwave radiation. During the winter of 1993-1994, most of the forest appeared to be very dark, particularly at low view angles. This is true even for deciduous areas, where low solar angles in winter compensate for low stem densities with the result that the bulk of the solar radiation appears to be intercepted by stems and bare branches. By contrast, the agricultural areas to the south and the tundra to the north of the forest appeared to be almost completely snow-covered and were highly reflective. To what extent does the radiation balance of the surface correspond with this visual impression? Could we quantify them using satellite data? The radiation sensors on the Automatic Meteorological Stations (AMS) in BOREAS-94 were not equipped with snow blowers or alcohol sprayers so much of their data from early 1994 (the systems came on-line in March 1994) are suspect. The complete set of these anti-frost devices were only installed before the winter of 1994-1995. In addition, we did not have a complete optical remote sensing data set, consisting of surface (PARABOLA) and airborne (ASAS, CASI) data, over the snow-covered SSA radiative transfer test sites from the 1994 focused field campaigns. Compilation of this data set with supporting ground truth (snow depth, snow water equivalent) measurements became a primary goal for a winter focused field campaign in 1996.

In addition to these shortcomings, there were some open issues or gaps in our understanding:

(v) **1994: a record warm, dry year**: 1994 was a record frost-free year for the SSA and the driest year on record in the NSA. Since 1994 was characterized by high temperatures and high vapor pressure deficits, it may have provided us with an image of the transient behavior of the boreal forest with respect to global change rather than a representative baseline for the status quo. The representativeness of the 1994 field year would have been a discussion issue in any case, but the fact that 1994 was so exceptional lead us to suspect that we may be seeing something more relevant to the future of the system rather than obtaining a clear picture of its current functionality. The anomalous meteorological conditions of 1994 could be expected to influence many aspects of the BOREAS-94 data set in addition to vegetation responses; for example, the TGB group was expected to show some evidence that the long, warm growing season led to an unusual time-profile of soil/wetland CO_2 and CH_4 fluxes in the SSA.

(vi) **Positive surface-atmospheric boundary layer drying feedback**: The development of deep dry boundary layers suggested that a positive drying feedback may be at work in this region at the beginning of the growing season when the soils are still partially frozen (see Betts et al.; in press) and also during warmer periods when the vapor pressure deficit feedback effect becomes important. We believe that we have the data from BOREAS-94 to make some headway on determining if this model holds up for the warm, dry conditions of 1994. If this turns out to be true or partially true for 1994, which is likely, to what extent would it hold for more 'normal' conditions? If this feedback system is the norm, it implies that the result of the vegetation's conservative water-stress avoidance strategy in the region is to exacerbate the degree of external stress. Teleologists would propose that this implies that the ecosystem is out of sync with its climate while strict Darwinists (Dawkins faction) might argue that this apparent reduction in ecosystem efficiency is to be expected from game theory. More data for a different kind of year would help to resolve some of these issues.

1.3 Objectives of BOREAS-96

The objectives for BOREAS-96 were drawn directly from the BOREAS White Papers. The next three subsections reproduce excerpts from the White Papers which summarize the goals and methodologies for BOREAS-96.

1.3.1 Fluxes and Processes at the Stand Level

The main goal of the proposed in situ stand level work is to develop an integrated approach to understanding fluxes and processes at the stand scale, specifically the roles of different components; canopy, understory, moss, soils, in contributing to the total fluxes of energy, water and carbon. Some TF measurements and associated in situ observations should extend from before until after the end of the 1996 growing season, i.e. from March through November. This should be augmented by a summer IFC designed to perform a well-coordinated three to four week experiment that will provide data from several key sites to test our physiological, net ecosystem exchange (NEE), and canopy-ABL feedback models.

The work will require continuous measurement of CO_2 and H_2O fluxes above stands at selected forest sites and concurrent eddy-covariance measurements of CO_2 and H_2O below the forest canopy. Chamber measurements of CO_2 (and other trace gas) fluxes from the forest floor will be made during daytime and night-time throughout the IFC. Chambers will be used to measure moss photosynthesis and respiration and tree bole respiration. These measurements are necessary to help resolve the difficult issue of estimating accurately the night-time net CO_2 efflux from the forest. Leaf or branch chambers should be operated and should be complemented with porometry measurements for stomatal conductance at 3 or more levels in the overstory and at least one level in the understory and moss layers. Heat balance or heat pulse techniques should be used to provide an independent measurement of tree transpiration. Chambers and lysimeters should be used to measure moss transpiration and forest floor evaporation.

Radiosonde and tethersonde ascents are important for the testing of ABL-mixed layer models of canopy evaporation and CO_2 exchange and to establish the role of negative feedback between the ABL and the stomatal conductance of the forest. Remote sensing indices, including NDVI, the simple ratio, bi-directional reflectance (PARABOLA) must be obtained together with canopy leaf area index and structure (LI-COR LAI 2000 and TRAC). Finally, high-quality supplementary measurements of climate (radiation fluxes, etc. from the AFM-7 Mesonetwork) and soil moisture (HYD groups) data must be maintained.

The specific measurement objectives for the 'ground' science teams working at or near Tower Flux (TF) sites are as follows:

(a) To determine the net ecosystem flux and associated processes of canopy assimilation and soil CO_2 efflux during the thaw period at the start of the season to determine whether the stands pass through a period of CO_2 efflux before assimilation takes over. Secondly, to determine the net ecosystem CO_2 flux during the autumn period at the end of the growing season through when the net CO_2 flux is near-zero when the system freezes up.

(b) To determine closed carbon, water and trace gas budgets for the stands over a year by measuring their fluxes during spring and fall IFCs. During a summer IFC, focused experiments to establish the validity of measurements of night-time CO_2 effluxes should be done.

(c) To measure fluxes and processes of the major components within the stand system, i.e. overstory, understory, moss and soil, in relation to environmental and state variables so as to understand and explain the stand scale fluxes. To investigate in greater detail sensitivity of the net ecosystem CO_2 flux to externally-caused changes in canopy assimilation and soil CO_2 efflux, with the aim of elucidating the controls that determine whether the net system flux is positive or negative.

(d) To measure water vapor and CO_2 fluxes, together with stomatal conductances, during a summer IFC in conjunction with a parallel concerted program of ABL measurements to ascertain whether avoidance of internal water stress by stomatal closure exacerbates the degree of external stress by positive feedback.

(e) To determine whether parameters obtained in 1994 are valid from year to year and in the proposed spring and fall periods in 1996 throughout the year, by an additional mid-season period of observations. To provide suitable data to parameterize and test both stand and regional scale models for those parts of the year for which data are currently non-existent or inadequate.

(f) To make contributions to basic micrometeorological and ecophysiological theory, particularly with regard to processes in the atmospheric boundary layer.

1.3.2 Surface and Atmospheric Boundary Layer Studies

The goal of the continued collection of surface, atmospheric boundary layer (ABL) and upper air data in BOREAS-96 is:

(i) to link the surface flux measurements to the atmospheric boundary layer, and
(ii) to provide validation data sets for modeling studies on all scales from the stand level up to global models and ecosystem models.

BOREAS-96 is driven by the need to get a complete seasonal cycle to address the annual carbon balance, and the desire to understand better the component fluxes, and the contributions by the understory (especially the moss layer). The 1994 measurement campaigns did not adequately sample the transitional seasons of spring and fall, nor provide adequate measurements of the understory except at the Old Aspen site.

The ABL measurements are largely in support of the tower flux measurements, as well as modeling studies. In 1994, the continuous surface flux and meteorological measurements and the more detailed ABL measurements by aircraft, rawinsondes, a wind profiler, cloud radar, lidar ceilometer and a cloud camera provided a detailed data set to analyze the interactions between the surface and the overlying atmosphere. Much of this analysis is still in progress. The 1994 campaign confirmed the importance of the feedbacks between deep dry ABL's, which produce large vapor pressure deficits at the surface, which reduce evapotranspiration though stomatal closure. In addition, studies at the NSA OJP site by TF-8 suggest the need for further studies of the links between cloud cover, and stomatal controls. The 1994 measurements were however probably not adequate to address the diurnal cycle of CO_2: there is a large storage component at night in the shallow nocturnal ABL, which is vented as the daytime ABL grows (on most but not all days). There were some deficiencies in the aircraft flux measurement program; the fluxes of energy and CO_2 from the lakes were not measured in autumn when the lakes are warm and fluxes are thought to be high. In addition, the 1994 aircraft measurements of absolute carbon dioxide concentration were not accurate enough to assess spatial variability above different land-cover elements or to be of much use to atmospheric tracer modeling studies.

It is important to maintain the surface meteorological network to provide long-term data for land surface and ecosystem models, and to make supporting ABL measurements during some of the 1996 IFC's. We believe that aircraft flux and upper-air measurements are integral to the overall BOREAS objective of upscaling tower fluxes and closing the surface carbon and water budgets at the regional scale. Aircraft flux measurements are needed to assess the spatial heterogeneity of surface energy and carbon fluxes and to quantify fluxes from different land-surface elements. Rawinsondes are needed to provide local atmospheric conditions for large-scale atmospheric models. The atmospheric models in turn produce gridded analyses for nesting column and mesoscale atmospheric models and for driving large-scale hydrologic and ecological models. Boundary-layer depth (as measured by vertical profilers and rawinsondes) is needed to relate the diurnal cycle of surface fluxes and climate to boundary-layer evolution.

At present, the surface meteorological measurements from BOREAS are being used to drive both local stand level SVAT models and regional ecosystem models. These models require long continuous time-series of forcing variables. Beyond the few years of surface data being collected for BOREAS, ecosystem models must use surface climate data (which typically lack the surface radiation budget) and global model products, which are limited by model accuracy. The BOREAS ABL data are being used to link the surface stand-scale measurements to the overlying atmosphere, and to address the difficult problem of scaling tower site fluxes up to larger scales (such as the 50km grid scale of a global forecast model). In addition these data are being used to directly test and improve the surface and ABL parameterizations in large-scale models. All these modeling studies will benefit greatly from a second data validation period within the longer period of background data.

The specific objectives for the BOREAS-96 ABL measurements are as follows:

(a) Continue the time-series of surface meteorological and radiation measurements for modeling studies through 1996.

(b) Provide monitoring of ABL depth (especially at night) and cloud fields (base and fraction) to support TF measurements, spring through fall of 1996.

(c) Use aircraft and radiosondes during the summer and fall IFC's to measure area averaged fluxes and daytime ABL evolution to scale from tower sites up to regional scale.

(d) To use these integrated data-sets for summer and fall IFC's for the further test and development of large-scale models within the long-term framework of the BOREAS surface observations.

1.3.3 Remote Sensing Science

During 1994, a large amount and variety of remote sensing data were collected from aircraft and satellites as well as at ground level. Many initial data products have been completed, and others are at various stages of development and verification. The 1994 data will be used to develop parameter fields for NSA and SSA. Nevertheless, there are three important areas where the 1994 data set does not satisfy the needs of the science teams. These are (1) winter radiation and reflectance measurements, (2) necessary mid-season satellite and aircraft optical data to estimate parameter fields, as well as to support the development and testing of critical algorithms, and (3) as revealed at the October 1995 BOREAS Workshop, data required to characterize the type, location and status of moss and understory.

The measurement goals for RSS for BOREAS-96 are as follows:

<u>Airborne/Satellite Observations</u>

(a) Obtain growing season airborne data required by the BOREAS MODLAND Team to develop algorithms applicable to EOS MODIS, i.e. where necessary, use AVIRIS as a MAS substitute, and ASAS for angular characterization. MODLAND representatives indicate that continuing the MAS/AVIRIS flights over the next two years is critical to preparations for the MODIS launch. MODIS data simulation for BOREAS can also be achieved using a combination of AVIRIS and TIMS. ASAS and PARABOLA data (with as much data as possible collected concurrently) are needed to better characterize and upscale spectral albedo, and FPAR and LAI at the TF sites during the growing season. AVIRIS imagery over the NSA and the SSA during winter/early thaw with continuous snow cover, and later during the thaw with partial snow cover to measure snow extent are also desirable. This is important to test the repeatability of mapping snow in discontinuous canopies and to link these products to models. Moreover, this product should provide a suitable reference against which to test other sensor algorithms (e.g. MODIS, SAR, Landsat TM).

(b) Basic (ASAS) bidirectional reflectance measurements over forest stands with a snow background must be acquired, since these measurements (missing from 1994) are necessary to characterize the wintertime radiation balance of boreal forests.

(c) Obtain and process GOES data to generate albedo, incoming photosynthetically active radiation, incoming total shortwave radiation, net radiation, and canopy temperature products. Ensure smooth transition to GOES-Next;

(d) Obtain ERS-1 and RADARSAT data to generate freeze/thaw products;

(e) Obtain sun photometer data for atmospheric correction of high resolution satellite optical data; for the winter campaign these needs may be met by deployment of CIMEL sun photometers separately with the PARABOLA and ASAS teams;

(f) Obtain LANDSAT data to generate leaf area index and the fraction of absorbed photosynthetically active radiation (assuming no crippling deterioration of Landsat sensor performance or of the orbit, which is a shaky assumption for 1996).

Surface Observations

(g) Obtain surface bidirectional reflectance and emission measurements within conifer and deciduous canopies in winter and during the growing season over visible, shortwave infrared and thermal infrared wavelengths, including the moss layer (e.g. PARABOLA-III). These observations will support ASAS/AVIRIS/ MAS acquisitions.

(h) Obtain measurements of the spatial distribution of incident shortwave and thermal radiation at the surface beneath selected canopies during the early and late thaw periods to provide key data for canopy radiation models designed to estimate wintertime albedo in boreal forests, as well as for modeling a snow melt process.

(i) Support winter AVIRIS overflights with co-incident ground measurements and observations of snow reflectance and grain size. Litter on snow surface will be measured, and hemispheric measurements of canopy closure will be made to test the canopy closure product algorithm.

(j) If possible, support AIRSAR overflights with ground measurements and deployment of calibration devices. Winter 1996 campaign AIRSAR data acquisition would be supported by field data collection (tree dielectric constant, snow depth and soil and snow dielectric constants) in the Northern and Southern study areas. The dielectric measurements will be conducted with the JPL TRACE TDR system and the waveguide probes that have been installed during the 1994 summer IFC. Close coordination of measurements with Hydrology group investigators will be necessary in order to reduce redundancies and expenses.

Snow cover data (depth, water equivalent, density) were acquired at NSA and SSA snow courses throughout the winter of 1994/95 (first and fifteenth of each month). This measurement program is planned to be repeated during the 1996 winter before 3/1/96. These measurements represent a core BOREAS snow cover data set which can support remote sensing algorithm development and hydrological modeling efforts as well as other

BOREAS science investigations. HYD-4 is responsible for coordinating this measurement program and providing the data to BORIS.

2.0 BOREAS-96 FIELD ACTIVITIES

2.1 Overview

The main components of BOREAS-96, in summary were:

(i) **Monitoring**: Continued automatic meteorological station measurements, hydrological measurements and satellite/sunphotometer observations.

(ii) **Winter RSS Campaign**: Airborne and in situ observations of the radiation field above and within winter forest canopies; followed-up on the remote sensing of winter albedos.

(iii) **NSA Growing Season Studies**: Surface studies involved TF measurements at four sites (NSA-OBS, NSA-OJP, NSA-Fen and NSA-YJP) took place from April through November 1996. Three small IFCs, which incorporated the bulk of the supporting TE work, took place in the thaw, summer and fall timeframes. TGB work was ongoing through this period.

(iv) **SSA Growing Season Studies**: Surface, principally TF, TE and HYD measurements, took place within the SSA from March through November. SSA-OA and SSA-OBS were the foci of most of this work. In parallel with the NSA schedule, there were three small IFCs which incorporated most of the coordinated TF and TE work.

(v) **Growing Season RSS and AFM activities**: Some airborne and surface RSS work during the summer IFC. Radiosoundings and airborne flux measurements were conducted during the summer and fall IFCs.

2.2 Monitoring

2.2.1 Automatic Meteorological Stations (AMS)

All of the 10 AMS sites continued in operation up to November 30, 1996; after that, only one station, at the Thompson airport, continued to collect data. The measurements taken at the sites are summarized in table 2.2.1

Table 2.2.1
Parameters Measured by the BOREAS AMS Network (AFM-7)

Parameters measured	Resolution	Accuracy	Typical sensor/supplier
Sensor suite A			
Above-canopy temperature	0.1deg C	+/- 0.4deg C	Vaisala HMP35C
Within-canopy temperature	0.1deg C	+/-0.25degC	Campbell 107F
Soil moisture H_20 potent. RF			Campbell scientific/matrix
Air Pressure	0.01kPa	+/-0.05kPa	Setra SB270
Humidity	1 percent	+/-3 percent	Vaisala HMP35C (same as air temperature)
Wind speed	.1m/s,1deg	5percent,2deg	RM Young Wind Monitor 05103-10
Precipitation *	1mm	5percent	AES Tipping Bucket Rain Gauge, Belfort Gauge
Snow depth	0.5cm	+/-1.0cm	Campbell Scien. UDG 1 ultrasonic depth sensor
Incident Shortwave	1percent	5percent	Eppley (PSP)
Incident PAR	1percent	2percent	Skye-Probetech (SKE510) PAR sensor
Reflected Shortwave	1percent	2percent	Eppley (PSP)
Net radiation	1percent	5percent	Fritschen type net radiometer
TIR Surface Temp	<1degC	+/-0.5°C	Everest (4000 AL)
Soil temperature	0.1degC	+/-0.4°C	Campbell scientific 107 BAM
Sensor suite B			
Diffuse Shortwave down	1percent	1percent	Eppley (PSP) plus shadow band
Longwave down	1percent	2percent	Eppley (PIR) plus shadow band

*The Belfort-type precipitation gauge are located in clearings within cable distance of the station. The field of view from the top of the gauge to the nearest obstruction should not be greater than 45 degrees.

2.2.2 Hydrological Measurements

The BOREAS-96 work plan involved activities similar to those in 1994 and 1995. All five stream flow and 22 precipitation gauges in the NSA and SSA were reactivated in April 1996. The sites were visited once every 3-4 weeks by University of Waterloo personnel (HYD-9) until November 1996. The catchments were:

SSA

White Gull Creek, gauged above Highway 106 and at Harding Road.

NSA

NW1 Basin, gauged on the Sapochi River at the Highway 391 bridge.
NW2 and NW3: two small watersheds which straddle route 391.

Locations of the gauges and details about the measurements can be found in EXPLAN-94, section 3.2.2.

2.2.3 Aircraft Observations

Dates, durations, activities and aircraft associated with BOREAS field campaigns.

	Start Date	End Date	Duration (days)	Activities	Aircraft
FFC-W	2/27/96 58	3/15/96 75	18	Snow remote sensing ~ 4 teams.	ER-2, C-130Q, Eyeball
IFC-1	4/02/96 93	4/28/96 109	27	Spring processes	Eyeball
IFC-2	7/09/96 191	8/09/96 222	32	Mid-Season Processes; RSS, AFM as well as surface teams	ER-2, C-130Q, Chieftain, Twin Otter, Eyeball
IFC-3	10/01/96 275	10/20/96 295	20	Fall processes; AFM work	Eyeball

Table 2.2.3
Aircraft in BOREAS

Aircraft/ Mission Identifier	Aircraft Type	Tail Number/ Call sign	Instruments	Cognizant Investigator	Team
Remote Sensing					
RC	C-130Q	NASA-427	ASAS, Photo	Irons	RSS-2
RE	ER-2	NASA-706	AVIRIS, MAS	Green/Ranson	RSS-18
RP	Chieftain	C-GCJX 'Trilium 103'	CASI	Miller	RSS-19
Flux					
FT	Twin Otter (DH-6)	C-FPOK 'Research 7'	Flux; H,LE,CO_2,τ	McPherson	AFM-4
FB	PA-34 C-172/C-182	C-GPFK 'Eyeball'	CO_2 profiles	Sellers	AFM-14

2.2.4 Satellite Observations

A program of satellite data acquisitions was coordinated during the 1996 field year; satellite instrument attributes are shown in Table 2.2.3. Sunphotometer data were acquired by RSS-11 using the automatic network in place.

GOES data were acquired continuously be RSS-14 and processed into a series of surface radiation budget products: S↓, S↑, PAR↓, PAR↑, albedo, L↓, L↑, R_n. The GOES data were acquired from the beginning of FFC-W through the end of IFC-3.

A full tabulation of satellite overpasses and geometry was given in EXPLAN-96, Appendix E with summaries for SPOTand Landsat shown in EXPLAN-96, Chapter 6. These tables showed the theoretical maximum number of scenes. The actual number received was subject to satellite performance as well as ground station constraints and, in the case of SPOT-HRV, constraints due to scheduling off-nadir takes for non-BOREAS users. There were limited opportunities for acquiring imagery for these three instruments because of orbital and instrument configurations.

<u>Landsat</u>: Four Landsat scenes are located within the BOREAS region; Southern Study Area (SSA), Transect West (TW), Transect East (TE) and Northern Study Area (NSA). Two of these scenes require that the scene center be shifted for a good transect coverage.

Table 2.2.4 Satellite Instrument Attributes

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	0.52 - 0.72	1 km	48 per day
	Infrared	16.47 - 7.0	4 km	48 per day
	Water vapor	20.2 - 11.2	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	

SPOT: There are two SPOT satellites in operation, each equipped with two pointable instruments. However, the instruments cannot acquire one site (say SSA) and then slew round to acquire the other (NSA) on the same orbit. It also requires two SPOT scenes to cover the SSA. Sometimes, images may be acquired for both sites on the same day when both SPOT satellites are in range.

ERS-1: The ERS-1 C-VV SAR operates at a fixed incidence angle of 23˚. The ERS-1 orbit is periodically changed by ESA which results in varying coverage of the BOREAS region. For example, complete coverage was provided by a 35-day repeat until December 15, 1993, a 3-day repeat until March 15, 1994 and a 176-day repeat from then on. During the 35- and 176- day repeat, the 1000 x 1000 km site is mapped every 17-days, and the instrument therefore collects data at weekly intervals, day and night, over the BOREAS region.

3.0 Experiment Execution

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

3.1 Environmental Conditions

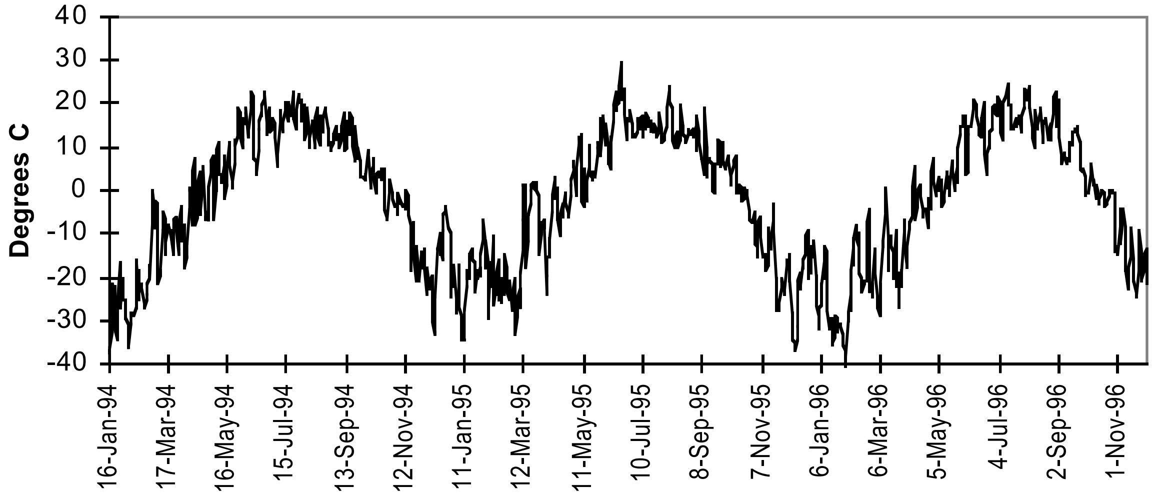
Climatology notes on the boreas years

Temperature:
1994 proved to be the warmest of the three years in both the Northern Study Area (NSA) and Southern Study Area (SSA). Average temperatures in the NSA for 1994 were 1.8 degrees warmer than in 1995 and 0.8 degreess warmer in 1996. Average temperatures in the SSA were about 0.25 degrees warmer than in 1995 and about 0.10 degrees warmer than in 1996. (Please note that 1996 contains no data for the month of December as the mesonet ceased operation on November 30, 1996). The warm year of 1994 can also be seen in the soils temperature, as the temperature readings from the soil probes appear to be slightly higher during 1994.

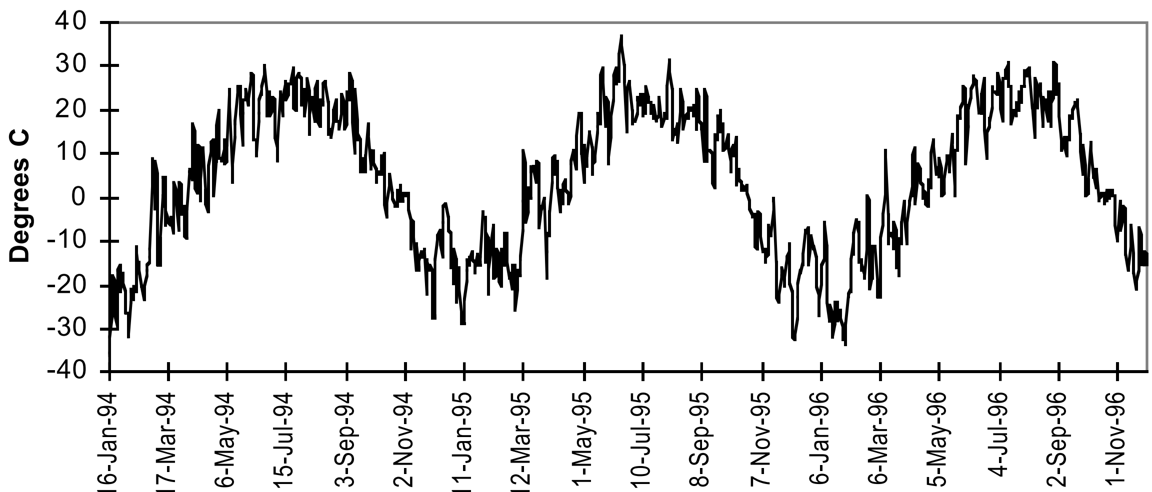
One curious note. It appears that the spring season of 1996 was longer than the other two year. An investigation of the soil temperatures for this year show a pronounced straight line around the freezing mark. This straight line indicates a thaw. During this thaw period, the energy the soil receives is used to change ice to water. (During this phase change, the temperature remains constant). At night, when no more energy can be received by the soils, the soils will refreeze due to energy loss, i.e. the water changes phase to ice. The next day this process will be repeated. The length of the straight line indicating the occurrence thawing and refreezing of ice indicates a longer thaw period.

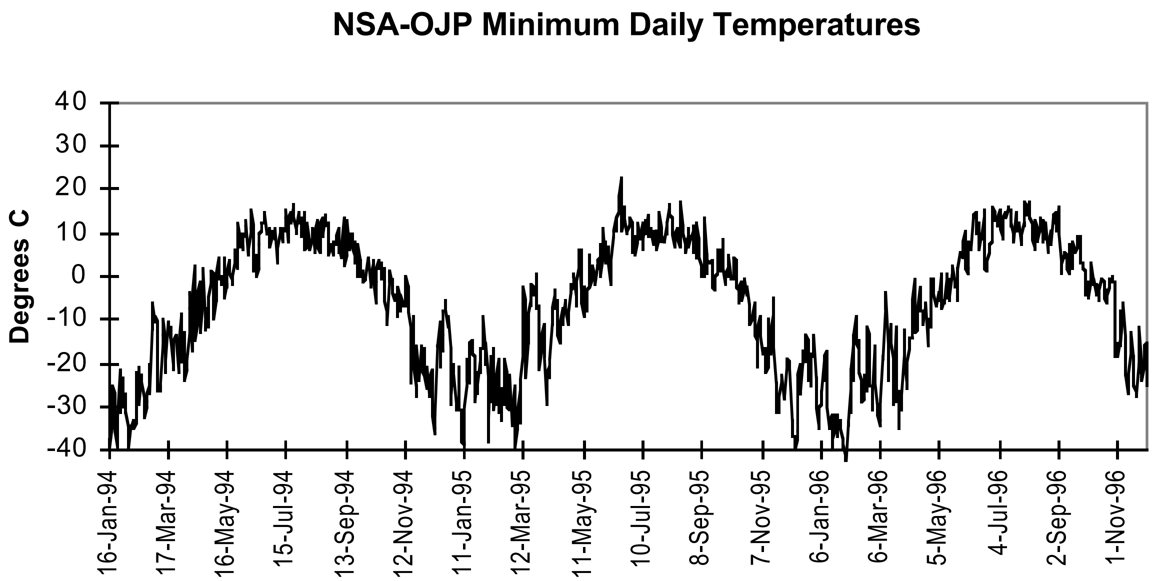
Precipitation:
Precipitation differs among the two sites. For the NSA, the amount of precipitation remains fairly consistent over the three year period, with 1994 having the most precipitation by about 2 cm over 1995 and 1996. The SSA saw a increase in precipitation over the three years period. Precipitation values were approximately 40 cm for 1994, 45 cm for 1995, and 54 cm for 1996. Although it is difficult to explain the anomalous reading for 1996, a longer spring (as explained above) may have produce a few more spring showers in 1996 than in the previous to years. (Once again, 1996 data does not included the month of December.)

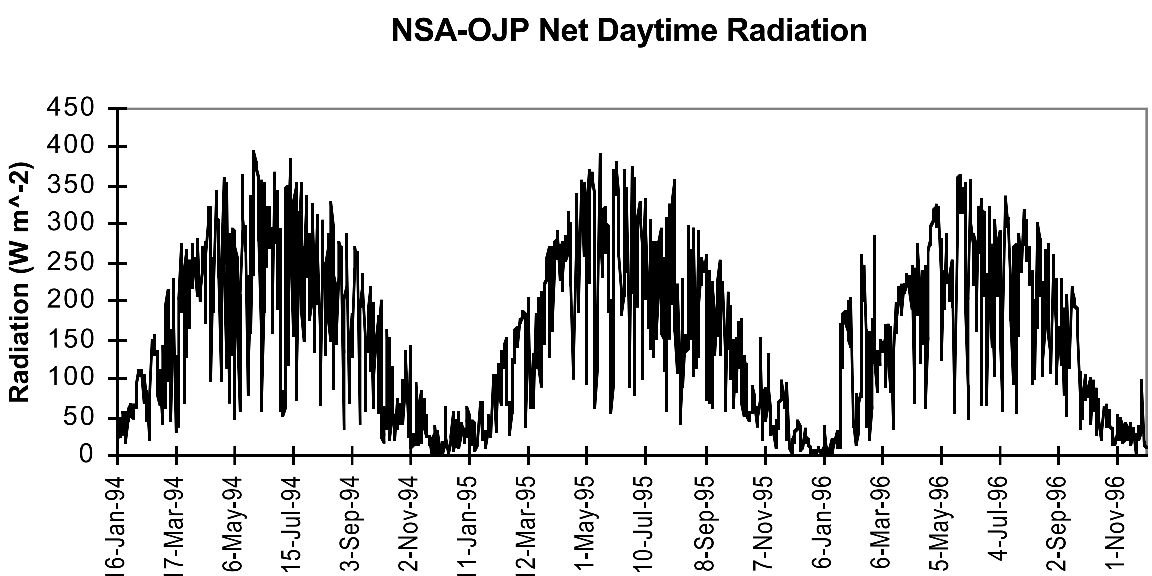
NSA-OJP Average Daily Temperatures



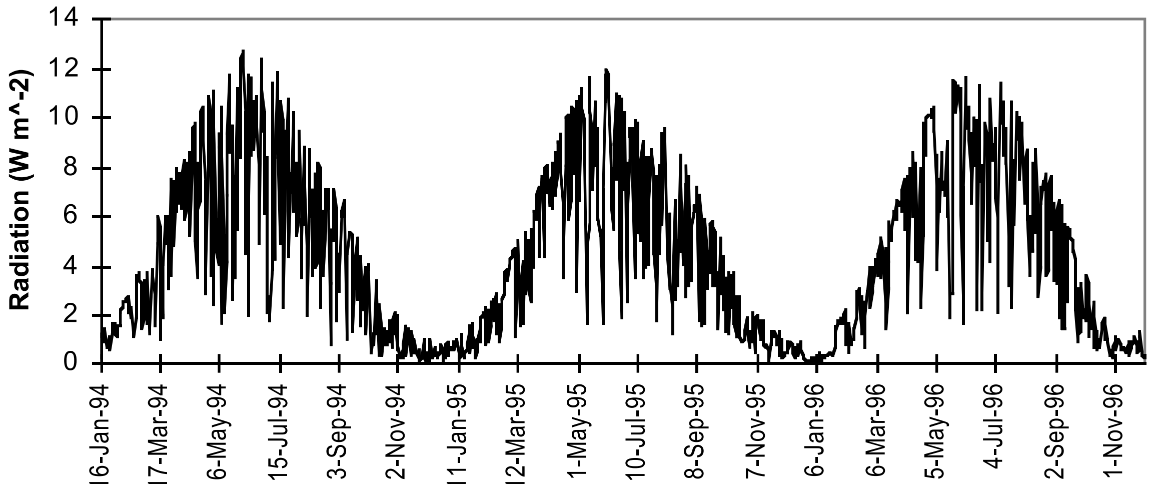
NSA-OJP Maximum Daily Temperatures



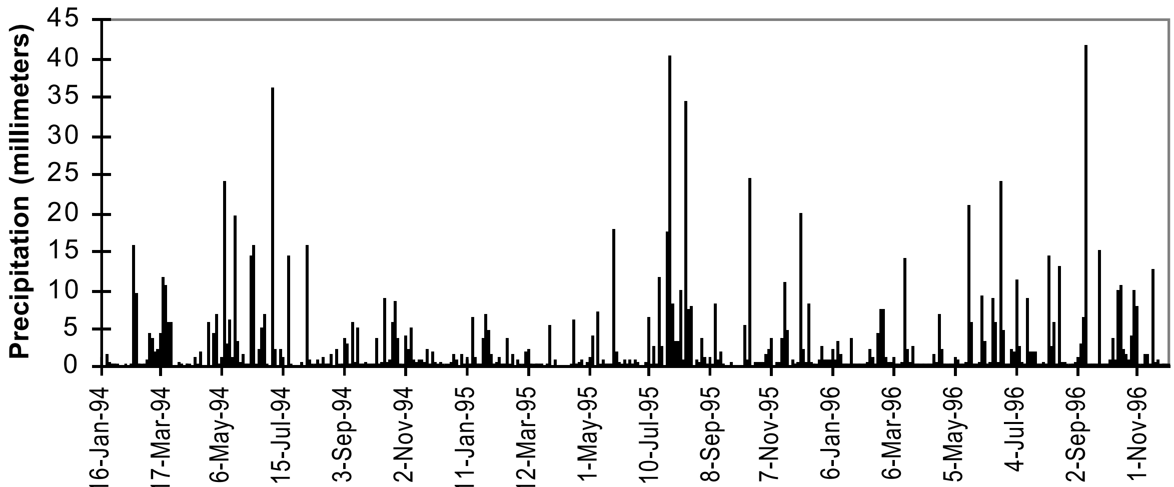

NSA-OJP Minimum Daily Temperatures
Degrees C
40
30
20
10
0
-10
-20
-30
-40
16-Jan-94
17-Mar-94
16-May-94
15-Jul-94
13-Sep-94
12-Nov-94
11-Jan-95
12-Mar-95
11-May-95
10-Jul-95
8-Sep-95
7-Nov-95
6-Jan-96
6-Mar-96
5-May-96
4-Jul-96
2-Sep-96
1-Nov-96


NSA-OJP Net Daytime Radiation
Radiation (W m^-2)
450
400
350
300
250
200
150
100
50
0
16-Jan-94
17-Mar-94
16-May-94
15-Jul-94
13-Sep-94
12-Nov-94
11-Jan-95
12-Mar-95
11-May-95
10-Jul-95
8-Sep-95
7-Nov-95
6-Jan-96
6-Mar-96
5-May-96
4-Jul-96
2-Sep-96
1-Nov-96

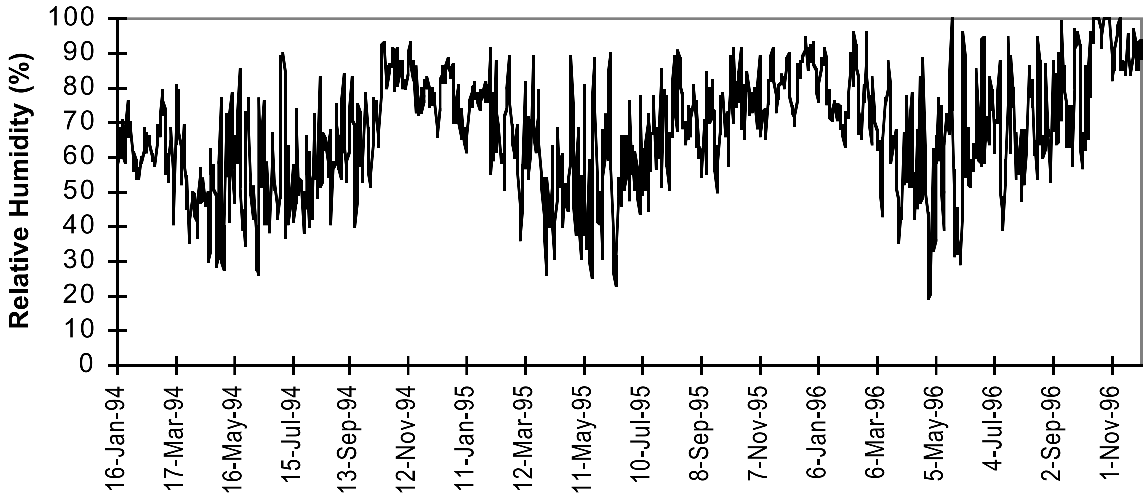
NSA-OJP Daily PAR Radiation



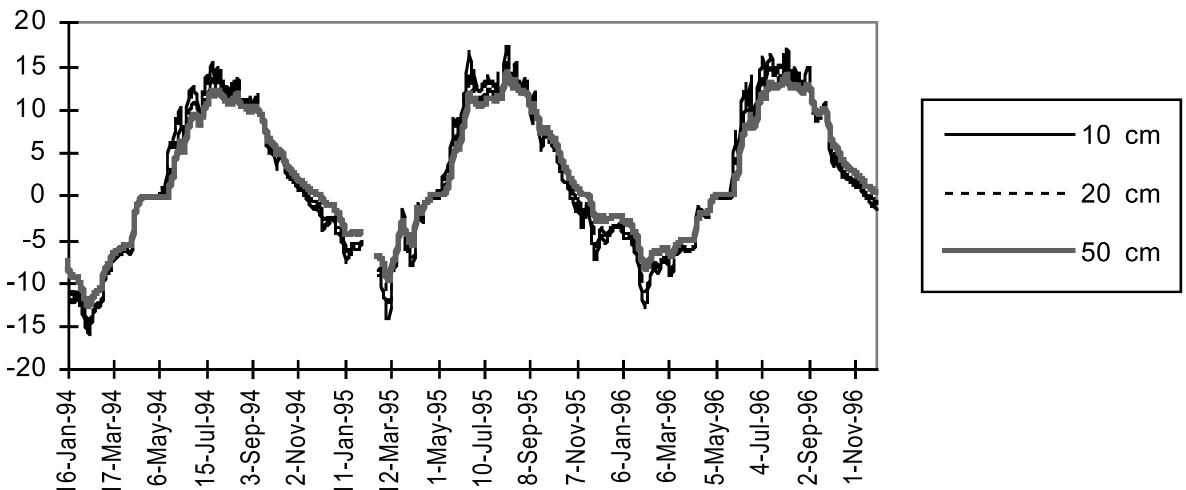
NSA-OJP Daily Precipitation



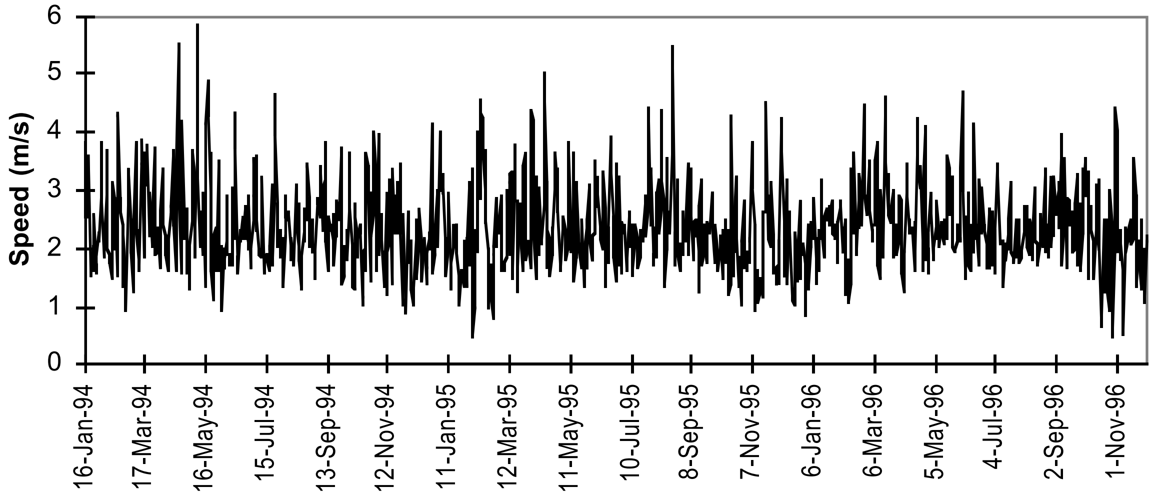
NSA-OJP Mean Daily Relative Humidity



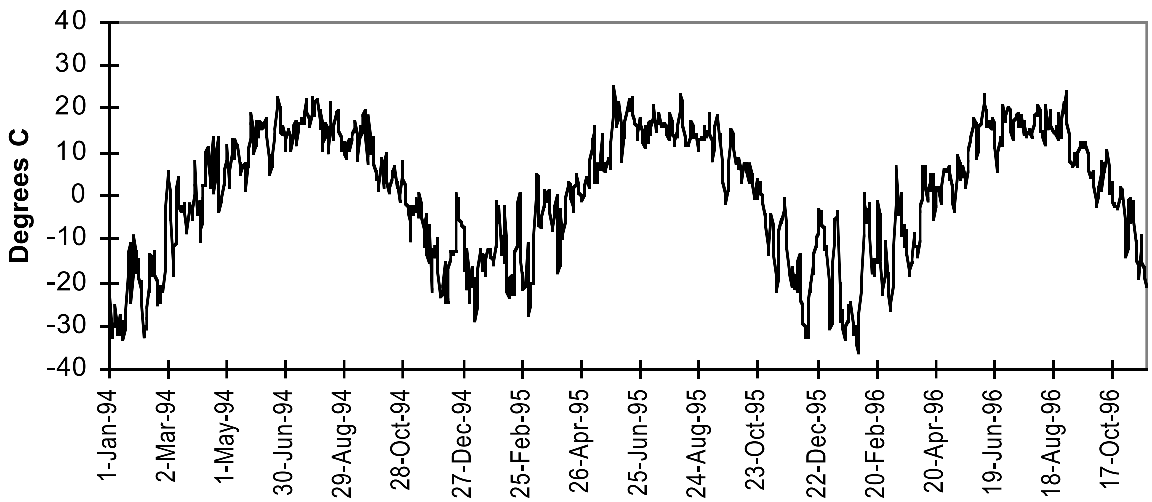
NSA-OJP Soil Temperatures

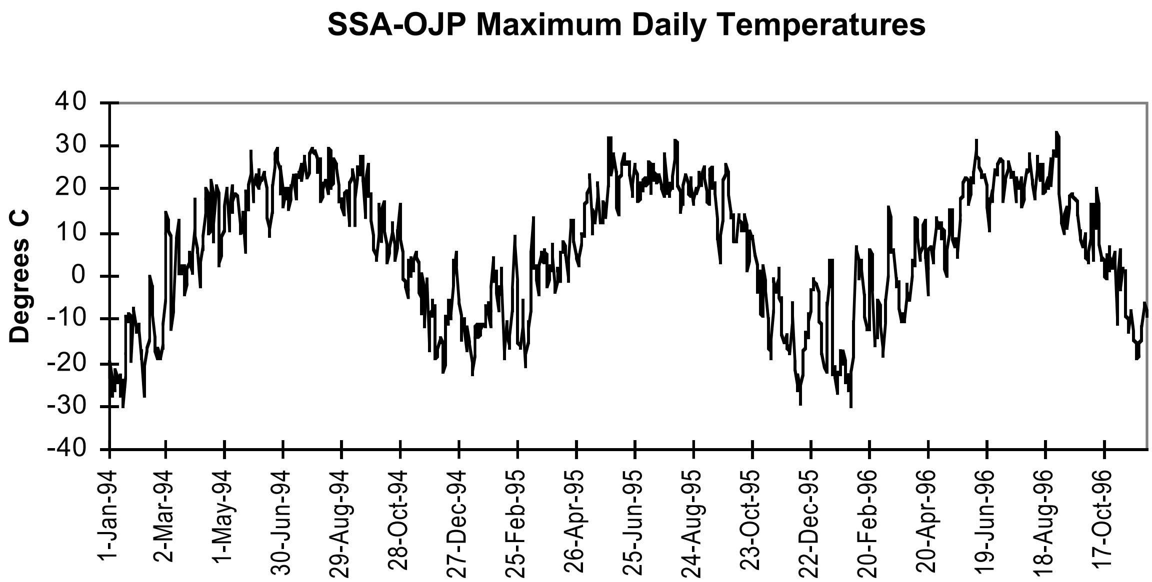


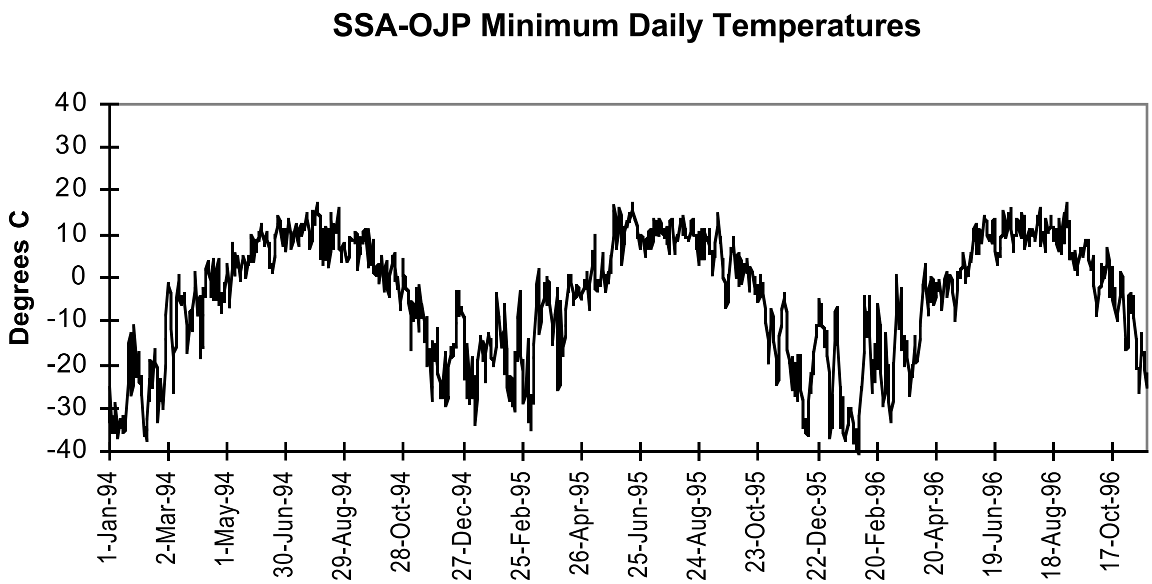
NSA-OJP Daily Wind Speed



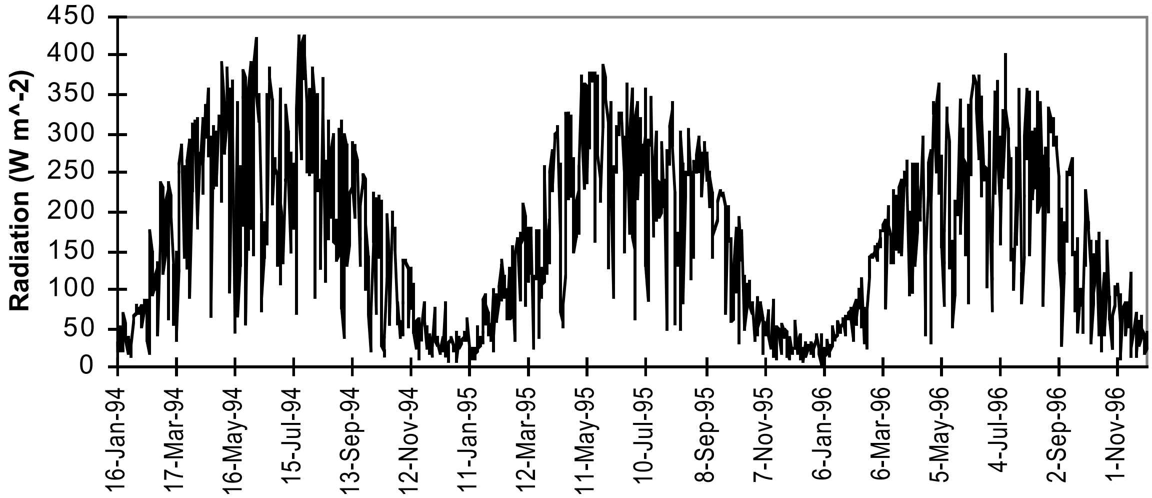
SSA-OPS Average Daily Temperatures



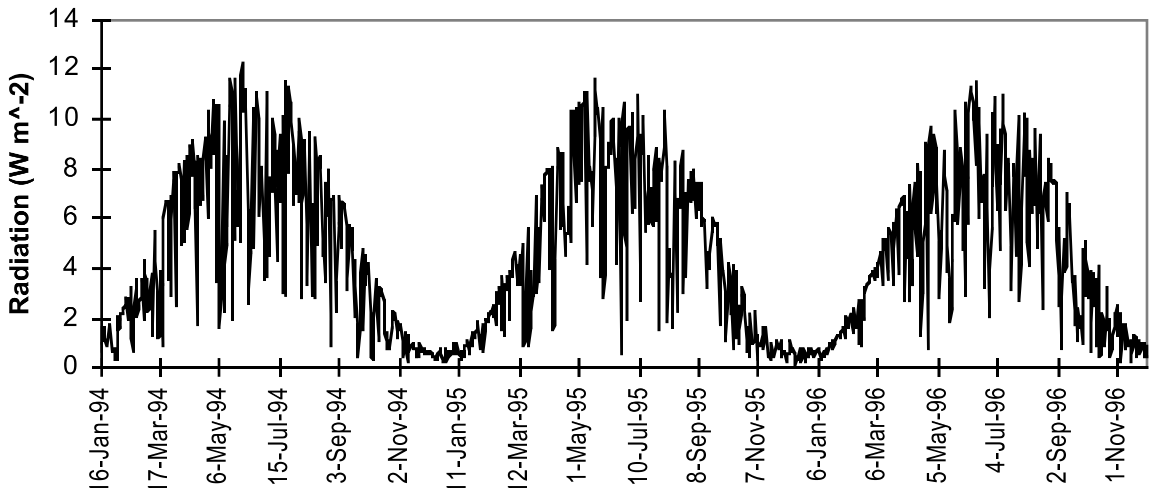

SSA-OJP Maximum Daily Temperatures
Degrees C
40
30
20
10
0
-10
-20
-30
-40
1-Jan-94
2-Mar-94
1-May-94
30-Jun-94
29-Aug-94
28-Oct-94
27-Dec-94
25-Feb-95
26-Apr-95
25-Jun-95
24-Aug-95
23-Oct-95
22-Dec-95
20-Feb-96
20-Apr-96
19-Jun-96
18-Aug-96
17-Oct-96


SSA-OJP Minimum Daily Temperatures
Degrees C
40
30
20
10
0
-10
-20
-30
-40
1-Jan-94
2-Mar-94
1-May-94
30-Jun-94
29-Aug-94
28-Oct-94
27-Dec-94
25-Feb-95
26-Apr-95
25-Jun-95
24-Aug-95
23-Oct-95
22-Dec-95
20-Feb-96
20-Apr-96
19-Jun-96
18-Aug-96
17-Oct-96

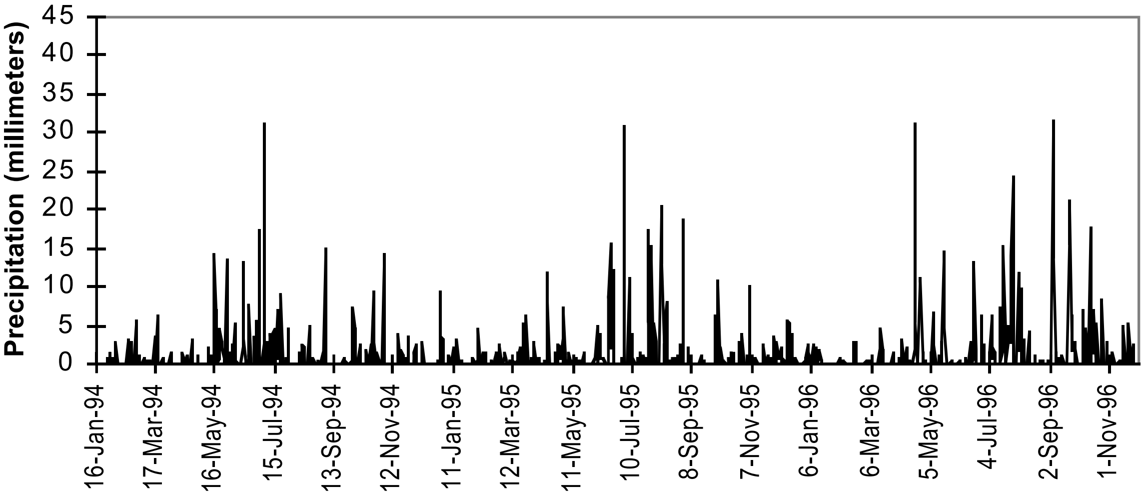
SSA-OJP Net Daytime Radiation



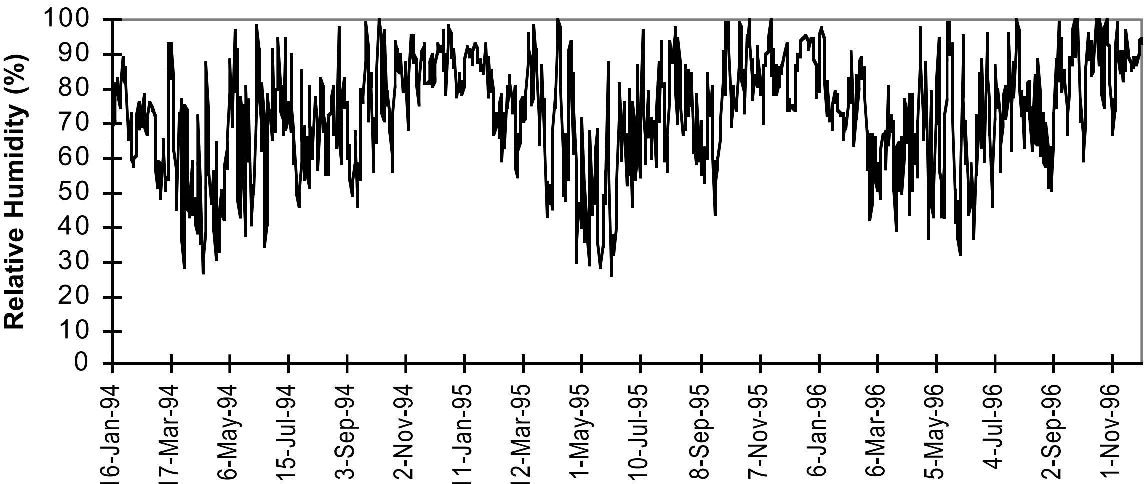
SSA-OJP Daily PAR Radiation

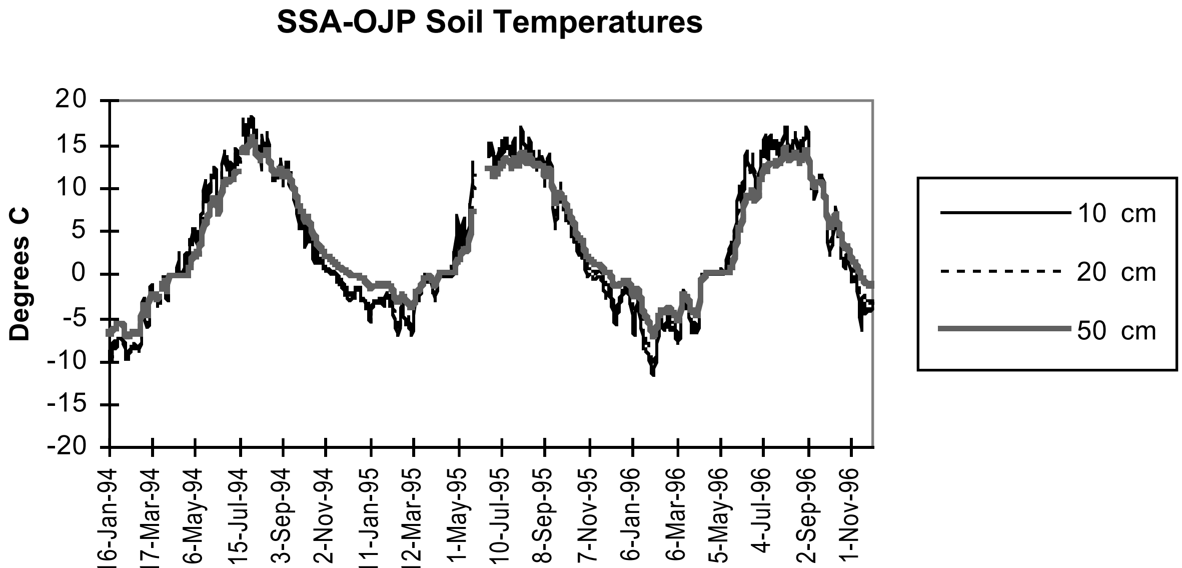


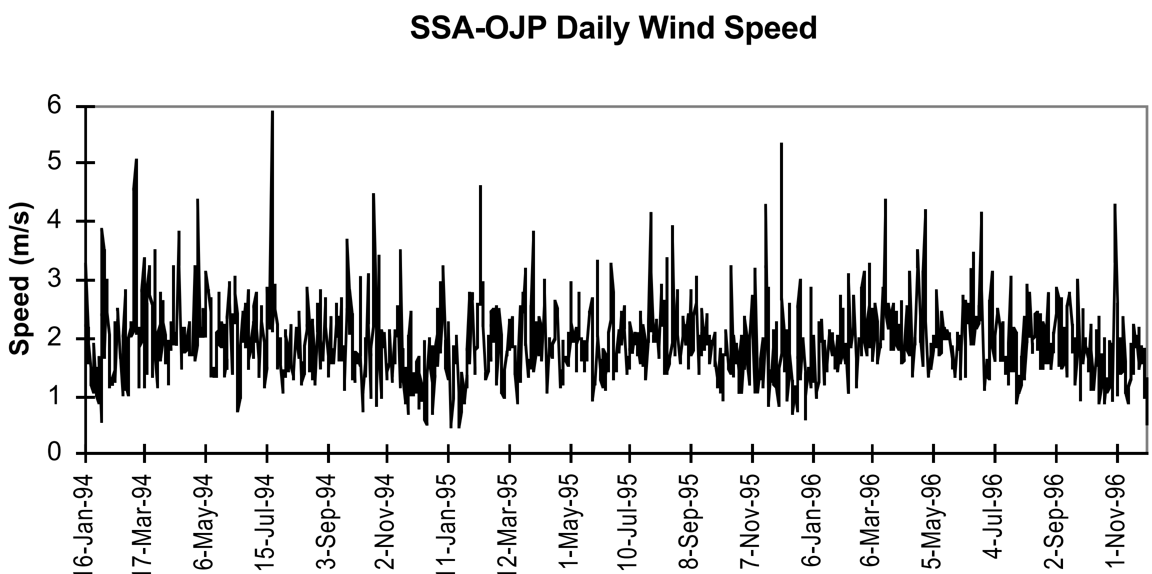
SSA-OJP Daily Precipitation



SSA-OJP Mean Daily Relative Humidity




SSA-OJP Soil Temperatures
Degrees C
20
15
10
5
0
-5
-10
-15
-20
16-Jan-94
17-Mar-94
16-May-94
15-Jul-94
13-Sep-94
12-Nov-94
11-Jan-95
12-Mar-95
11-May-95
10-Jul-95
8-Sep-95
7-Nov-95
6-Jan-96
6-Mar-96
5-May-96
4-Jul-96
2-Sep-96
1-Nov-96
10 cm
20 cm
50 cm


SSA-OJP Daily Wind Speed
Speed (m/s)
6
5
4
3
2
1
0
16-Jan-94
17-Mar-94
16-May-94
15-Jul-94
13-Sep-94
12-Nov-94
11-Jan-95
12-Mar-95
11-May-95
10-Jul-95
8-Sep-95
7-Nov-95
6-Jan-96
6-Mar-96
5-May-96
4-Jul-96
2-Sep-96
1-Nov-96

3.2 BOREAS-96 Field Campaigns

3.2.1 Focused Field Campaign - Winter 1996

The first field campaign was the Focused Field Campaign - Winter (FFC-W ‘96) held from February 27 to March 15. FFC-W '96 was run only in the Southern Study Area (SSA), where the snow covered boreal forest was studied. FFC-W was designed to have a focus on the remote sensing of snow in the forest environment and acquire the measurements to help us understand radiative transfer between the forest canopy, the underlying snow-covered ground and the sky radiation field. These data should help us do a much better job of modeling the energy balance of the boreal forest for meteorological forecasts, hydrology, climate models and carbon cycle models.

Two aircraft, the NASA C-130, equipped with the pointable ASAS instrument, and the NASA ER-2, equipped with AVIRIS, over flew targets in the SSA. These aircraft were supported by ground teams who made radiometric measurements within and above the forest canopy, and in situ measurements of snow depth and properties. The RSS-1 team used the multiangle PARABOLA instrument to take data over and beneath forest canopies at three sites. At these sites, a lake, and an agricultural site, the HYD-3 team gathered in situ snow characterization data and subcanopy radiation measurements. These sites made up the primary targets for the C-130 and were also covered in the ER-2 AVIRIS mapping mission. Fluxes were measured above the frozen lake site by the HYD-5 team. Also, the `Eyeball' aircraft, a twin-engined PA-34 which was used for site and weather reconnaissance over BOREAS, was equipped with a CO_2 sampling system and took CO_2 concentration measurements along low-level transects and up and down a series of sounding patterns.

From the 10000' altitude vantage point of the aircraft, it was remarkable to see how the forest makes its own weather. The dark trees absorb the solar radiation, force convection and often generate herds of puffy cumulus clouds over the forest. As the airmass moves from the forest onto the snow-covered agriculture , the convection is cut off and the clouds promptly dissipate.

3.2.1.1 FFC-W '96 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	*	*									*												
Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

3.2.1.2 FFC-W '96 Aircraft Operations

	2/27	2/28	2/29	3/1	3/2	3/3	3/4	3/5	3/6	3/7	3/8	3/9	3/10	3/11
ER-2 (RE)										MS				
C-130 (RC)							TS	TS						TS
Chieftain (RP)														
Eyeball (FB)	TS	TS		VS		ES, VS	ES, VS	VS						
Twin Otter (FT)														
LANDSAT														
SPOT														

	3/12	3/13	3/14	3/15
ER-2 (RE)				
C-130 (RC)	TS			
Chieftain (RP)				
Eyeball (FB)				
Twin Otter (FT)				
LANDSAT				
SPOT				

3.2.2 1996 Intensive Field Campaign - 1

The First Intensive Field Campaign 1996 (IFC-1 '96) was April 2 to April 28. During IFC-1 the tower flux (TF) teams set up their eddy correlation instruments and began to collect carbon and energy flux data at the SSA Old Black Spruce (OBS) and Old Aspen (OA) sites and at the Northern Study Area (NSA) Young Jack Pine (YJP), Fen, and Old Jack Pine (OJP) sites (the NSA OBS site continued running, as it has since 1993). At the SSA sites branch bags were installed to measure branch level fluxes. In the NSA several Trace Gas Biogeochemistry (TGB) groups began installing chambers at TF sites, beaver ponds, and burn areas, as well as setting up a laboratory in the Heritage North Museum. The TGB groups concentrated on soil surface exchanges of CO_2 and CH_4. Only the "Eyeball' aircraft flew this IFC, collecting CO_2 concentration data.

During this IFC comparisons were made between the the European Center for Medium Range Weather Forecasting (ECMWF) 12- and 24-hour forecasts with observations. Whenever the ECMWF model predicted snow on the ground, the near-surface air temperatures were underestimated by up to 20° C! Whenever the surface was predicted to be snow-free, the observed and predicted temperatures converged to within 1° C or so. A dialogue with scientists at ECMWF revealed that they currently specify the snowbound forest to have an albedo of about 80%, the same as on open snow-covered field, whereas in practice the forest canopies stick up above the snow and give rise to a relatively low albedo, 12% or so, which is only a little bit more than when it is snow-free. ECMWF is working on a fix.

3.2.2.1 IFC-1 '96 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																							
Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

3.2.2.2 IFC-1 '96 Aircraft Operations

	4/2	4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15
ER-2 (RE)														
C-130 (RC)														
Chieftain (RP)														
Eyeball (FB)												VS	VS	
Twin Otter (FT)														
LANDSAT														
SPOT														

	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
ER-2 (RE)													
C-130 (RC)													
Chieftain (RP)													
Eyeball (FB)								VS, RT	VN	VN, RT	VS, RT	VN	VN, RT
Twin Otter (FT)													
LANDSAT													
SPOT													

3.2.3 1996 Intensive Field Campaign - 2

The Second Intensive Field Campaign 1996 (IFC-2 '96) was July 8 to August 9. Many teams were in the field at this time. The Terrestrial Ecology (TE) groups were making measurements such as sapflow; leaf level stomatal conductance; understory plant, moss, and lichen photosynthesis; soil CO_2 flux; and leaf and needle optical properties. The TF groups continued their eddy correlation measurements as well as launching tether sondes to measure profiles of CO_2 and CH_4. Boundary layer measurements were made using radiosondes and ceilometers. The hydrology groups continued monitoring soil moisture, throughfall, and moss moisture content. PARABOLA data were collected at SSA sites. In the NSA the TGB groups continued chamber measurements.

Five aircraft were active in IFC-2. The NASA C-130 (equipped with ASAS and SLICER) and the Canadian Navajo aircraft (equipped with CASI) made remote sensing measurements. The NASA ER-2, equipped with the AVIRIS and MAS sensors, successfully collected data for both study areas, however due to poor weather the ER-2 mission was not completed until after the IFC. The two other BOREAS aircraft are equipped to study the lower atmosphere. The Canadian NRC Twin Otter measured surface-atmosphere fluxes of heat, water vapor and CO_2. The "Eyeball" aircraft continued to make measurements of regional CO_2 gradients and vertical profiles over the study areas.

During IFC-2 '96, the TF teams saw the very high sensible heat (H) fluxes and low latent heat (LE) fluxes that generated such surprise in 1994 (Bowen ratios greater than 2 were common.). Water was freely available and spring was late that year; but we still saw the 'green desert' effect. At the SSA-OA there were large LE fluxes, in contrast to all the coniferous sites. These were matched by much higher (about a factor of 10) stomatal conductances. The CH_4 fluxes observed by the TGB teams started up in a serious way on 06/08/96 and followed their previously observed pattern of high fluxes in hollows and low fluxes on hummocks. Preliminary results indicate moss accounts for about 15-25% of the carbon uptake at the SSA-OBS.

3.2.3.1 IFC-2 '96 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	*	*					*	*			*				*	*		*	*				
Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

3.2.3.2 IFC-2 '96 Aircraft Operations

	7/9	7/10	7/11	7/12	7/13	7/14	7/15	7/16	7/17	7/18	7/19	7/20	7/21	7/22	7/23
ER-2 (RE)															
C-130 (RC)										TN		TS			
Chieftain (RP)										TN	TN TS	TS		TS	
Eyeball (FB)	ES VS	ES VS	ES	VS RT	RT	VS	ES VS	VS RT	VN RT						
Twin Otter (FT)	GS, Z TS	TS, Z	TS	VS, GS		CS	test				TS	CS, GS			
LANDSAT	N														
SPOT	S														

	7/2 4	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
ER-2 (RE)															
C-130 (RC)	TN					TS	TS								
Chieftain (RP)	TS		TN	TN		Cal TS	TS Cal	TS MS							
Eyeball (FB)															
Twin Otter (FT)			CS, TS, AG	GS, TS		GS, TS TS	CS	GN, TN	FN	GN, TN	GN TN		GN TN		TN
LANDSAT							alt- S								
SPOT			S	S			S								

3.2.4 1996 Intensive Field Campaign - 3

The Third Intensive Field Campaign (IFC-3 '96) ran from October 1 to October 21. The TF groups continued measurements through this period. Soil moisture and stream flow were also monitored. Extra radiosonde flights were resumed for this IFC. In the NSA the TGB groups continued making chamber measurements of CO_2 and CH_4. Also, measurements were made of ^{14}C isotopes to determine if old carbon is a significant component of fall soil respiration. With the onset of fall the TE groups removed their sapflow measuring equipment. This IFC TE investigators also collected tree cores for NPP studies, made gas exchange and fluorescence measurements, and collected flask samples for stable isotope studies. ‘Eyeball’ was the only aircraft that flew this IFC, it again measured CO_2 concentrations.

Through November and December the TF towers shut down, leaving only the SSA-OA and NSA-OBS flux towers running. The automated meteorology stations were shut down at the end of November, except for a tower in Thompson, MB.

3.2.4.1 IFC-3'96 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											*												
Team	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23

3.2.4.2 IFC-3'96 Aircraft Operations

	10/1	10/2	10/3	10/4	10/5	10/6	10/7	10/8	10/9	10/10	10/11	10/12	10/13	10/14
ER-2 (RE)														
C-130 (RC)														
Chieftain (RP)														
Eyeball (FB)												VS	VS	RT VS
Twin Otter (FT)														
LANDSAT														
SPOT														

	10/15	10/16	10/17	10/18	10/19	10/20	10/21	10/22
ER-2 (RE)								
C-130 (RC)								
Chieftain (RP)								
Eyeball (FB)	RT							
Twin Otter (FT)								
LANDSAT								
SPOT								

4.0 Data Collected

4.1 Data Types Collected

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

Table 4.1 Ecophysiological measurements in NSA

		Sites				
Task	**Timing**	**OBS**	**OJP**	**YJP**	**Fen**	**OA (TE)**
Xylem flow	IFC-1 IFC-2 IFC-3	--- TE-2 TE-2	-- TE-2 TE-2	-- TE-2 TE-2	- - -	- - -
Branch bag A_n, g_s	IFC-1 IFC-2 IFC-3	-- TE-4 --	-- TE-4 --	-- TE-4 --	- - -	- - -
Canopy leaf A_n, g_s	IFC-1 IFC-2 IFC-3	-- TE-2, 4 ?	-- TE-2, 4 ?	-- TE-2, 4 TF-10	- TE-4 -	- TE-4 -
Canopy Chemistry	IFC-1 IFC-2 IFC-3	-- TE-4 --	-- TE-4 --	-- TE-4 --	-- TE-4 --	-- TE-4 --
Understory A_n, g_s	IFC-1 IFC-2 IFC-3	- TE-4 -	- - -	- - -	- - -	- - -
Moss; soil A_n, resp^n	IFC-1 IFC-2 IFC-3	-- TGB-1 TGB-1	- TGB-1,3 TGB-1,3	- TGB-1,3 TGB-1,3	TGB-1,3 TGB-1,3 TGB-1,3	- - -
Isotopes	IFC-1 IFC-2 IFC-3	TGB-12 - TGB-12	TGB-12 - TGB-12	TGB-12 - TGB-12	TGB-12 - TGB-12	TGB-12 - TGB-12
Litterfall, NPP, NEP	IFC-1 IFC-2 IFC-3	-- TE-6 --	-- TE-6 --	-- TE-6 --	TGB-1 TGB-1 TGB-1	-- TE-6 --

Table 4.2 Ecophysiological Measurements in SSA

Task	Timing	Sites	
		OBS	OA
Xylem flow	IFC-1	TE-7	TE-7
	IFC-2	TE-7	TE-7
	IFC-3	TE-7	TE-7
Branch bag A_n, g_s	IFC-1	TF-9	TE-4, 7, 11; TF-1
	IFC-2	TF-9	TE-4, 7, 11; TF-1
	IFC-3	TF-9	TE-4, 7, 11; TF-1
Canopy leaf A_n, g_s	IFC-1	TE-4	-
	IFC-2	TE-10	TE-4, 7, 10
	IFC-3	TE-4	-
Understory A_n, g_s	IFC-1	-	-
	IFC-2	TE-12	TE-7, TF-1
	IFC-3	-	-
Moss; soil A_n, $resp^n$	IFC-1	-	TE-7
	IFC-2	TE-6, 5, 4	TE-7
	IFC-3	-	TE-7
Canopy Chemistry	IFC-1	-	-
	IFC-2	TE-10, 4	TE-10, 4
	IFC-3	-	-
Undercanopy radiation, T_s	IFC-1	-	-
	IFC-2	TE-5, 6	-
		HYD-8	-
	IFC-3	-	
Isotopes	IFC-1	TGB-12	TGB-12
	IFC-2	TE-5	-
	IFC-3	TGB-12	TGB-12
Litterfall, NPP	IFC-1	TE-6	TE-6
	IFC-2	TE-6	TE-6
	IFC-3	TE-6	TE-6

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.

Northern Study Area -- Beaver Pond (NSA-BP)

NSA BP IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
TGB-1	Crill														X	X	X	X			X		X										
TGB-3	Moore																									X			X				
TGB-4	Roulet						X	X	X								X	X		X	X	X	X	X	X	X						X	
TGB-5	Zepp	X	X	X	X																												

NSA BP IFC-3 1996		1-Oct	2-Oct	3-Oct	4-Oct	5-Oct	6-Oct	7-Oct	8-Oct	9-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct
TGB-5	Zepp							X											X		

Northern Study Area -- Fen (NSA-Fen)

NSA Fen IFC-1 1996		2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr
HYD-3	Davis																								X			
TF-10	McCaughey																							X	X	X	X	X
TGB-1	Crill										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
TGB-5	Zepp																X											

NSA Fen IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
RSS-19	Miller																			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	X
TGB-1	Crill	X	X	X	X		X	X	X	X	X					X		X		X	X		X	X			X			X	X	X	X
TGB-12	Trumbore																										X				X	X	
TGB-3	Moore	X						X	X						X	X		X			X		X						X	X	X	X	

NSA Fen IFC-3 1996		1-Oct	2-Oct	3-Oct	4-Oct	5-Oct	6-Oct	7-Oct	8-Oct	9-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct
TF-10	McCaughey															X			X		
TGB-1	Crill															X		X		X	
TGB-12	Trumbore												X		X						
TGB-3	Moore				X							X				X					

Northern Study Area -- Old Aspen (NSA-OA)

NSA OA IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
TE-6	Gower							X																									

NSA OA IFC-3 1996		1-Oct	2-Oct	3-Oct	4-Oct	5-Oct	6-Oct	7-Oct	8-Oct	9-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct
TE-6	Gower				X																

Northern Study Area -- Old Black Spruce (NSA-OBS)

NSA OBS IFC-1 1996		2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr
HYD-3	Davis																											X
TE-4	Berry																						X					
TGB-1	Crill																									X		
TGB-3	Moore																									X		

NSA OBS IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
HYD-1	Cuenca	X	X	X				X			X	X		X	X			X		X		X		X		X			X		X		
HYD-9	Soulis																									X							
RSS-19	Miller																			X													
TE-2	Ryan		X									X	X	X	X																		
TE-23	Rich																		X	X		X											
TE-4	Berry												X													X	X	X	X	X	X		
TE-6	Gower							X																									
TF-3	Wofsy												X	X	X																		
TGB-1	Crill		X	X							X			X																			X
TGB-12	Trumbore																											X	X	X			
TGB-3	Moore			X							X									X		X			X					X			

NSA OBS IFC-3 1996		1-Oct	2-Oct	3-Oct	4-Oct	5-Oct	6-Oct	7-Oct	8-Oct	9-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct
HYD-1	Cuenca							X			X	X									
TE-2	Ryan													X	X	X					
TE-6	Gower								X												
TF-3	Wofsy																			X	
TGB-1	Crill			X	X		X				X	X	X		X			X			
TGB-12	Trumbore													X	X						
TGB-3	Moore			X				X			X		X		X		X				

Northern Study Area -- Old Jack Pine (NSA-OJP)

NSA OJP IFC-1 1996		2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr
HYD-3	Davis																										X	
TE-4	Berry																					X		X				
TF-8	Fitzjarrald								X	X	X	X		X	X	X	X	X										
TGB-1	Crill															X												
TGB-3	Moore															X												

NSA OJP IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
HYD-1	Cuenca				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
RSS-19	Miller																			X													
TE-2	Ryan	X		X			X	X	X	X	X			X																			
TE-23	Rich																	X	X			X											
TE-4	Berry													X	X	X	X	X	X	X	X	X	X	X	X	X	X						
TE-6	Gower						X																										
TF-10	McCaughey																								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	X	X	X	X	X	X	X
TGB-1	Crill				X												X		X														
TGB-3	Moore				X							X					X		X							X							X
TGB-4	Roulet													X										X									
TGB-6	Wahlen																										X						

NSA OJP IFC-3 1996		1-Oct	2-Oct	3-Oct	4-Oct	5-Oct	6-Oct	7-Oct	8-Oct	9-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct
HYD-1	Cuenca								X												
TE-2	Ryan									X			X		X	X					
TE-6	Gower				X																
TF-8	Fitzjarrald	X	X																		
TGB-1	Crill	X														X	X		X	X	
TGB-3	Moore	X						X	X							X				X	

Northern Study Area -- Young Jack Pine (NSA-YJP)

NSA YJP IFC-1 1996		2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr
TE-4	Berry																						X					

NSA YJP IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
HYD-1	Cuenca					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
RSS-11	Markham																									X							
RSS-19	Miller																			X													
TE-2	Ryan	X			X	X			X					X																			
TE-23	Rich																			X													
TE-4	Berry																															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	X	X		X	X	X	X	X	X	X	X
TGB-1	Crill																					X											
TGB-3	Moore		X							X												X		X								X	
TGB-6	Wahlen																										X						

NSA YJP IFC-3 1996		1-Oct	2-Oct	3-Oct	4-Oct	5-Oct	6-Oct	7-Oct	8-Oct	9-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct
HYD-1	Cuenca								X	X	X	X									
TE-2	Ryan									X					X						
TF-10	McCaughey		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											

Southern Study Area -- Fen (SSA-Fen)

SSA Fen IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
TF-11	Verma														X	X	X	X	X	X	X	X	X										

Southern Study Area -- Old Aspen (SSA-OA)

SSA OA FFC-W 1996		27-Feb	28-Feb	Feb-29	1-Mar	2-Mar	3-Mar	4-Mar	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar
HYD-3	Davis							X				X							
RSS-1	Deering										X	X	X						

SSA OA IFC-1 1996		2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr
TE-7	Hogg														X		X											
TF-1	Black											X	X	X	X	X	X	X	X	X	X	X	X					

SSA OA IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
AFM-5	Atkinson	X	X																														
HYD-1	Cuenca																			X				X									
RSS-1	Deering																	X															
TE-10	Middleton									X																							
TE-5	Ehleringer						X																										
TE-6	Gower						X																										
TE-7	Hogg	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	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	X	X	X	X	X	X	X	X
TF-8	Fitzjarrald			X	X																												

SSA OA IFC-3 1996		1-Oct	2-Oct	3-Oct	4-Oct	5-Oct	6-Oct	7-Oct	8-Oct	9-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct
AFM-5	Atkinson		X																		
HYD-1	Cuenca			X	X																
TF-1	Black	X	X	X	X	X	X	X	X	X	X	X	X								

Southern Study Area -- Old Black Spruce (SSA-OBS)

SSA OBS FFC-W 1996		27-Feb	28-Feb	Feb-29	1-Mar	2-Mar	3-Mar	4-Mar	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar
HYD-3	Davis	X	X	X	X	X	X						X						
RSS-1	Deering		X	X	X		X	X	X	X									
RSS-11	Markham								X										

SSA OBS IFC-1 1996		2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr
TE-4	Berry																										X	X
TE-7	Hogg											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					

SSA OBS IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
AFM-11	Mahrt						X		X																								
HYD-1	Cuenca																				X	X	X										
HYD-8	Band	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	X	X
HYD-9	Soulis							X																									
RSS-1	Deering															X	X		X	X	X	X	X	X	X								
RSS-15	Ransom																							X	X								
RSS-16	Saatchi																					X	X			X							
RSS-19	Miller													X																			
RSS-7	Chen	X		X		X																											
TE-10	Middleton					X	X																										
TE-12	Walter-Shea	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X														
TE-23	Rich													X	X	X	X																
TE-5	Ehleringer					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								
TE-6	Gower	X	X	X	X	X	X	X	X	X	X	X																					
TE-7	Hogg		X								X	X												X				X		X	X		
TF-2	den Hartog										X																						
TF-7	Desjardins	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X															
TF-8	Fitzjarrald				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	X	X	X	X	X	X	X	X	X	X

Southern Study Area -- Old Black Spruce (SSA-OBS) (continued)

SSA OBS IFC-3 1996		1-Oct	2-Oct	3-Oct	4-Oct	5-Oct	6-Oct	7-Oct	8-Oct	9-Oct	10-Oct	11-Oct	12-Oct	13-Oct	14-Oct	15-Oct	16-Oct	17-Oct	18-Oct	19-Oct	20-Oct
AFM-5	Atkinson			X																	
HYD-1	Cuenca					X															
TE-10	Middleton											X									
TE-4	Berry	X	X	X	X		X	X	X	X	X										
TE-5	Ehleringer	X	X	X	X	X	X	X	X	X	X	X	X								
TE-6	Gower											X	X								
TF-9	Jarvis	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Southern Study Area -- Old Jack Pine (SSA-OJP)

SSA OJP FFC-W 1996		27-Feb	28-Feb	Feb-29	1-Mar	2-Mar	3-Mar	4-Mar	5-Mar	6-Mar	7-Mar	8-Mar	9-Mar	10-Mar	11-Mar	12-Mar	13-Mar	14-Mar	15-Mar
HYD-3	Davis								X				X		X				
RSS-1	Deering														X				
RSS-11	Markham														X				

SSA OJP IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
HYD-1	Cuenca																				X												
HYD-8	Band				X									X			X																
RSS-1	Deering		X	X	X	X	X	X	X	X	X	X	X	X	X	X																	
RSS-19	Miller													X																			
TE-23	Rich											X	X																				
TE-6	Gower	X						X	X																								

Southern Study Area -- Young Aspen (SSA-YA)

SSA YA IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
RSS-15	Ransom																												X	X			

Southern Study Area -- Young Jack Pine (SSA-YJP)

SSA YJP IFC-2 1996		9-Jul	10-Jul	11-Jul	12-Jul	13-Jul	14-Jul	15-Jul	16-Jul	17-Jul	18-Jul	19-Jul	20-Jul	21-Jul	22-Jul	23-Jul	24-Jul	25-Jul	26-Jul	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	1-Aug	2-Aug	3-Aug	4-Aug	5-Aug	6-Aug	7-Aug	8-Aug	9-Aug
HYD-1	Cuenca																					X											
RSS-11	Markham	X																															
RSS-19	Miller													X																			
TE-10	Middleton					X	X																										
TE-23	Rich											X											X										

5.0 Science Team Activities

5.1 AFM - Aircraft Flux and Meteorology

5.1.1 AFM-4

P.I. Name: Ian MacPherson - NRC Flight Research Laboratory
Co-I Names: Ray Desjardins - Agriculture Canada, Peter Schuepp - McGill University
Collaborators: Larry Mahrt - Oregon State University, Richard Leaitch - Atmospheric Environment Service

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

Objective of Study:
The NRC Twin Otter atmospheric research aircraft participated in IFC-2 of the 1996 field program, making areal estimates of the fluxes of mass and energy over the various sites in both the SSA and the NSA. The principal objective of the Twin Otter's 1996 campaign was similar to that of 1994 - to provide airborne flux data to be used in scaling up energy/mass exchange estimates from tower scales to the landscape scales observed by satellites. Most of the flight tracks flown were identical to those of 1994 in order to allow direct comparison of the fluxes, radiometric data, etc., to help answer questions about inter-annual variability. The flight plans are detailed in Section 5.2.5 of EXPLAN 96. The focus of the flights was the grid pattern, the site specific (tower fly-by), the agricultural line, the Candle Lake run and soundings. Two special flights (#63 and 67) consisted of repeated runs at various altitudes across the north end of Candle Lake to examine the lake's effects on the boundary layer, and its roles in transporting carbon dioxide to higher altitudes.

Equipment Used:
Configured for flux measurement, the basic instrumentation aboard the Twin Otter atmospheric research aircraft measured the following:

- the three orthogonal components of atmospheric motion.
- the vertical fluxes of sensible and latent heat, momentum, turbulent kinetic energy, $C0_2$ and ozone.
- concentrations of $C0_2$, H_20 and ozone.
- atmospheric state parameters such as pressure, temperature, dew point, and mean winds.
- aircraft position (GPS), motion and attitude (Litton-90 Inertial Reference System), pressure height, and height above ground (radio-altimeter, laser altimeter).
- radiometric surface temperature, incident and reflected solar radiation, net radiation, greenness index (NDVI), 4-channel satellite simulator (Landsat or SPOT).
- VHS videotape using under-nose and side-looking cameras with superimposed listing of time, altitude, heading, latitude and longitude.

Some significant changes and additions to the aircraft instrumentation were made for the 1996 campaign. First, the airborne computer in the Twin Otter was changed to a VME-based system, with the data recording rate increased from 16 to 32 Hz, improving the short wavelength resolution of the flux data. A new, stiffer carbon-fibre noseboom was also fitted to the aircraft prior to BOREAS-96. Additional instruments flown on the Twin Otter in BOREAS-96 consisted of the following:

_ Laser altimeter: This instrument gives fast-response absolute height above the terrain, for use in studies of surface roughness, and will be easier to interpret than current radio-altimeter measurements.
_ Upgraded Licor $C0_2/H_20$ analyzer, replacing Licor 6262 flown in 1994. (The AgCanada ESRI infrared analyzer was also flown).
_ An NO/NOX analyzer to provide measurements used in interpreting the ozone chemistry.
_ Aerosol probe: This PC-ASP particle probe measured the concentration and the spectrum of aerosol particles in 15 size ranges between approximately 0.1 and 2 microns. Its data were recorded on a separate data acquisition system provided by the AES, who are responsible for its analysis.
_ Eddy accumulation system: This was used on six flights in an experiment to measure the vertical flux of isoprene, in addition to $C0_2$ (for comparison with the eddy correlation measurements).

Some instrumentation problems were experienced in the 1996 flight program. On several flights in the SSA, the GPS navigation data was lost for several minutes as a result of a poor satellite configuration. There was also some uncertainty about the accuracy of the $C0_2$ analyzers on the aircraft on 2 or 3 flights. This will be resolved through intercomparison with the tower data. A detailed listing of instrumentation problems will be published in an NRC Laboratory Technical Report in early 1997.

Flight and Run Summary:
The aircraft arrived at Prince Albert on Sunday, July 7, and operated in the SSA for about two thirds of the IFC, before flying the transect to Thompson on July 30. The aircraft was operated in the Thompson area through August 9. The number of flying hours flown in BOREAS-96 was 87, consisting of 64 project, 21 transit and 2 test flight hours. The following table summarizes the project flights, and includes the number of runs flown on each type of flight track for each flight.

TWIN OTTER RUNS FLOWN BY TYPE - 1996

SSA * number of runs of each type

Date	Fl	Ag	Intf	CL	Grid	SS				Bud	TRS	Other	Snd
1996		W-X	X-Y			OA	BS	JP	Fen				
Jul 09	58	2	2		18								2
Jul 09	59					6							1
Jul 10	60	2	2				8	7					1
Jul 11	61	1	1	1		9	6						1
Jul 12	62	2	2							11			1
Jul 14	63	8	2									7	2
Jul 15	65	2											
Jul 19	66					6							1
Jul 20	67						2					16	3
Jul 20	68	2			18								1
Jul 26	70	1		1		6						1	1
Jul 27	71	1			18		2						1
Jul 29	72	2			18		8						2
Jul 29	73	1				7						8	1
Jul 30	74			1							1		2
	17	24	9	3	72	34	26	7		11	1	32	20

CL: 62 nm Candle Lake SND: Sounding Bud: Flux Budget
TRS - transect PA/Flin Flon (SSA) Flin Flon/Thompson (NSA) SS: Site-specific (towers)
Ag - Agricultural Run Intf - extended ag run interface to forest

NSA

Date	Fl	Grd		SS			M-O	TRS	Other	Snd
			burn	BS	OJP	YJP				
Jul 30	75			6			1	1		1
Jul 31	76	18		5	8				2	2
Jul 31	77		9			8				1
Aug 01	78		8*							
Aug 02	79	18		5	8	6				2
Aug 03	80	18		6		5			4	1
Aug 05	81	18			12				6	2
Aug 07	82		6	12					4	5
Aug 08	83	18		6						1
	09	90	23	40	28	19	1	1	16	15

SND: Sounding *- 4 at 100', 4 at 500'

5.1.2 AFM-5

PI Name: A. Barr - Environment Canada

Title: Upper Air Network

5.1.3 AFM-11

PI Names: Jielun Sun - Oregon State University, Larry Mahrt - Oregon State University, and Ray Desjardins - Agriculture Canada

Title: Fluxes Over Inhomogeneous Surfaces in BOREAS

Objective of study:
Study the horizontal transport of carbon dioxide in the nocturnal boundary layer and examine the hypothesis that the carbon dioxide is vented vertically in preferred locations. This hypothesis is motivated by the known behavior of nocturnal circulations and the apparent missing carbon dioxide when attempting to balance respiration, storage and and eddy correlation measurements of the upward flux out of the nocturnal canopy layer.

Types of data collected, equipment used:
Low level Twin Otter aircraft flights and boat-measured carbon dioxide with the LICOR LI-6262 CO_2 analyzer data and Candle Lake surface temperatures with a slow response thermistor.

Summary of places and times of measurements:
Candle Lake area on 19-20 July. The deck boat completed a number of transects across Candle Lake between 2200 19 July and 900 20 July. The deck boat executed both north-south

and east-west transects but concentrated on an east-west track across the northern part of the lake which approximately coincided with the Twin Otter track.

For the early morning Twin Otter flight, an M-pattern was implemented over Candle Lake and surrounding land surface to investigate the vertical structure over the lake and over the land at both sides of the lake. In addition, the Twin Otter crossed the lake at approximately 4 levels, 17, 67, 167, and 333m with six repeated passes at 17m and three at the other three levels.

Other information:
The observations indicate the CO_2 rich air flows in a cool land breeze out over Candle Lake. The CO_2 is vented vertically in a convectively driven internal boundary layer which is generated by the warmer lake surface.

5.1.4 AFM-12

PI Names: Dr. Roger Piekle - Colorado State University, Pier L. Vidale - Colorado State University, Lou Steyaert - US Geological Survey
Note: Also, worked jointly with Dr. Forrest Hall, PI, TE-18

Title: Modeling Biosphere - Atmosphere Interactions at Various Scales in Support of BOREAS

Objective of study:
Develop 1-km AVHRR land cover classification for BOREAS region to support RAMS Mesoscale Modeling and other BOREAS Research.
Conduct Multiresolution Land Cover Mapping Research with 1-km AVHRR and 30-m Landsat TM

Types of data collected, equipment used:
Collected field data on land cover and fire history in Northern Manitoba from ground and low-level aircraft transits. Conducted three flights during the week of 12-19 July.

Summary of places and times of measurements:
Flights were out to Gillam area then N-NW, east of Lake Winnipeg, and NW to Lynn Lake then North to 59.5N. All flights originated at Thompson. Flights were on July 13, 14, and 16. Ground obs in/near NSA and out to Gillam.

Known problems or caveats:
None

5.1.5 AFM-13

PI Name: Peter H. Schuepp - McGill University
Co-investigators: R.L. Desjardins - Agriculture Canada and J.I. MacPherson - NRC Flight Research Laboratory

Objective of study:
(i) To map surface source and sink distributions for sensible heat, latent heat and CO_2, and radiometrically observed surface characteristics (surface temperature and greenness) from Twin Otter airborne observations over the SSA and NSA grid sites;
(ii) to compare these maps, and the relationships beteen them, against those observed in 1994.

Types of data collected, equipment used:
eddy-correlation flux estimates (high resolution observations of turbulence, temperature and mixing ratio), and spectral data in the visible and IR, at a height of 30 m, digitixed at 30 Hz. Air motion from Rosemount 858AJ28 probe on nose boom; air temperature by Rosemount 102DJ1CG heated probe; CO_2 and H_2O mixing ratio by ESRI and LI-COR LI-6262 gaz analyzers; radiometric data by PRT-5 IR thermometer and Exotech 100BX satellite simulator.

Places and time of measurement:
SSA grid sampled on (month/day): 07/09, 07/20, 07/27, 07/29
NSA grid on 07/31, 08/02, 08/03 and 08/05.

Known problems or caveats:
There was a growing discrepancy between CO_2 flux estimates based on the ESRI and LI-COR analyzers which could not be resolved in the field. It is being further investigated through aircraft-tower intercomparison (AFM-4). If an uncertainty remained, it would not significantly affect spatial distribution patterns of flux, but be of importance in absolute flux comparisons between 1994 and 1996.

5.1.6 AFM-14

PI Names: P. J. Sellers - NASA/Goddard Space Flight Center, F. G. Hall - NASA/GSFC, and R.L. Desjardins - Agriculture Canada

Title: Aircraft Measurements of CO2 Concentrations

5.2 TF - Tower Flux

5.2.1 TF-1
PI Names: A. Black - University of British Columbia, M. Novak - UBC, and P. Voroney - University of Guelph

Title: Measurement of Tower Fluxes at BOREAS Southern Study Area Old Aspen Site (SSA-OA)

5.2.2 TF-2
PI Names: H. Neumann - Atmospheric Environment Service, R. Mickel - AES

Title: CO_2 Profiles: Exchange of Energy, Water Vapor, and Trace Gasses Project at BOREAS Southern Study Area Old Aspen Site (SSA-OA)

5.2.3 TF-3
PI Names: S. Wofsy - Harvard University, M. Goulden - Harvard University, B. C. Daube - Harvard University, J. W. Munger - Harvard University

Title: Eddy Covariance Measurements of CO_2 and Water Vapor Flux at BOREAS Northern Study Area Old Black Spruce Site (NSA-OBS)

5.2.4 TF-7
PI Names: R.L. Desjardins - Agriculture Canada, E. Pattey - Agriculture Canada, P. Sellers - NASA/Goddard Space Flight Center, L. Mahrt - Oregon State University, J. Berry - Carnegie Institution, J. Cihlar - Canadian Centre for Remote Sensing, and J.I. MacPherson - NRC Flight Research Laboratory

Title: Measurement of Fluxes from Changes in Concentration at BOREAS Southern Study Area Old Black Spruce Site (SSA-OBS)

5.2.5 TF-8
PI Names: D. Fitzjarrald - State University of New York Albany, K. Moore - SUNY

Title: Surface Exchange Observations in the Canadian Boreal Forest Region at BOREAS Northern Study Area Old Jack Pine Site (NSA-OJP)

5.2.6 TF-9

PI Names: Paul Jarvis - University of Edinburgh and John Moncrieff - University of Edinburgh
Co-I Names: Jonathan Massheder - University of Edinburgh and Mark Rayment - University of Edinburgh

Title: The CO_2 Exchanges of Boreal Black Spruce Forests at BOREAS Southern Study Area Old Black Spruce Site (SSA-OBS)

Objective of study:
To estimate carbon and energy balances for the SSA OBS by measuring stand CO_2 and energy fluxes for the whole growing season. Especially for the begining and end of the season which we missed in 1994. Also to make measurements of branch scale fluxes, sap flow and soil CO_2 efflux to allow investigation of the balance and physiology of the constituent fluxes.

Types of data collected, equipment used:
Above canopy CO_2 and energy fluxes - Eddy covariance (EdiSol)
Below canopy CO_2 and energy fluxes - Eddy covariance (EdiSol)
CO_2 and H_2O concentration profiles - IRGA and sampling system
Branch CO_2 exchange and transpiration - Branch cuvettes
Sapflow - Le Granier system
Soil CO_2 efflux - Chambers
Weather station and soil heat flux and temperature data

Summary of places and times of measurements:
The measurements were made at SSA OBS.
Above canopy CO_2 and energy fluxes - Mid-March until December
Below canopy CO_2 and energy fluxes - May until December
CO_2 and H_2O concentration profiles - Mid-March until December
Branch CO_2 exchange and transpiration - April until December
Sapflow - August until December
Soil CO_2 efflux - Mid-March until December
Weather station - Mid-March until December
Soil heat flux and temperature data - November 1995 until December 1996

5.2.7 TF-10

PI Names: J. H. McCaughy - Queen's University, P. Lafleur - Trent University, J. Buttle - Trent University

Title: Surface Energy and Water Balances of Forest and Wetland Subsystems in the Boreal Forest at BOREAS Northern Study Area Fen and Young Jack Pine Sites (NSA-Fen and NSA-YJP)

5.2.8 TF-11

PI Names: Shashi Verma -University of Nebraska - Lincoln, Tim Arkebauer - UNL, and Dave Billesbach - UNL

Title: Measurement of Effects of Water Surface Films on Release of Trace Gasses at BOREAS Southern Study Area Fen (SSA-Fen)

Objective of Study:
To measure and quantify the effect of naturally occurring films on the release of trace gases from water surfaces at the SSA Fen Site.

Types of data collected, equipment used:
Chamber fluxes of CO_2 and CH_4 were collected from clean and film covered water surfaces at the SSA Fen Site. A Licor Li-6250, portable photosynthesis IRGA was used to measure surface CO_2 fluxes from a 1 liter chamber. A Shimadzu GC-8 gas chromatograph was used to measure surface fluxes of CH_4 and CO_2 from a 40 liter chamber.

Summary of places and times of measurements:
Measurements were taken along the boardwalk at the SSA Fen Site. The chambers were placed about 35 meters out from the shore, in areas of open water. Measurements were taken periodicaly during the day from 23-Jul-96 (day 205) until 31-July-96 (day 213).

Known problems and caveats:
Only one flux measurement was obtained with the G.C. It seemed to have some problems and ran out of air during the second set of flux syringes

Other information:
Good data were obtained with the Licor, and the one set of CO_2 fluxes obtained with the G.C. agreed with those from the Licor taken at the same time. Preliminary results show that the film which forms on the open water surface of the fen caps between 60% and 80% of the potential CO_2 and CH_4 released from the water. Further if this film is disturbed, it will re-form in about 5 hours.

5.3 TE - Terestial Ecology

5.3.1 TE-2

PI Name: M. G. Ryan - USDA

Title: Autotrophic Respiration in Boreal Ecosystems

5.3.2 TE-4

PI Name: J. Berry - Carnegie Institution
Collaborators: Wei Fu, Art Fredeen, John Surfus, Jeff ___ (Fitzjarrald's team)

Objective of Study:
1) To link dynamic narrow-band reflectance signals (e.g. the Photochemical Reflectance Index) to light environments and photosynthetic fluxes measured by leaf gas exchange, branch bag gas exchange, and eddy correlation (NSA, OJP site). 2) To examine alternative reflectance inputs (e.g. NDVI vs. spectral mixture analysis) to photosynthesis models (SiB).

Types of data collected:
Primarily spectral reflectance at the single needle, branch, canopy and stand scales in conjunction with photosynthetic studies.

Summary of places and times of measurements:
NSA, OJP site, late July-early Aug 1996

Know problems or caveats:
While we have some unique data sets (e.g. spectral reflectance of single needles, and diurnal reflectance patterns from the needle to the stand scale for this site), we often use newly developed "non-standard" methods, so some care must be taken in using or interpreting the data at this point. Modelers may be interested in our results, but they should beware of how they are obtained. Much work remains to be done in interpretation.

Other information:
One goal was to link our ground efforts with remote measurements (e.g. CASI or AVIRIS data). For example, CASI data were collected in a unique way at this site during these dates - down the solar beam - and these data could be of great use to us. I have not yet been able to contact John Miller re. the status of these remote images. AVIRIS imagery could also be useful, particularly if they are corrected to reflectance and georeferenced. Also, some of our measurements examined effects of alternating cloud and sunlight on spectral reflectance, and these could be of interest to members of Fitzjarrald's team once they are analyzed. To complete our analysis, we will probably need some micromet and flux data from this site during this period.

5.3.3 TE-5
PI Name: L. Flanagan - Carleton University
Collaborator: J. Ehleringer - University of Utah

Title: Vegetation-Atmosphere CO_2 and H_2O Exchange Processes: Stable Isotope Analysis

Types of Data Collected, Equipment Used:
1) Environmental regulation of photosynthetic gas exchange (CO_2 and H_2O fluxes) in mosses. These measurements were made on field collected samples placed in an controlled environment, open gas exchange system operated in the tower hut. Responses of moss photosynthesis to light, CO_2, temperature, water content were generated. Biochemical parameters for leaf photosynthesis models have been generated from this data.
2) Field measurements of CO_2 and water vapor flux from the moss/soil surface were collected using a modified Li-Cor photosynthesis chamber clamped on collars installed in the moss/soil. Measurements were made in feather moss (Pleurozium) and Sphagnum dominated areas. Chambers were exposed to natural light and were also darkened to obtain dark respiration rates. Associated measurements of soil, moss and air temperature, moss water content, light intensity, and relative humidity were also made. Experiments were conducted to test the effect of water addition on moss/soil gas fluxes.
3) For approximately 2 weeks during IFC2, an eddy covariance system was installed and operated at 2.1 m height in the trunk space of the forest canopy. This system primarily consisted of a Solent sonic anemometer, Li-Cor 6262 gas analyzer and a microcomputer running Edisol software. CO_2 and water flux data were collected using these instruments.
4) During the summer and fall IFC's, measurements were made of the concentration and stable isotope ratio of atmospheric CO_2 collected at different heights within the forest canopy during diurnal cycles. In addition we made collections of CO_2 respired into the headspace of the soil respiration chambers for analysis of the isotope ratio of respired CO_2. This data will be used with other information in calculations of the proportion of ecosystem respired CO_2 contributed by the moss.
5) Measurements were made of the carbon isotope ratio of leaf tissue in all the major species at the site collected during IFC-2. This provides useful information about the ratio of photosynthetic capacity to stomatal conductance in these species.

Summary of Places and Times of Measurements:
All measurements were made at the Old Black Spruce site in the Southern Study Area. Except as noted above, all measurements were during all three IFC's in 1996.

Known Problems:
There are no known problems with the data at this point.

5.3.4 TE-6

PI Names: Chris Kucharik - University of Wisconsin and John Norman - University of Wisconsin

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

Objective of Study:
Indirectly measure LAI, canopy non-randomness, sunlit and shaded LAI, and stem and branch architecture with Multiband Vegetation Imager; make measurements of canopy light distribution in aspen to indirectly solve for an estimate of the leaf angle distribution (LAD).

Compare values of LAI measured with MVI to LAI-2000 values measured in same locations; use data as input to Monte Carlo model that simulates canopy architecture and study behavior of non-randomness factors as a function of zenith angle through canopy, along with suggestions of how to estimate sunlit LAI in non-random canopies.

Types of Data Collected, Equipment Used:
Gap fraction (LAI), non-randomness factors, branch and stem architecture, sunlit and shaded LAI; obtained with Multiband Vegetation Imager (MVI); some indirect LAI data also collected with LAI-2000

Summary of Places and Times of Measurements:
SSA-OBS July 8,9,10 1996 30 2-band MVI image pairs captured along Transect B (RSS-7) every 3 m from 40-125 m markings; Allometry Plot 1 and 3 (TE-6) had two-band images taken that covered each plot's crown area. LAI-2000 Measurements were made in each allometry plot also.
SSA-OA July 14, 1996; 8am-1pm; 40 image pairs captured every 3 m along Transect B (RSS-7) from 10 m - 110 m from tower. 15 image pairs taken on Allometry plot 4 that covered the entire crown area over the plot.
SSA-OJP July 15, 1996; 8 pm CST; LAI-2000 Measurements made in each of 4 allometry plots set-up by TE-6

Known Problems:
None

Other Information:
Non-randomness data is processed for aspen and will be published in JGR special issue; Sunlit and shaded LAI along with LAD information for aspen will be presented in future paper submitted to Ag and Forest Met. Branch and stem architecture and theory to correct indirect LAI measurements will be presented in future publication, probably submitted to Ag and Forest Met. in late spring '97. Future photosynthesis scaling paper will address non-randomness factors in conifers, and will use all previous MVI data to scale photosynthesis from the leaf to canopy scale; date to be submitted, late-spring '97.

<u>5.3.5 TE-7</u>

PI Name: E.H.(Ted) Hogg - Forestry Canada
Co-I Name: P.A. (Rick) Hurdle - Forestry Canada

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

Objective of Study:
1. To measure sap flow in aspen and black spruce stands as a means of comparing transpiration responses to environmental conditions.
2. Conduct collaborative measurements with other BOREAS teams to determine factors governing transpiration, canopy (stomatal) conductance and photosynthesis.

Types of Data Collected, Equipment Used:
- Hourly sap flow using heat pulse method, air temperature and RH at 1.5 m height using Vaisala probes (SSA OA, OBS and Batoche)
(see also TE-2, sap flow using Granier method at SSA OBS)
- In collaboration with TE-11 (B. Saugier): Half-hourly photosynthesis, transpiration and conductance of aspen and hazelnut branches at SSA OA, using branch bags and Li-Cor 6262 analyzer; associated environmental measurements (PAR, CO_2, air temperature and RH)
- Relative changes in latent and sensible heat flux using above-canopy 1-D gill prop, Vaisala sensor and fine-wire thermocouples; above canopy air temperature and vapour pressure (SSA OA, OBS and Batoche)
- In collaboration with TF-1 (T.A. Black): Stomatal conductance and leaf water potential of aspen and hazelnut (Li-Cor 1600 porometer and Scholander pressure chamber).
- Cores or disks, basal area and sapwood area in plots (OA, OBS)

Summary of Places and Times of Measurements:
- Sap flow SSA OA, OBS: mid Apr - late Oct 1996
Batoche: late June - late Oct 1996
- Branch bags SSA OA, best data from 11 July - 22 August 1996 (TE-11 and TE-7)

- Stomatal conductance (TF-1) OA; midday most days, 12 Jul- 6 Aug
- Leaf water potential (TE-7) OA; midday on 10 days, 12 Jul- 6 Aug

Known problems or caveats:
A few periods of data loss for some measurements due to wind storms, power loss or animal damage

5.3.6 TE-10
PI Name: E. Middleton - NASA/GSFC

Title: CO_2 and Water Fluxes in the Boreal Forest Overstory: Relationship to Fapar and Vegetation Ineices for Needles/Leaves

5.3.7 TE-12
PI Names: Elizabeth A. Walter-Shea - Universtiy of Nebraska, Lincoln and Timothy J. Arkebauer - UNL

Title: Radiation and Gas Exchange of Canopy Elements in a Boreal Forest

Objectives of study:
Our goal is to gain an understanding of radiation and gas exchange of the dominant understory species (under shade and sunlit conditions) at the SSA OBS site. Two scientific objectives have been identified to achieve this goal:
(1) Characterize the PAR environment of the dominant understory species
(2) Characterize the gas exchange of the dominant understory species

Types of data collected, equipment used:
PAR environment. PAR irradiance transmitted through the upper story layer was measured at an average understory canopy height (60 cm above ground level) using 10 randomly located quantum sensors (Li-Cor Inc., Lincoln, NE) within a 25m x 25m area within the SSA-OBS site from July 4 through July 24, 1996. Incident instantaneous photosynthetic photon flux density (PPFD) at each location was measured at a 1 sec frequency and averaged to yield 1 minute averages of PPFD using a CR-10 data logger (Campbell Scientific, Logan UT). Occasionally, the photon flux was measured at a frequency of 0.125 sec and averaged to yield 1 sec averages of PPFD to get detailed definition of sunfleck characterization. PPFD was measured continuously during daylight hours (0400-2200) on each day. In addition, leaf optical properties of the dominant understory species in the PAR region was measured using a Li-Cor integrating sphere, quantum sensor and datalogger (polycorder, Omnidata, Logan UT). The fraction of PAR absorbed by the understory was measured using a Li-Cor line quantum sensor at selected plots in the vicinity of the quantum sensors.
Gas exchange. Diurnal courses of leaf CO_2 assimilation, stomatal conductance, air and leaf temperature, PPFD and VPD were quantified using a Li-Cor LI-6400 and LI-6200 portable gas exchange systems (Li-Cor Inc., Lincoln, NE). Diurnal courses were measured on days of appropriate weather conditions. The measurement of the diurnal courses were coordinated with the PAR environment characterization. In addition, response curves were characterized as a step toward modeling leaf diurnal patterns (i.e., response to sunflecks, PPFD, air temperature, VPD).
Supporting measurements. LAI was determined using a Li-Cor LAI-2000 on several occasions; destructive samples were collected at the end of our experimental period. Upperstory LAI was determined using coordinated measurements from an LAI-2000 above the understory canopy near the quantum sensors and from an LAI-2000 mounted on the

OBS tower (TE-6). Upperstory conditions were documented using hemispherical photographs; also TE-23 measured upperstory conditions at the same plots.

Summary of places and times of measurements:
SSA OBS site from July 4 through July 24, 1996.

Known problems or caveats:
None at this time.

5.3.8 TE-15

PI Names: R. P. Bukata - National Water Research Institute, J. H. Jerome - NWRI

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

5.3.9 TE-19

PI Name: S. E. Frolking - University of New Hampshire

Title: Modeling Climate-Biosphere Interactions in the Boreal Forest

5.3.10 TE-23

PI Name: Paul M. Rich - University of Kansas
Collaborators: Richard Fournier - CCRS and David A. Vieglais

Title: Canopy Architecture of Boreal Forests: Studies of Solar Radiation, Leaf Area Index, and Forest Dynamics

Objective of study:
Work focused on acquiring additional sets of hemispherical photographs to enable better integration of PAR measurements, gas flux measurements, and canopy architecture measurements.

Types of data collected, equipment used:
1) hemispherical photographs acquired at OJB and OBS tower sites, both north and south; and 2) additional measurements of the geometry of trees in mapped plots at the various study sites.

Summary of places and times of measurements:
SOBS, SOJP, NOBS, NOJP -- July 1996 (exact dates do not affect these structural measurements over short time intervals).

Known problems or caveats:
Some photographs lost because photographic processing company destroyed film.

5.4 TGB - Trace Gas and Biogeochemistry

5.4.1 TGB-1

PI Name: Patrick M. Crill - University of New Hampshire
Collaborators: Jill Bubier - McGill University, Ruth Kerwin, Andrew Mosedale, Barret Rock - University of New Hampshire, Tim Moore - McGill University, Kathleen Savage - University of Sherbrooke, Cindy Honeywill, Nigel Roulet - McGill University, Jenny Marie Ferrone, Michael Goulden - Harvard University

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

Objective of study:
The objective of our 1996 field campaign at the BOREAS NSA was to measure surface/atmosphere trace gas exchange. We focussed on the magnitudes and community level controls on the soil surface and ecosystem exchange of CH_4 and CO_2. We measured during and between the spring thaw, mid-summer IFC, and the freeze up. Our sites included: NSA Old Black Spruce, Old Jack Pine, Tower Fen, Collapse Bog, Collapse Fen, and Zoltai Fen. We also completed a survey of Beaver Pond sites for DIC.

Types of data collected, equipment used:
We collected Net Ecosystem Exchange (NEE) measurements from the Tower Fen, Collapse Bog, Collapse Fen, and Zoltai Fen. A LICOR infrared Gas analyzer and clear, humidity controlled chamber were used to measure NEE in the wetlands. CH_4 fluxes were also measured at the time of the NEE measurements in collaboration with Tim Moore, TGB-3, McGill University. The gas samples were taken to the Museum lab and analyzed with a Shimadzu Flame Ionization Detector (FID). Water level and temperature profiles (4 depths) were monitored throughout the sampling period and hourly averages were determined with a CR10 and multiplexer measurement control system. Percent cover of bryophyte and vascular plant species was recorded in all collars. Above ground net primary productivity (NPP) of mosses and vascular plants was also measured.

In collaboration with Barry Rock, UNH and Tim Moore, TGB-3, spectral reflectance measurements of plant communities were made in all the NEE/CH4 collars during the Mid-summer IFC. The visible/infrared intelligent spectrometer (VIRIS, GER, Inc.) was used by the UNH group. A LICOR spectroradiometer was used by the group from McGill University, TGB-3.

In collaboration with Harvard University, TF-3, NEE was measured at the Old Black Spruce site using automated clear chambers and a LICOR infrared gas analyzer. Temperature at the surface and 5 cm was collected as well. CH_4 and CO_2 exchange was measured at the Old Jack Pine and Young Jack Pine sites with dark aluminum chambers. Temperature in the chamber was recorded during the flux measurements. Gas samples were analyzed with a Shimadzu 14-A equipped with a FID and a thermal conductivity detector (TCD).

Ambient CH4 was measured from two heights on the tower at the Tower Fen site. An automated system set up in the tower hut sampled the two heights and ran a calibrated standard approximately every three minutes using automatic valves and a Shimadzu MINI-2 FID. The measurements were made in conjunction with the Queens

University, TF-10, meteorological measurements completed during the entire sampling period.

Dissolved Inorganic Carbon and CO_2 fluxes were measured during a Beaver Pond survey in collaboration with TGB-4, Nigel Roulet of McGill University. The water samples were analyzed with a HORIBA PIR detector and sparging apparatus.

Summary of places and times of measurements:
The CH_4 fluxes, CO_2 fluxes, and NEE measurements at OJP, YJP, Collapse Fen, Tower Fen, Zoltai Fen, and Collapse Bog were made approximately every seven days from April 17, 1996 through October 21, 1996. The Beaver Pond survey occurred during the mid-growing season IFC: July 9, 1996 through August 9, 1996. The ambient tower CH_4 measurements at the Tower Fen were made every 3 minutes from April 14, 1996 through October 21, 1996. The NEE measurements at OBS were made approximately every ten minutes from the beginning of June, 1996 through October, 1996.

Known problems or caveats:
At this time there are no large problems associated with the sampling and data analysis. More details will be included in the BORIS documentation for the 1996 data.

Other information:
If you are interested in more complete descriptions or have questions you may reach Patrick Crill at patrick.crill@unh.edu or Ruth Kerwin at ruth.kerwin@unh.edu

5.4.2 TGB-3

PI Names: T. R. Moore - McGill University and R. Knoles - McGill University

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

5.4.3 TGB-4

PI Name: Nigel Roulet - McGill University

Title: Determination of CO_2 flux from Beaver Ponds in the BOREAS Northern Study Area

5.4.4 TGB-5
PI Name: R. G. Zepp - US Environmental Protection Agency
Co-I Names: R. A. Burke , Jr. - US Environmental Protection Agency and R. A. Bourbonniere - Environment Canada,

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

Objective of study:
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 5 upland black spruce sites located in about 100 km northeast of Thompson, Manitoba. 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 collected, equipment used:
Gas fluxes were determined at the fire sites using the closed chamber techniques with gas chromatography to measure carbon gas concentrations. Also, vertical profiles of carbon gases were obtained in snow at the sites. Data on soil temperature, moisture, and nutrient content also were obtained. Piezometers were deployed to collect water leached from the fire sites during spring snow melt for characterization of the dissolved organic matter and nutrients in the leachate. Studies at the tower pond included measurements of carbon monoxide and dissolved inorganic and organic carbon concentrations in the water column. These measurement were complemented by concurrent measurements of solar radiation and water chemistry characteristics (pH, dissolved oxygen). Water samples were collected and the dissolved organic carbon was collected and fractionated. During April, carbon gas concentrations in the ice were determined.

Summary of places and times of measurements:
Data were obtained in April-June and October, 1996 at the fire sites and during May-September, 1996 at the tower pond site in the NSA. Studies of the trace gas exchange in fire scars were conducted at 5 upland black spruce sites. 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. Data for nearby stands that had not been burned for over 70 years are provided for comparison to the recently burned sites.

The tower pond site was one of the BOREAS tower sites located about 18 km from Thompson. Studies were conducted from May-September, 1996 .

5.4.5 TGB-6
PI Name: Martin Wahlen - Scripps Institution of Oceanography
Co-I Name: Bruce Deck - Scripps Institution of Oceanography

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

Objective of study:
Isotopic Composition of Methane Produced and Consumed in Boreal Ecosystems

Types of data collected, equipment used:
Gas samples from flux enclosures (chambers) over the soil and subsurface soil gas samples were taken and returned to our lab for analysis. Data were collected at three time periods from two sites near the towers at the Old Jack Pine (OJP) and Young Jack Pine (YJP) sites, in the Northern Study Area (NSA). While some concentration measurements were made in the field in conjunction with others investigators, our data set consists of methane concentration and carbon isotope ($^{13}C/^{12}C$) ratios for each sample.

Summary of places and times of measurements:
The sites sampled in 1996 duplicated the NSA sites which we sampled in 1994. At OJP the Crill Lichen chamber #4 and the Crill Moss chamber #7 were sampled. For the YJP Moore Chambers, #4 and #6 were sampled. Two liter samples were taken from each of the chambers, drawn over a 1 min. sampling period, at times of 1 to 7 hr depending on estimated methane uptake. The chambers at the OJP are approximately 30m apart while those of the YJP were within 5m of each other. Soil probe samples were taken at shallow depths in the immediate (1m) vaccinate of the chambers. Samples were drawn slowly (5 min. for 2 liters) to avoid contamination from intermediate levels.
A Summary of the samples follows.
Sampling 5/29/96 to 6/3/96 Ground frozen below 15 cm. surface soil < 10°C with water saturation. One sample taken at each chamber , OJP at approximately 4.5 hr., YJP at approximately 6 hr. No soil probe samples.
Sampling 6/28 and 6/29/96 One sample taken from each chamber at 1.5 to 2 hr . No soil samples.
Sampling 8/1/96 to 8/4/96 General surface temperatures approximately 25°C weather good and dry. Duplicate samples at 45 and 90 min. for both OJP chambers 4 soil probe samples, two near each chamber at approx. 20 cm. depth. Sampling for the YJP site was identical except times of 1 and 2 hr for the chambers were used.
Sampling 9/8/96 to 9/12/96 OJP sampled, light showers two days prior, chamber samples in duplicate at 1 and 2 hr times. Soil samples, two near each chamber at approximately 15 cm depth. Cold heavy rain for two days. OJP samples taken on 9/11, temp. <9°C. Duplicate taken each chamber at 1 and 2 hr. Two soil probe samples taken 15,17 cm. Two ambient air samples taken.

Known problems or caveats:
Data quality appears to be high for all of the data set, although not all analysis completed. Low consumption of methane in the soils resulted in final concentrations of methane in the chambers somewhat higher than desired but the use of duplicate samples reduces the

error. Soil methane flux measurements using our data are lower than the values determined by other groups sampling for shorter periods.

5.4.6 TGB-12

PI Name: S. Trumbore - University of California, Irvine
Collaborators: J. Harden - US Geological Survey, E. Davidson - Woods Hole Research Center, E. Sundquist - US Geological Survey

Objective of study:
Use of radiocarbon and changes in C storage to study the accumulation and turnover of organic matter in boreal soils.

Types of data collected, equipment used:
Samples collected in 1996 included:
(1) soil samples, from the NSA and SSA OBS for detailed study of C accumulation and turnover in moss layers. Moss profiles were collected in Sphagnum and feathermoss sites near Crill/Goulden NEE chambers (OBS NSA) and Flanagan moss NEE sites (OBS SSA). Isotopic analyses of these soils is still in progress, but should be finished in March/April 1997. Additional data to be reported will be: bulk density, %C, %N, moisture content (for some samples).
(2) cores from the NSA and SSA fen sites. Long cores were collected using a piston corer (thanks to Dorothy Peteet of NASA GISS) and are presently being picked for aquatic macrofossils for ^{14}C dating. Freeze cores were collected for details of the upper meter of accumulation. Analyses of these are still in progress,but should be finished in March/April 1997. Additional data to be reported will be: bulk density, %C, %N, moisture content (for some samples).
(3) A program was begun to sample isotopes in total soil respiration to augment our data set of soil CO_2 isotopes. Samples were collected in June, August, October, (all 1996) and January (1997). Samples were collected at (1) NSA fen and bog collapse, (2) NSA OBS (feather moss and Sphagnum sites) and (3) Gillam Road 1992 burn site (Zepp's 1992 burn site). January data are from NSA OBS only. Radiocarbon analyses are complete for 1996 data, but we are awaiting a few ^{13}C analyses before data can be submitted.

Summary of places and times of measurements:
Soil sampling took place the July 10-19 (NSA) and July 21-August 1 (SSA) in 1996.
Gas sampling in the NSA took place June 1 - 9, 1996; July 17-20, 1996, October 10-15, 1996 and January 25-6, 1997. See above for site information.

Known problems or caveats:
Isotopic data are not finished yet but should be available in spring 1997. No other known problems at this point.

Other information:
Call Sue Trumbore if there are questions.

5.5 HYD - Hydrology

5.5.1 HYD-1

PI Name: R. Cuenca - Oregon State University

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

5.5.2 HYD-3

PI Name: R. Davis - US Army Corps of Engineers
Collaborators: J. Hardy - US Army Corps of Engineers and C. Woodcock - Boston University

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

Objective of study:
The objective of this work was to collect data to support our modeling effort aimed toward predicting spatial distributions of snow properties important to the hydrology of the area and the remote sensing signatures from snow-covered boreal scenes.

Types of data collected, equipment used:
To meet our objectives, we conducted detailed snow pack characterization at each site and made several random measurements of snow depth (n=100) and integrated snow water equivalence (SWE) among the trees. Additionally we used a grain sieve for snow grain size analysis and took photos of the snow crystals. Our radiometer array operated for 5 clear days to measure the magnitude and variability of sub-canopy radiation. The array consisted of 10 pyranometers and 2 pyrgeometers placed randomly on the snow surface, and 3 thermal radiometers used to measure trunk and canopy temperatures.

Summary of places and times of measurements:
Place and time of snow measurements:

29 Feb.	SSA-OBS	snow pit, depths, SWE, grain size
1 March	SSA-OBS	grain photos, new snow characterization
1 March	SSA-Ag	snow pit, depths, SWE, grain size and photos
2 March	SSA-OBS	SWE near trees
3 March	SSA-OBS	new snow characterization
4 March	SSA-OA	snow pit, depths, SWE, grain size and photos
5 March	SSA-OJP	snow pit, depths, SWE, grain size and photos
7 March	Namekus Lake	snow pit, depths, grain size and photos
11 March	SSA-OJP	snow pit, depths, grain photos
11 March	SSA-Ag.	snow pit, depths, grain photos
12 March	Waskesiu Lake	snow pit and grain photos

24 April	NSA-burned spruce	SWE
25 April	NSA-FEN	snow pit, SWE
27 April	NSA-OJP	SWE
28 April	NSA-OBS	SWE

Place and time of sub-canopy radiation measurements:
28 Feb.- 3 March SSA-OBS
4-8 March SSA-OA

Known problems or caveats:
none

Other information:
An additional effort during FFC-W was to obtain hemispheric photos of the canopy near the OBS radiometer array. We also made miscellaneous measurements of canopy closure and stem density to help calibrate the radiative transfer model.

5.5.3 HYD-5

PI Name: R. Harding - Institute of Hydrology

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

5.5.4 HYD-8

PI Name: L. Band - University of Toronto
Co-I Names and Collaborators: D. Lettenmaier - University of Washington, E. Wood - Princeton University, A. Price - University of Toronto, T. Carleton - University of Toronto, R. Fernandes - University of Toronto

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

Objective of study:
Measurements of Above Ground Hydrological Processes at the Southern Old Black Spruce Stand

Types of data collected, equipment used:
i) Precipitation - rain only (mm).
ii) Throughfall - rain only (mm).
iii) Stemflow - (mm).
iv) Live turf weight - (g).
v) Live + Fermentation turf weight - (g).
vi) Spaghnum turf weighth - (g).
vii) Live turf water equivalent depth - (mm).
viii) Live + Fermentation turf water equivalent depth - (mm).
ix) Spaghnum turf water equivalent depth - (mm).
x) Depth to water table - pizeometer measurement (mm).

Summary of places and times of measurements:
Places: Seven 5m diameter plots located along a 500m transect starting at the SOBS flux tower and extending parallel with the boardwalk towards the road access point. Plots contained 5 live moss, 3 live + fermentation layer moss, 1 spaghnum moss turfs in mesh type lysimeters, 5 throughfall catch gauges beside each live moss turf and 1 standpipe.

Two additional 20m square throughfall plots were located along the transect with 20+ throughfall catch gauges and stemflow gauges. Two rainfall gauges were placed in openings along the transect.

Times: Daily measurements were made between July 6, 1996 and August 13, 1996 inclusive. Additional measurements were made after precipitation events where possible.

Known problems or caveats:
Standpipe measurements began July 16, 1996.

Other information:
Ancillary information was collected for each plot including location relative to SOBS tower, moss cover, canopy density, dbh of selected trees, and for some plots effective LAI.

5.5.5 HYD-9

PI Name: N. Kouwen - Universtiy of Waterloo

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

5.6 RSS - Remote Sensing Science

5.6.1 RSS-1

PI Name: D.W. Deering - NASA/GSFC
Co-I Names: T.F. Eck - Hughes STX and E.M. Middleton - NASA/GSFC
Collaborators: M. Verstraete - Institute for Remote Sensing Applications, B. Pinty - LERTS/CNES, and R.Myneni - Boston University

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

Objective of Study:
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 data were collected at 10 degree solar zenith angle intervals, clouds permitting, from approximately 70 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. The prototype PARABOLA III instrument was utilized in July 1996, and data quality at this point in time is unknown.

Summary of Places and Times of Measurements:
Measurements were made in 1996 at 3 sites in the BOREAS Southern Study Area (SSA): Old Aspen (OA), Old Black Spruce (OBS), and Old Jack Pine (OJP).

FFC-Winter: OBS-3/5; OA- 3/8; OJP- 3/11 & 3/12/96
IFC-1: OJP-7/20; OBS-7/29 & 7/30/96

5.6.2 RSS-2
PI Name: J. R. Irons - NASA/GSFC
Co-I Names: Philip W. Dabney - NASA/GSFC, John V. Martonchik - NASA/JPL, K. Jon Ranson - NASA/GSFC, and Charles L. Walthall - US Department of Agriculture
Collaborators: Carol Russell - University of Maryland

Title: Dynamics of Canopy Photosynthesis and Stomatal Conductance in the Boreal Forest: A Study Using Airborne, Multi-Angle, Imaging Spectroradiometer Data

Objective of study:
Specific objectives for RSS-2 are to: develop linkages between multi-angel optical remote sensing and boreal zone biophysical parameters at scales intermediate to field and satellite observations; develop capabilities to remotely monitor the state of the snowpack in the boreal forest; study the bidirectional reflectance properties of snow and boreal forest canopies with/without a snow background; contribute to studies of phenologic variations, and simulate MISR instrument data by acquiring data at MISR view zenith angles.

Types of data collected:
The data acquired were multi-angle, hyperspectral digital image data acquired over flux tower sites and a few auxiliary sites.

Equipment used:
RSS-2 used the NASA/GSFC Advanced Solid-State Array Spectroradiometer (ASAS) flown aboard the NASA/WFF C-130Q aircraft

Summary of places and times of measurements:
ASAS data were acquired for two BOREAS field campaigns in 1996:
FFC-W : Focused Field Campaign - Winter [27 February through 15 March 1996]
IFC-2 : Second Intensive Field Campaign [8 July through 9 August 1996]

During FFC-W ASAS data were only acquired over the following sites in the SSA on the following dates:

11MAR96

Flight 1: Acquired data over Old Aspen, Old Black Spruce, Young Jack Pine, Old Jack Pine.

Flight 2: Acquired data over agriculture site and Namekus Lake.

12MAR96

Flight 1: Acquired data over agri, Old Jack Pine, Young Jack Pine.

Flight 2: Acquired data over Old Black Spruce and Old Jack Pine.

During IFC-2 ASAS data were acquired over sites in both the SSA and the NSA on the following dates:
18JUL96 / All in NSA - Old Aspen, Old Jack Pine, Fen, Old Black Spruce, Young Jack Pine
20JUL96 / All in SSA - Old Black Spruce, Fen, Old Aspen
24JUL96 / All in NSA - Old Jack Pine, Old Aspen, Fen,
29JUL96 / All in SSA - Old Black Spruce
30JUL96/ All in SSA - Young Jack Pine, Old Jack Pine, Young Aspen, Old Black Spruce

5.6.3 RSS-7
PI Name: J. Chen - Canadian Centre for Remote Sensing

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

5.6.4 RSS-8
PI Name: Z. Wan - University of California, Santa Barbara
Collaborators: W Snyder - UCSB, J. Feng - UCSB, and D Wilson - UCSB

Title: MODIS Land Team Algorithm Development for Boreal Forests

Objective of study:
To validate thermal infrared land surface temperature algorithms to be used with EOS/MODIS.

Types of data collected, equipment used:
We collected kinetic temperature data, wideband infrared radiometric data, and spectral thermal radiometric data. We used logging thermistors, two wideband radiometers, and a FTIR spectrometer.

Summary of places and times of measurements:
The data were collected only during the 1996 MAS flight over the SSA on 14 August (about 10:30 am local). We had thermistors in White Swan Lake, and at the OBS site. There was a spectrometer and a radiometer on the tower at the OBS site. There was also a radiometer at Candle lake for open field measurements.

Known problems or caveats:
No

Other information:
The MAS data for this collection is available directly from NASA. We can supply any ground truth data on request.

5.6.5 RSS-11

PI Name: B. Markham - NASA/GSFC
Collaborator: J. Schafer - Hughes STX

Title: Characterization of Atmospheric Optical Properties for BOREAS

Objective of study:
A network of five automated and two handheld solar radiometers were operated during the 1996 BOREAS campaign in northern Saskatchewan and Manitoba, Canada, in order to characterize the atmospheric aerosol properties.

Types of data collected:
Direct solar measurements were used to measure atmospheric transmission and infer aerosol optical thickness and water vapor column abundance. Sky radiance of solar aureole (measurements around the solar disk) was used to estimate the aerosol size distribution.

Equipment used:
The automatic instruments were Cimel sunphotometers equipped with 10 nm bandpass filters in the visible and near infrared with center wavelengths at 340, 380, 440, 500, 670, 870, 940 and 1020. In addition to the solarirradiance measurements which they make with a field of view of 1.2 degrees, these instruments measure the sky radiance in four spectral bands (440, 670, 870 and 1020 nm) along the solar principal plane (i.e., at constant azimuth angle, with varied solar zenith angles) up to nine times a day and along the solar almucantar (i.e., at constant solar zenith angle, with varied azimuth angles) up to six times a day. A preprogrammed sequence of measurements was taken by these instruments starting at an airmass of 7 in the morning and ending at an airmass of 7 in the evening. Airmass is calculated as 1 / cos(solar zenith angle). During the large airmass periods direct sun measurements is made at 0.25 airmass intervals, while at smaller airmasses the interval between measurements is typically 15 minutes. The almucanter measurements are taken at 0.5 degrees intervals near the sun (within 6 deg), and increase from 2 to 10 degree intervals away from the solar position. The data were collected and transmitted via GOES satellite at one hour intervals to a computer at Wallops Island facility [Holben et al., 1996]. The data

were analyzed on a daily basis for aerosol optical thickness, water column abundance and aerosol size.

The two handheld sunphotometers have four channels (500, 670, 870 and 940 nm). They are capable of only the direct solar measurements and require manual data entry. They have a peak hold feature that allows them to record the highest voltage response when pointed in the generaldirection of the sun.

Summary of places and times of measurements:
The 1996 operation periods for the automatic instruments are listed:

Paddockwood, SK	2/27-11/07
NSA-YJP, MB	5/14-9/24, 9/30-10/09
SSA-YJP, SK	5/10-5/14, 5/28-9/20, 10/01-10/23
Waskesiu, SK	5/08-5/14, 5/23-9/04, 9/29-10/27
Thompson, MB	5/14-10/09

The handheld instruments were located at Thompson, MB and Waskesiu, SK and operated continuously throughout 1996.

Known problems or caveats:
Some intermittent problems occurred with the Paddockwood instrument when an exposed lens was occasionally slow to dry after rainstorms. This condition also occurred less frequently at other locations. Such events produced artificially high aerosol optical depths until the lens dried, and are readily identifiable on inspection of the diurnal pattern of measurements.

Final calibration values have not been established for all sunphotometers, however it appears that the instruments have been relatively stable throughout the season, and calibration is expected to change little for most wavelength channels.

Reference:
Holben, B.N., T.F. Eck, I. Slutsker, D. Tanré, J.P. Buis, A. Setzer, E. Vermote, J.A. Reagan, Y.J. Kaufman, T. Nakajima, F. Lavenu and I. Jankowiak, Automatic sun and sky scanning radiometer system for network aerosol monitoring, to be in Remote Sens. Environ.

5.6.6 RSS-15
PI Name: K. Jon Ranson - NASA/GSFC
Collaborators: G. Sun - SSAI, S. Fifer - Hughes STX, B. Montgomery - Hughes STX, R. Lang - George Washington University, N. Chauhan - GWU

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

Objective of study:
1) Estimate woody bimass density for several stands in the BOREAS SSA
2) Acquire spruce tree and stand measurements required for radar backscatter models

Types of data collected, equipment used:
1) Biomass: Diameter Breast Height, Species of all trees in five circular plots also heights of selected trees within plots, DBH tapes, inclinometers, measuring tapes.
2) Tree architecture: inclinometers, tapes, calipers, rulers, Dielectric constants: dielectric probes.

Summary of places and times of measurements:
1) Biomass plot locations were near OBS site (Black Spruce) , White Swan lake (White spruce+aspen), South Candle Lake (White spruce+aspen, aspen), west Candle Lake (aspen). Daylight hours July 31-August 6, 1996.
2) Geometry: OBS vicinity, daylight hours August 14-20, 1996

Known problems or caveats:
None

5.6.7 RSS-16
PI Name: S. Saatchi - NASA/JPL
Co-I Names: J. VanZyl - NASA/JPL, M. Mogaddam - NASA/JPL, and E. Engman - NASA/GSFC

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

5.6.8 RSS-18
PI Name: R. Green - NASA/JPL

Title: Surface and Atmosphere Measurements and Radiative Transfer Modeling for the Calibration and Validation of the Airborne Visible-Infrared Imaging Spectrometer (AVIRIS) for Quantitative Data Analysis at BOREAS

5.6.9 RSS-19
PI Name: J.R. Miller - York University
Collaborators: N. O'Neill - Sherbrooke University, A. Royer - Sherbrooke University, E. LeDrew - University of Waterloo, J. Chen - CCRS, D. Jelinski -University of Nebraska, Lincoln, H. McCaughey - Queen's University, J. Bubier - McGill University, T. Moore - McGill University, J. Harden - USGS, R. Bukata - NWRI, R. Desjardin - Agriculture Canada

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

Objective of study:
To redeploy an enhanced Compact Airborne Spectrographic Imager (CASI) in 1996 to evaluate the robustness of algorithms currently being developed using 1994 BOREAS data. The CASI sensor will be configured to mimic MODIS bands between 400 and 960 (Bands

1,2,3,4, 8-19) and provide 1 metre spatial resolution imagery over target sites, permitting ambiguities related to spatial hetrogeneity in model-based algorithm evaluation for interpretation of canopy BRDF and canopy cover to be addressed with actual airborne data. Specific science objectives are as in the BOREAS '96 plan Vol II.

Types of data collected, equipment used:
CASI sensor used. Image data acquired at altitudes ranging from 500 ft to 10,000 ft above ground level providing image resolutions ranging from sub-meter to 4 meters.

Summary of places and times of measurements:
Period: July 8 to August 1, 1996
Locations: 1) All Flux Tower Sites, NSA and SSA
2) SSA: Lake Waskesiu (for Bukata (TE-15))
3) SSA: Agriculture Line (for Desjardins (TF-7))
4) SSA: AFM Grid (for Desjardins/Schuepp (TF-7))
5) SSA: RSS-19 cal site (for O'Neill (RSS-19))
6) SSA: OBS high spatial resolution grid
7) NSA: 21 new aux. sites north of Gillam for variable LAI (for Cheng (RSS-7))
8) NSA: Fen high spatial resolution grid
9) NSA: burn line (for Harding (HYD-5))

Comments:
Problems encountered in 1994 with up- and down- spectral irradiance measurements were recitified. 1996 data will now permit previous plan to examine albedo spatial variability to be addressed from low level (500 ft passes over TF sites).

6.0 BOREAS Information System (BORIS)

During the BOREAS planning and data collection period, the BORIS functions have included:
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 development and data handling efforts of BORIS were 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 were likely to change as BOREAS progressed, BORIS was 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 divided its handling of the data sets based on their size. Those that were too large to easily store on-line (i.e., image data) were kept off-line on 8 mm tapes and those that were small enough to be kept on-line were placed in a structured set of directories on a disk on the BOREAS.GSFC.NASA.GOV system. The data were accessible by all BOREAS investigators and concerted efforts were made to provide rapid responses to questions and requests for available data. Information about the experiment and data (for authorized users) are accessable through the World-Wide Web at http://boreas.gsfc.nasa.gov/. For the image data stored off-line, BORIS placed data base inventory listings of the current holdings in the specific directories. These inventory listings were 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 organization and storage of the on-line data followed the experiment plan. The two top directories of DATA and SOFTWARE divide the data holdings from available software. The DATA directory contains a series of sub-directories for the various science groups, teams, and data sets. In a similar fashion, the STAFF sub-directory is divided into the various staff data components.

In order to access the on-line data and inventory information, BORIS implemented access via the World-Wide Web (WWW) and established user accounts on the BOREAS.GSFC.NASA.GOV system. 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 were informed of the periodic password changes by email. The password was posted on the electronic bulletin board of the BOREAS.GSFC.NASA.GOV system for access by those with system accounts.
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. Graphs showing on-line data access via the WWW and FTP for January to December 1996 are given as figures 6.2-1 and 6.2-2.

User support personnel were 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 are obtainable by contacting Beth McCowan.

6.3 Data and Documentation Submission and Distribution

6.3.1 General Information

BORIS expects 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 encouraged 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. As new data versions are added, the 0_README.TXT and documentation 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 easier. For the point source measurements, the most common file format is a tabular ASCII (American Standard Code for Information Interchange) 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 uses 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 works 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 encourages 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. The Canada Centre for Remote Sensing (CCRS) and BORIS staff have processed the level-3s products delivered by CCRS to level-3a products with the following file structure:

```
FILE 1 (90 byte ASCII text records)

FILES 2 - 8 (A band sequential set of files containing image bands 1 to 7,
             respectively.)
```

6.3.3 Measurement Units

A significant help to BORIS is having data submitted with date, time, and measurement fields in a consistent and standard form with appropriate measurement units. Certain reporting formats and measurement unit standards were 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/(m^2 * second)

Radiometric measurements in units of Watts/(m^2 * steradian * micrometer) except those for Photosynthetically Active Radiation (PAR) which should be expressed as microEinsteins/(m^2 * 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 WWW site contains the current version of the annotated documentation outline with samples of various data set documents.

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 data that BORIS has for each of the science team and staff data sets is shown in the following tables.

Aircraft Flux and Meteorology (AFM)

Group	Data Set	Dates Available
AFM-01	Moving Window	IFC-1, IFC-2, IFC-3
AFM-02	Preliminary Aircraft Flux	IFC-1, IFC-2, IFC-3
	Moving Window	IFC-1, IFC-2, IFC-3
	Sounding	IFC-1, IFC-2, IFC-3
AFM-03	Preliminary Aircraft Flux	IFC-1, IFC-2, IFC-3
	40 km Sub-legs Moving Window	IFC-1, IFC-2, IFC-3
	LIDAR	IFC-1, IFC-2, IFC-3
	Sounding	No Data Received
AFM-04	Preliminary Aircraft Flux	1994 and 1996
	Sounding	1994 and 1996
AFM-05	AES Upper Air Level-0	IFC93, 1994
	AES Upper Air Level-1	IFC93, 1994, 1996
	AES Upper Air Level-2	IFC93, 1994, 1996
AFM-06		
Profiler	Mean Wind Profiles	May --> Sep 94
	Mean Temperature Profiles	May --> Sep 94
	Boundary Layer Heights	May --> Sep 94
	Surface Met Data	May --> Sep 94
Radar	Vertical Doppler Radar	16-Jul-94 --> 8-Aug-94
	Conical Scan Doppler Radar	No Data Received
AFM-07	SRC Met Data	15-Dec-93 --> December 1996
AFM-08	Boundary Layer Modeling	No Data Received
AFM-09	BATS Modeling	No Data Received
AFM-11	Aircraft Flux Analyses	No Data Received
AFM-12/Staff	Regional AVHRR Classification	1994
AFM-14	SiB2 Model	No Data Received
AFM-15	CCC GCM	No Data Received

Hydrology (HYD)

Group	Data Set	Dates Available
HYD-01	Soil Moisture (volumetric)	1994
	Soil Hydraulic Properties	NSA, SSA Tower sites (except fen)
	Under Canopy Precipitation	1994
HYD-02	Microwave Measurements	Feb-94
	Snow Water Equivalent from microwave	No Data Received
HYD-03	Sub-canopy Radiation from SSA OJP	1994 and 1996
	Canopy Wind Speed (2 meters SSA-OJP)	1994 and 1996
	Snow Temperature Profiles	1994 and 1996
	Canopy Density	Feb, Apr-94
	Snow Depth and Water Equivalent	1994 and 1996
HYD-04	Standard Snow Course	1994, 1995
	Snow Water Equivalent from satellite	No Data Received
	Special Snow Course	1994
HYD-05	Snow Fuxes	No Data Received
	SVAT Modeling	No Data Received
HYD-06	Gamma Aircraft Soil Moisture	1994
	Ground-based Soil Moisture	1994
	Ground-based Moss Moisture	1994
HYD-08	Moss Monitoring Data	1994 and 1996
	Canopy Interception	1996
	Forest Floor Interception	1996
	Digital Elevation Model	Circa 1978
HYD-9	Belfort Rain Gauge	1994 and 1995
	Tipping Bucket Rain Gauge	1994 and 1995
	Stream Gauging	IFC-1, IFC-2, IFC-3
	Radar Precipitation	IFC-1, IFC-2, IFC-3
	Standpipe Observation	No Data Received

Tower Fluxes (TF)

Group	Data Set	Dates Available
TF-1	SSA-OA Flux Data	1993 --> 1994
	SSA-OA Met Data	1993 --> 1994
	SSA-OA CH_4, NO_2 Flux	1994
	SSA-OA Soils Data	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, 1995, 1996
	NSA-OBS Met Data	1993, 1994, 1995, 1996
	NSA-OBS Soils Data	1993, 1994, 1995, 1996
	NSA-OBS Soil Chamber Data	1995, 1996
TF-4	SSA-YJP Flux Data	26-May --> 20-Sep-94
	SSA-YJP Met Data	IFC93, 15-May-94 --> 20-Sep-94
	SSA-YJP Canopy Met Data	1994
	SSA-YJP Soils Data	1994
TF-5	SSA-OJP Flux Data	1993, 1994
	SSA-OJP Met Data	1993, 1994
	SSA-OJP under canopy Flux data	1993, 1994
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	1994
	SSA-OBS Met Data	1994
TF-8	NSA-OJP Flux Data	1994
	NSA-OJP Met Data	1994
	NSA-OJP Soils Data	1994
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	1993, 1994
	NSA-YJP Met Data	1993, 1994
	NSA-YJP Porometry	1993
	NSA-Fen Flux Data	1993, 1994
	NSA-Fen Met Data	1993, 1994
TF-11	SSA-Fen Flux Data	1994
	SSA-Fen Met Data	1994
	SSA-Fen Chamber Data	1994

Trace Gas Biogeochemistry (TGB)

Group	Data Set	Dates Available
TGB-01		
Chamber Flux	CH_4, CO_2, SF4	1994
Tower Flux	CH_4	1994
Tracers	Rn	No Data Received
Soil Profiles	CH_4 and CO_2	1994
DIC		No Data Received
NEE		No Data Received
TGB-03		No Data Received
Gas Flux	CH_4, CO_2	1994, 1996
	CO_2 and PAR	1994
Soil Profiles	CH_4, CO_2	1994, 1996
	Water table and peat temperature	1994
Substrate	DOC	1994, 1996
TGB-04		
Substrate	Water Table and sediment temperature	1994
Tower Flux	NSA Beaver Pond	1994
TGB-05		
Gas Flux	CH_4, CO_2, CO, NO, N_2O	1994
Soil Profiles	CH_4, CO_2	No Data Received
Substrate	DOC fract'n, DIC, DOC	1993, 1994
TGB-06		
Isotopes Flux	$d^{13}CH_4$, D/H	No Data Received
Substrate	DH_2O	No Data Received
TGB-07		
Tower Trace Gas	Herbicides, Organic Chlorine	1993, 1994
TGB-08		
Tower Trace Gas	Monoterpene	1994
Starch	Starch	1994
Photosynthesis	Photosynthesis	1994
TGB-09		
Tower Trace Gas	NMHC Mixing Ratio	1994
	Isoprene Concentration	1994
TGB-10		
Tower Trace Gas	NMHC, O_3/H_2O_2, Peroxides	1994
TGB-12		
Gas Flux	Winter Flux	14-Nov-93 --> 27-Apr-94
Isotopes Soil Gas	$d^{13}CO_2$, $d^{14}CO_2$	1994
	^{14}C(dom)	Aug 93, Aug 94
	soil C	No Data Received
	soil N	Aug 93, Aug 94
Tower	Soil Temp, Other Soils Data	Aug 93, Aug 94

Terrestrial Ecology (TE)

Group	Data Set	Dates Available
TE-01		
Gas Flux	CH_4	SSA 1994
Soil Profiles	CH_4, CO_2	No Data Received
Soils Data	SSA Soil properties	SSA 1994
	SSA Vector Soil Map	Circa 1994
TE-02	Leaf Respiration	NSA 1994
	Leaf Conductance	NSA 1994
	Bole Respiration	NSA 1994
	Leaf Nitrogen	No Data Received
	Wood Nitrogen	No Data Received
	Sap Flow	No Data Received
TE-04	Leaf Photosynthesis	1994
	Leaf Respiration	1994
	Leaf Conductance	1994
	Leaf Optical Properties	1994
TE-05	Air Stable Isotope	NSA/SSA 1994
	CO_2 Profile	NSA/SSA 1994
	Gas Exchange	NSA/SSA 1994
	Leaf carbon isotope	NSA/SSA 1994
	Meteorological data	NSA/SSA 1994
	Tree Ring Data	No Data Received
TE-06	Biometry	No Data Received
	Allometry	No Data Received
	Net Primary Production	NSA/SSA/Aux 1994
	Predawn leaf water potential	NSA/SSA/Aux 1994
	Site Characteristics	NSA/SSA/Aux 1994
	Temperature	NSA 1996
	Soil CO_2 Flux	No Data Received
TE-07	Leaf Photosynthesis	No Data Received
	Leaf Conductance	No Data Received
	Litterfall	No Data Received
	biomery/allometry ringwidth/density	No Data Received
	Sap flow	SSA 1994
TE-08	Bark Chlorophyll	No Data Received
	Bark optical properties	SSA 1994
TE-09	Photosynthetic Response to CO_2, Light, Temperature, VPD, Water Potential	NSA 1994
	Leaf biochemistry	NSA 1994
	Understory Reflectance	NSA 1994
	N vs PAR Profile	NSA 1994
	N vs Photosynthesis	NSA 1994
	Diurnal Gas Exchange	No Data Received
	Chlorophyl	NSA 1994

Terrestrial Ecology (TE) (continued)

Group	Data Set	Dates Available
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
	Sap flow	SSA 1994
	Lichen and Moss Photosynthesis	No Data Received
TE-12	Shoot Geomtery	1994
	Leaf Optical Properties	1994
	Leaf Gas Exchange	No Data Received
	Shoot bidirectional data	1994
	Leaf Nitrogen	No Data Received
	Leaf water potential	1994
	Canopy PAR transmittance	No Data Received
	Leaf PAR properties	No Data Received
TE-13	Biometry	1994
	Allometry	No Data Received
	Tree ring/cores	No Data Received
TE-14	NCAR CCM	No Data Received
TE-15	Limnological Carbon Modeling	No Data Received
TE-16	Leaf area index	No Data Received
TE-17	NPP via PEM	No Data Received
TE-18	Landsat TM Classifications	NSA/SSA 1994
	Biophysical Parameter Maps	No Data Received
TE-19	BCM3 Model	Test Data
TE-20	Biometry	SSA 1994
	Stem Maps	No Data Received
	Models - FroST, Tower Flux, Gap, HYBRID	No Data Received
	NSA Soil Lab Data	1994
	NSA Vector Soils Map	Circa 1994
TE-21	GPP, NPP, NEE, R - tower sites	see RSS-08
	GPP, NPP, NEE, R - 1 km resolution	see RSS-08
	LAI - 1 km resolution	see RSS-08
	Landcover	see RSS-08
	Daily met	see RSS-08
	Carbon and Water Budget Modeling	see RSS-08
TE-22	ZELIG, FED, HYBRID Models	No Data Received
	Stem Maps	NSA/SSA 1994
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

Remote Sensing Sciences (RSS)

Group	Data Set	Dates Available
RSS-01	PARABOLA Data	94 FFC-T, IFC-1, IFC-2
	PARABOLA III Data	No Data Received
	Albedo	No Data Received
RSS-02	BRDF	No Data Received
	ASAS Level-1b images	1994
RSS-03	MMR	1994
	SE-590	No Data Received
	Video	1994
	Aerial Photography (Helo)	No Data Received
	Optical Thickness	No Data Received
RSS-04	fPAR/LAI	1993, 1994
	Foliar Samples	1993, 1994
RSS-05	Model Data	No Data Received
RSS-06	Radiative Transfer Model	No Data Received
RSS-07	fPAR/LAI	1994
	LAI 2000	1994
	AVHRR LAI and fPAR	Region
	Landsat TM LAI and fPAR	SSA
RSS-08	BRDF	IFC-3
	Canopy Photography	IFC-3
	Surface Temperature	No Data Received
	Land Cover	No Data Received
	LAI Map	No Data Received
	NPP, GPP, NEE, R Maps	No Data Received
	Snow Cover	1994, 1995
	BIOME-BGC Results	files for tower sites
RSS-09	Phenology Modeling	No Data Received
RSS-10	PAR. Ozone, UV	No Data Received
RSS-11	Optical Thickness (automatic)	1994, 1996
	Optical Thickness (handheld)	1994, 1996
RSS-12	Optical Thickness (Ground)	IFC-1, IFC-2, IFC-3
	Optical Thickness (C130)	
RSS-13	Scatterometer Data	No Data Received
RSS-14	GOES-7 Level-1 images	1994, 1995
	GOES-7 Level-1a images	1994, 1995
	GOES-7 Level-2 (Surface Rad ASCII)	1994, 1995
	GOES-7 Level-2a (Surface Rad Images)	1994, 1995
	GOES-7 Level-2a Net Longwave images	1994, 1995
	GOES-7 Level-3 Gridded surface radiation	1994, 1995
	GOES-8 Level-1 images	1995, 1996
	GOES-8 Level-1a Images	1995, 1996
	GOES-8 Level-2 images	No Data Received

Remote Sensing Sciences (RSS) **(continued)**

Group	Data Set	Dates Available
RSS-15	Biomass	No Data Received
RSS-16	AirSAR CM Level-3b	1993, 1994
	AirSAR SY Level-3b	1993, 1994
	Parameter maps (LAI, Water Content, Biomass)	No Data Received
	Model analysis results	No Data Received
RSS-17	Air, soil, stem temperature	1994
	Dielectric profiles	No Data Received
	Xylem flux	No Data Received
	Freeze/Thaw maps	1994
RSS-18	Ground Reflectance	No Data Received
	Optical Thickness	IFC-1, IFC-3
	AVIRIS Level-1b Images	1994, 1996
	AVIRIS Parameter Maps	No Data Received
RSS-19	Reflectance spectra	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
	POLDER Data	1994

Staff

Group	Data Set	Dates Available
Staff Sat. Images	AVHRR Level-3b	1994, 1995
	AVHRR Level-4b	1994
	AVHRR Level-4c	1994
	JERS Level-0	1994
	Landsat TM Level-3s (CCRS systematic)	1984 --> 1996
	Landsat TM Level-3p (CCRS precision)	1988, 1989, 1991, 1994
	Landsat TM Level-3a (BORIS BSQ DN)	1984 --> 1996
	Landsat TM Level-3b (BORIS BSQ Rad)	1984 --> 1996
	Landsat MSS Level-1	1972 --> 1978
	SPOT Level-3s (CCRS systematic)	1993 --> 1996
	SPOT Level-3a	Not Yet Available
	SPOT Level-3b	Not Yet Available
Staff Aircraft Images	AOCI Level-0	94 IFC-2
	Daedalus TMS Level-0	94 IFC-3
	C130 Navigation Data	1994 flights
	MAS Level-0 BSQ	21-Jul-94 SSA
	MAS Level-1b (HDF)	21-Jul-94 SSA
	MAS Level-1b (BSQ)	21-Jul-94 SSA, 04-Aug-94 NSA
	MAS Level-2	21-Jul-94
	NS001 Level-0	1994
	NS001Level-1a	Not Yet Available
	NS001 Level-1b	Not Yet Available
	NS001Level-2	Not Yet Available
	TIMS Level-0	94 FFC-T, IFC-3
	TIMS Level-1b	94 FFC-T, IFC-3
	ER2 Navigation Data	1994
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
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
Staff Analog Data	C130 Photography	1994
	C130 Flight Logs	1994
	C130 Videos Tapes	IFC-3
	ER2 Photography	1994, 1996
	ER2 Flight Logs	1994, 1996
	Hardcopy Maps	1971 --> 1993
	PI Reports	Miscellaneous
	Publications	Miscellaneous

Staff **(continued)**

Group	Data Set	Dates Available
CanSIS/Staff	Region Vector Soils (1:1M)	circa 1984
Staff	Region Raster Soils (1:1M)	circa 1984
CanSIS/Staff	SSA Vector Soils (1:125K)	28-Aug-87 --> 14-Feb-89
Staff	SSA Raster Soils (1:125K)	28-Aug-87 --> 14-Feb-89
MNR/Staff	NSA Vector ForCover (1:15840)	circa 1988 (BORIS use Only)
Staff	NSA Raster ForCover (1:15840)	circa 1988
SERm/Staff	SSA, EOPP, NOPP Vector ForCover (1:12500)	circa 1988
Staff	SSA Raster ForCover (1:12500)	circa 1988
PANP/Staff	PANP Vector ForCover (1:50K)	circa 1978
SERM/Staff	Saskatchewan Vector ForCover (1:1M)	circa 1988
Geomatics/Staff	NSA Vector Topo (1:250K)	Preliminary
Geomatics/Staff	SSA Vector Topo (1:250K)	Preliminary
Geomatics/Staff	NSA Vector Topo (1:50K)	circa 1978
Geomatics/Staff	SSA Vector Topo (1:50K)	circa 1978
Staff	NSA and SSA Elevation Contours (1:50K)	circa 1978
HYD-08/Staff	NSA Raster UTM DTM (1:50K)	circa 1978
Staff	NSA Raster AEAC DTM (1:50K)	circa 1978
HYD-08/Staff	SSA Raster UTM DTM (1:50K)	circa 1978
Staff	SSA Raster AEAC DTM (1:50K)	circa 1978
EDC/Staff	Region Raster Lat/Long DTM (1:1M)	Available
Staff	Region Raster AEAC DTM (1:1M)	Available
TGB-05/Staff	Manitoba Vector FireHist (1:125K)	1980 --> 1992
Staff	Manitoba Raster FireHist (1:125K)	1980 --> 1992
SERM/Staff	Saskatchewan Vector FireHist (1:125K)	1943 --> 1989
Staff/TE-01	SSA Raster Tower Soils	1994
Staff/TE-20	NSA Raster Tower Soils	1994

6.5 The BOREAS Grid System

A key element of the information system effort was 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 18 degrees of longitude (93° W to 111° W) and 9 degrees of latitude (51° N to 60° N) area. Based on previous experience, 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, 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 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 working to meet a December 1997 deadline of having the data integrated into the on-line data base and documented. 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 and likely into the initial phases of the follow-on research efforts. However, as BOREAS staff and science teams complete needed data manipulations, quality checks, and documentation, the data will be handed off to the EOSDIS ORNL DAAC as the long term archive center. The Earth Observing System Data and Information System (EOSDIS) Oak Ridge National Laboratory (ORNL) Distributed Active Archive Center (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
Bldg. 1507, MS-6407
Oak Ridge, TN 37830-6407
phone: 423-376-2655
fax: 423-574-4665
internet: mjg@walden.rmt.utk.edu

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.