

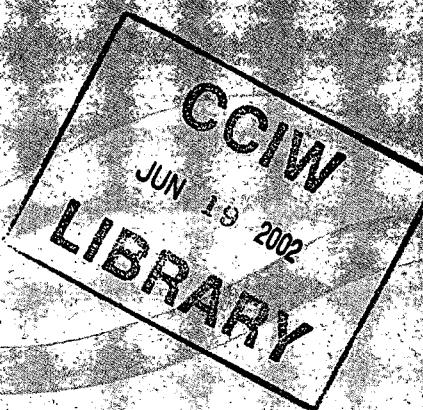
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**WOLF CREEK DATA INDEX REPORT  
1993-2001**

**Hedstrom, N.R., R.J. Granger, D.K. Bayne  
and R. Janowicz**

**NWRI Technical Report No. AEI-TN-02-001**

# **WOLF CREEK DATA INDEX**

**1993 – 2001**



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## **Management Perspective**

The project began as a component of Indian and Northern Affairs Canada's Arctic Environmental Strategy, in partnership with Environment Canada's National Hydrology Research Institute and was designed to improve knowledge of Yukon waters. The process information gained at Wolf Creek can be transferred to other parts of the Yukon for input to flood forecasting, environmental impact assessments, and water license reviews. In 1994 the site was adopted as a Canadian Global Energy and Water Cycle Experiment (GEWEX) Program site, linked with the World Climate Program. The goal of the GEWEX program is to help develop accurate computer models of energy and water balance processes in order to learn more about the effects of climate change. Wolf Creek was the third site in Canada to join the GEWEX program. In 1997, Wolf Creek was added to the list of about one hundred stations making up Canada's Ecological Monitoring and Assessment Network (EMAN). The goal of EMAN is to monitor environmental stress on Canadian ecosystems, particularly on the plants and animals that are part of them. A Smithsonian Institute/ Man and the Biosphere biodiversity plot was established in 1998. In conjunction with the Smithsonian Institution/Man and the Biosphere Biological Diversity Program (SI/MAB) an extensive long term biodiversity monitoring component of EMAN has been established by Environment Canada's Canadian Wildlife Service to provide data for comparative assessments of biodiversity. Established within the lower boreal forest ecosystem to document and monitor plant diversity, the one-hectare forest inventory plot provides the ability for obtaining long term data on growth, mortality, regeneration and dynamics of forest trees. The surveyed forest diversity data will be archived in an international database (MABflora). International Tundra Experiment (ITEX) sites were also established the same year. The Wolf Creek Project has expanded to include research activities consisting of vegetation, fishery and wildlife components leading a full integration of the overall project. More than 30 separate research and monitoring projects are now under way or have been completed by government agencies. These include: Indian and Northern Affairs Canada (Water and Forest Resources), Environment Canada (National Hydrology Research Centre, Canadian Wildlife Service, Environmental Protection, Atmospheric Environment Branch), Agriculture Canada, Fisheries and Oceans Canada, Yukon Renewable Resources, Universities (Saskatchewan, Simon Fraser, Ottawa, Waterloo, McMaster, British Columbia, Quebec, York) Yukon College, Whitehorse schools and public interest groups (Yukon Conservation Society and Yukon Fish and Game Club). The Wolf Creek studies offer opportunities for broad educational use. Yukon College uses data from Wolf Creek for student demonstrations, field exercises, and laboratory assignments. Since the Wolf Creek Drainage basin is so close to Whitehorse, it also gives school classes a chance to see science in action.

The success of the project can be attributed to its great diversity, close proximity to Whitehorse, easy access, and well-established meteorological monitoring infrastructure and logistical support.

## **Sommaire à l'intention de la Direction**

Au début, le projet était une composante de la Stratégie pour l'environnement arctique du ministère des Affaires indiennes et du Nord canadien, en partenariat avec l'Institut national de recherches hydrologiques d'Environnement Canada; le projet devait servir à mieux connaître les eaux du Yukon. L'information sur les processus acquise au ruisseau Wolf peut être adaptée à d'autres parties du Yukon et servir pour la prévision des crues, les évaluations d'impacts environnementaux et les examens concernant les permis d'exploitation hydraulique. En 1994, ce site a été adopté dans le cadre du programme de l'Expérience mondiale sur les cycles de l'énergie et de l'eau (GEWEX), lié au Programme climatologique mondial. L'objectif du programme GEWEX est de faciliter l'élaboration de modèles informatisés précis des processus du bilan énergétique et hydrique de façon à pouvoir mieux comprendre les effets du changement climatique. Le ruisseau Wolf était le troisième site au Canada à faire partie du programme GEWEX. En 1997, le ruisseau Wolf a été ajouté à la liste d'environ cent stations constituant le Réseau d'évaluation et de surveillance écologiques (RESE) du Canada. L'objectif du RESE est de surveiller les contraintes environnementales s'exerçant sur les écosystèmes canadiens, et particulièrement sur les végétaux et les animaux qui en font partie. En 1998, le Smithsonian Institute (SI) a créé une parcelle dans le cadre de l'étude de la biodiversité du programme « L'homme et la biosphère » (MAB). Conjointement à ce programme SI/MAB, le Service canadien de la faune d'Environnement Canada a mis en œuvre une composante de surveillance étendue et à long terme de la biodiversité dans le cadre du RESE, de façon à recueillir des données aux fins d'évaluations comparatives de la biodiversité. Établie à l'intérieur de l'écosystème de la forêt boréale inférieure afin de documenter et de surveiller la diversité végétale, la parcelle de 1 hectare de l'inventaire forestier permet de recueillir des données à long terme sur la croissance, la mortalité, la régénération et la dynamique des arbres forestiers. Les données sur la diversité de la forêt ainsi étudiée seront archivées dans une base de données internationales (MABflora). La même année, des sites ont également été créés dans le cadre de l'International Tundra Experiment (ITEX).

Le projet du ruisseau Wolf a été élargi pour inclure des activités de recherche portant sur la végétation, les pêches et la faune, activités qui ont conduit à une intégration complète de l'ensemble du projet. Plus de 30 projets distincts de recherche et de surveillance sont maintenant en cours ou ont été parachevés par divers organismes gouvernementaux ou autres. Parmi ces organismes, on peut citer les suivants : ministère des Affaires indiennes et du Nord canadien (Ressources en eaux et en forêts), Environnement Canada (Centre national de recherche en hydrologie, Service canadien de la faune, Protection de l'environnement, Direction de l'environnement atmosphérique), Agriculture Canada, Pêches et Océans Canada, Richesses renouvelables Yukon, Universités (Saskatchewan, Simon Fraser, Ottawa, Waterloo, McMaster, Colombie-Britannique, Québec, York) Yukon College, écoles et groupes de défense de l'intérêt public de Whitehorse (Yukon Conservation Society et Yukon Fish and Game Club). Les études du ruisseau Wolf offrent de vastes possibilités d'application en éducation. Le Yukon College utilise les données du ruisseau Wolf pour des démonstrations, des exercices sur le terrain et des travaux de laboratoire à l'intention des étudiants. Enfin, comme le bassin hydrographique du ruisseau Wolf est situé tout près de Whitehorse, les classes des écoles ont une chance unique de voir concrètement la science en action.

Le succès du projet peut être attribué à sa grande diversité, à sa proximité immédiate de Whitehorse, à sa facilité d'accès, ainsi qu'au support logistique et à l'infrastructure de surveillance météo déjà bien établis.

## **Abstract**

The Wolf Creek Research Basin was established in 1992 to primarily carry out water related studies. Since that time the project has evolved into a fully integrated, multidisciplinary research project which includes studies of climate and climate change, vegetation, forestry, fisheries and wildlife. Wolf Creek is located 15 kilometres south of Whitehorse. A tributary to the Yukon River, the basin has a drainage area of 195 square kilometres. With a relief of 1300 metres, the watershed is quite diverse, ranging from rugged mountaintop to thick boreal forest. The basin has a sub-arctic continental climate, which is characterized by a large variation in temperature, low relative humidity and relatively low precipitation. Mean annual temperature is in the order of -3°C, with summer and winter monthly mean temperatures ranging from 5° to 15° and -10° to -20°C respectively. Summer and winter extremes of 25° and -40°C are not uncommon. An Arctic inversion develops during the winter months when air temperature can increase with elevation. Mean annual precipitation is 300 to 400 mm with approximately 40 percent falling as snow. Basin streamflow characteristics and response are typical of a mountainous subarctic regime. Streamflow response is characterized by peak flows of 10 to 20 m<sup>3</sup> /s in late May or early June due to snowmelt, with low flows occurring in March. Due to the significant lake storage within the basin and groundwater contribution, minimum winter flows are relatively high, in the order of 0.4 m<sup>3</sup> /s. The basin is susceptible to intense summer rainstorm events which produce secondary peaks. Three meteorological stations were established in 1993 within the three different ecological zones in the drainage basin. These consist of boreal forest, buckbrush taiga (subalpine shrubland), and alpine tundra. Each of the stations monitor air temperature, rainfall, snowfall, wind speed, humidity, solar radiation, snow depth, blowing snow, soil temperature and soil heat flux. The following report details all data collected at the three sites from 1993 to 2001.

## Résumé

Le bassin de recherche du ruisseau Wolf a été créé en 1992, principalement pour des recherches sur les eaux. Depuis cette date, le programme d'études s'est transformé en un projet de recherche multidisciplinaire, pleinement intégré, qui comprend des études sur le climat et le changement climatique, la végétation, la foresterie, les pêches et la faune. Le ruisseau Wolf est situé à 15 km au sud de Whitehorse. Affluent du Yukon, le ruisseau Wolf forme un bassin hydrographique d'une superficie de 195 kilomètres carrés. Avec une dénivellation de 1300 m, le bassin est très diversifié, passant d'un sommet montagneux aride à une épaisse forêt boréale. Le bassin a un climat continental subarctique, caractérisé par une forte variation de température, une faible humidité relative et assez peu de précipitations. La température annuelle moyenne est de l'ordre de -3 °C, et les températures mensuelles moyennes en été et en hiver se situent respectivement dans des plages de 5° à 15° et de -10° à -20 °C. Des températures extrêmes de 25° en été et de -40 °C en hiver ne sont pas exceptionnelles. Une inversion arctique se produit durant les mois d'hiver lorsque la température de l'air peut augmenter avec l'altitude. Les précipitations annuelles moyennes sont de 300 à 400 mm, dont environ 40 pour cent en neige. Les caractéristiques du débit fluvial du bassin sont celles que l'on retrouve généralement dans un régime montagneux subarctique. Le débit est maximal, 10 à 20 m<sup>3</sup>/s, à la fin de mai ou au début de juin lorsqu'il y a fonte des neiges, et il est minimal en mars. Par suite d'un important stockage en milieu lacustre à l'intérieur du bassin et de l'apport d'eaux souterraines, le débit minimal est relativement élevé, de l'ordre de 0,4 m<sup>3</sup>/s, en hiver. Le bassin est exposé à de fortes pluies d'orage en été, qui produisent des pics secondaires. En 1993, trois stations météorologiques ont été créées dans les trois différentes zones écologiques du bassin hydrographique, à savoir la forêt boréale, la végétation arbustive subalpine et la toundra alpine. Chacune des stations enregistre et surveille les éléments suivants : température de l'air, précipitations, chutes de neige, vitesse du vent, humidité, rayonnement solaire, hauteur de neige, poudrerie, température et flux thermique du sol. Le rapport qui suit présente toutes les données recueillies à ces trois stations de 1993 à 2001.

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## LIST OF SYMBOLS AND ABBREVIATIONS

m	meters
cm	centimeters
m/s	meters per second
W/m <sup>2</sup>	Watts per meter squared
°C	degrees Celsius
%	percent
°	degree
V	volts
mb	millibars
mm	millimeters
km <sup>2</sup>	square kilometers
Global	direct solar radiation
TDR	time domain reflectometry
DC	direct current
AC	alternating current
JPEG	digital photo image
SR50	sonic ranging sensor
UDG01	ultrasonic depth gauge
CS615	water content reflectometer
SRG	standard rain gauge
WC	water content
FOV	field of view
N, E, S, W	north, east, south, west
N/A	not available
M	missing data
CRHM	Cold Regions Hydrological Model
CSI	Campbell Scientific Incorporated
NRG	NRG Systems
YSI	Yellow Spring Instrument Company
REBS	Radiation and Energy Balance Systems Incorporated
Texas	Texas Electronics
Li-Cor	Li-Cor Incorporated
RMY	R M Young Company
NWRI	National Water Research Institute
DIAND	Department of Indian and Northern Affairs

## **1. WOLF CREEK STATION CHARACTERISTICS AND SITE DESCRIPTIONS**

The Wolf Creek basin is located 15 kilometres south of Whitehorse, Yukon Territory at approximately 61 degrees north latitude. The basin occupies a 195 km<sup>2</sup> area in the southern Yukon headwater region of the Yukon River. With a northeasterly aspect, elevations range from 800 to 2250 metres with the median elevation at 1325 metres. It is situated within the "Boreal Cordillera Ecozone" straddling the "Southern Yukon Lakes" and "Yukon-Stikine Highlands Ecoregions. The geological makeup is primarily sedimentary in nature comprised mainly of limestone, sandstone, siltstone and conglomerate. Some volcanic materials consisting of andesite and basalt are present with some intrusions of granite. The basin is overlain with a mantle of glacial till ranging from a thin veneer to depths of one to two metres. The deposits consist of glacial, glaciofluvial and glaciolacustrine origins. Fine textured alluvium covers most of the valley floors adjacent to drainages. Upper elevations have shallow deposits of colluvial material with frequent bedrock outcrops present. Valleys are extensively scoured. The lower forest soils are comprised primarily of an orthic regosol with a variable texture ranging from gravel to clay. The parent material is mixed alluvial, lacustrine and morainal material that is poor to well drained. The upland soils are primarily orthic eutric brunisols. The texture ranges from a sandy loam to a gravelly sandy loam. The parent material consists of moderately stony morainal deposits. These soils are fairly well drained. The basin is underlain with a 2 cm volcanic ash layer approximately 10 cm below the surface. The basin is within the discontinuous/scattered permafrost zone with sporadic permafrost at higher elevations.

The basin has a sub-arctic continental climate which is characterized by a large variation in temperature, low relative humidity and relatively low precipitation. Mean annual temperature is in the order of -3°C, with summer and winter monthly mean temperatures ranging from 5° to 15°, and -10 to -20°C respectively. Summer and winter extremes of 25° and -40°C are not uncommon. An Arctic inversion develops during the winter months when air temperature can increase with elevation. Mean annual precipitation is 300 to 400 mm with approximately 40 percent falling as snow.

Basin streamflow characteristics and response are typical of a mountainous subarctic regime. Streamflow response is characterized by peak flows of 10 to 20 m<sup>3</sup> /s in late May or early June due to snowmelt, with low flows occurring in March. Due to the significant lake storage within the basin and groundwater contribution, minimum winter flows are relatively high, in the order of 0.4 m<sup>3</sup> /s. The basin is susceptible to intense summer rainstorm events which produce secondary peaks. Following extremely cold winters, defined as winters with at least 3 consecutive day periods with the mean daily temperature, as measured in Whitehorse, lower than -40°C, an aufeis formation at the outlet of Coal Lake, can completely restrict outflow from the lake and result in the formation of an ice dam. The ice dam has been observed to fail at the onset of snowmelt. The resulting flood wave may, on occasion, produce the annual peak flow in Wolf Creek.

The Wolf Creek watershed consists of three principle ecosystems: alpine tundra, buckbrush taiga (shrub tundra) and boreal forest (spruce, pine, aspen) with proportions of 20, 58 and 22 percent respectively. Treeline is located roughly at 1300 metres.

## 1.1 Alpine Tundra

### **Soils:**

Top 3 cm lichen moss organic, below this a rocky/bouldery mineral soil. Soil profile in Table 1.

**Area represented:** 39 km<sup>2</sup> of basin total (195 km<sup>2</sup>)

**Elevation:** 1615 m

**Location:** 60°34.04 N 135°08.98 W

### **Snow Course:**

Consists of 25 depth points spaced 5 m apart with a snow density every 5th depth (25 m apart). This course extends along the plateau top on a consistent line and is monitored monthly. Twice over the winter (November and February) and once just before spring melt (April) two additional snow courses of similar length may be monitored from the plateau edge, one north and one south going directly downhill.

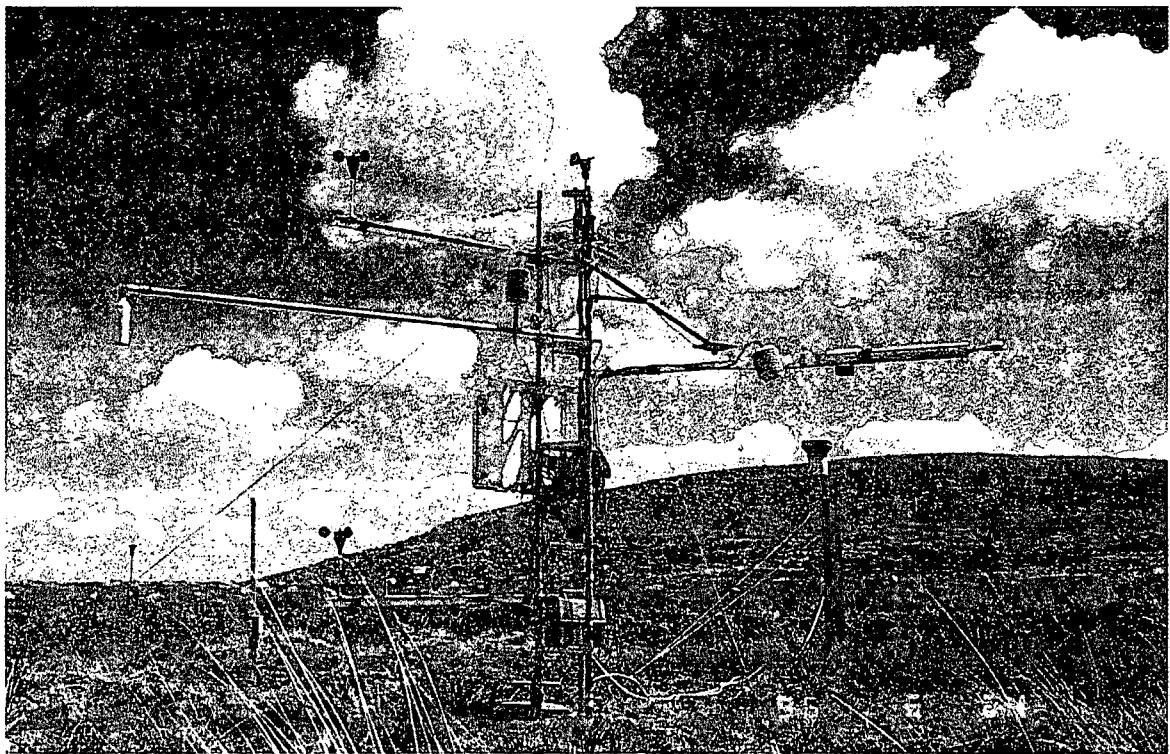
### **Description:**

Area is a wind swept, high alpine tundra plateau along the drainage divide at the northern edge of the basin. A reasonably level fetch extends for several hundred meters to the north, south, and west. A rounded hilltop (35 meters) rises about 50 meters to the east. Vegetation is sparse and consists of mosses and lichens with occasional patches of scrub willow and birch no more than 20 cm tall. Boulders up to 1 m tall are scattered on the plateau (Figures 1, 2, and 3).

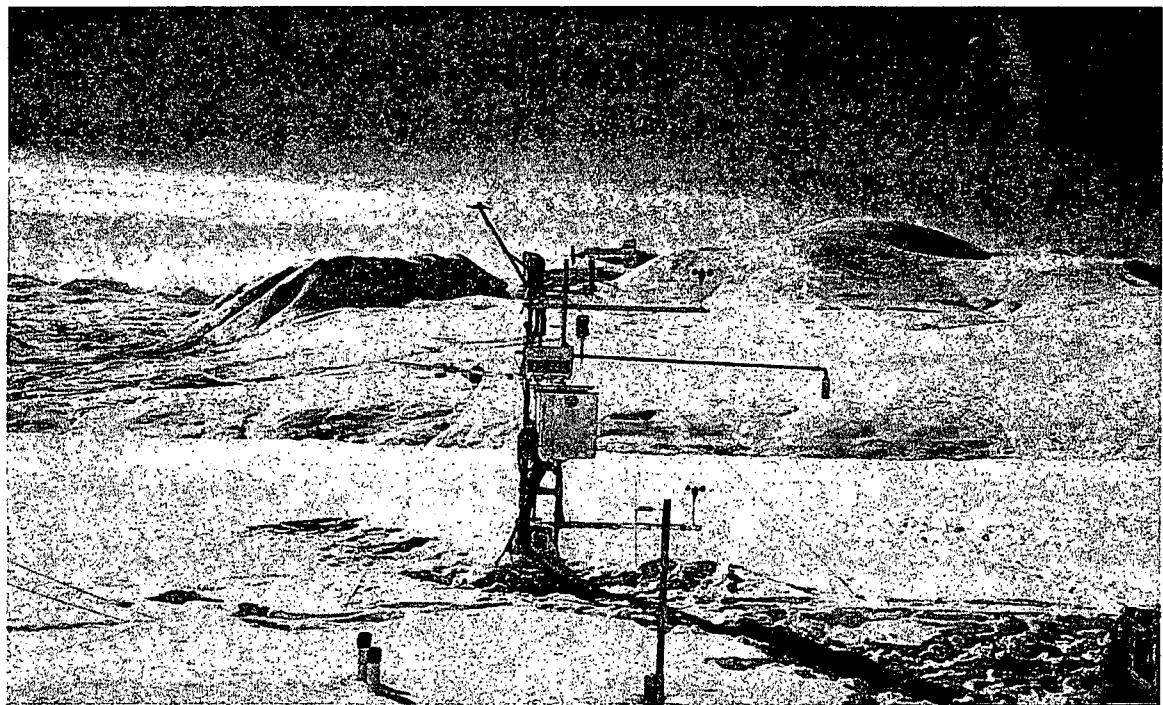
**Figure 1      Alpine site (autumn) looking south towards Coal Lake.**



**Figure 2      Alpine Site (summer) looking east.**



**Figure 3      Alpine Site (winter) looking southwest.**



## 1.2 Buckbrush Taiga

### Soils:

Top 6 cm moss organic, below this an alluvial fan of rocks and silt. Soil profile in Table 1.

**Area represented:** 113 km<sup>2</sup> of basin total (195 km<sup>2</sup>)

**Elevation:** 1250 m

**Location:** 60°31.34 N 135°11.84 W

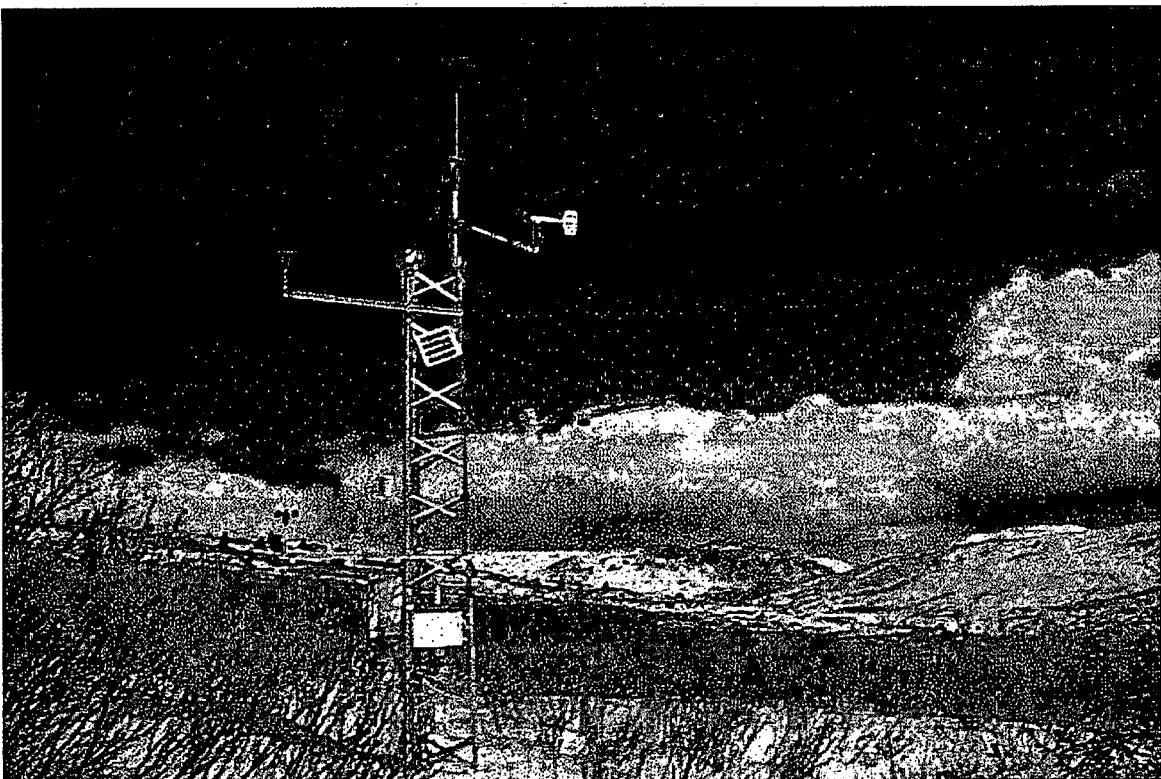
### Snow Course:

Consists of 25 depth points spaced 5 m apart with a snow density every 5th depth (25 m apart). This course extends along the valley side, at 154° magnetic from the nipher snow gauge on a consistent line and is monitored monthly.

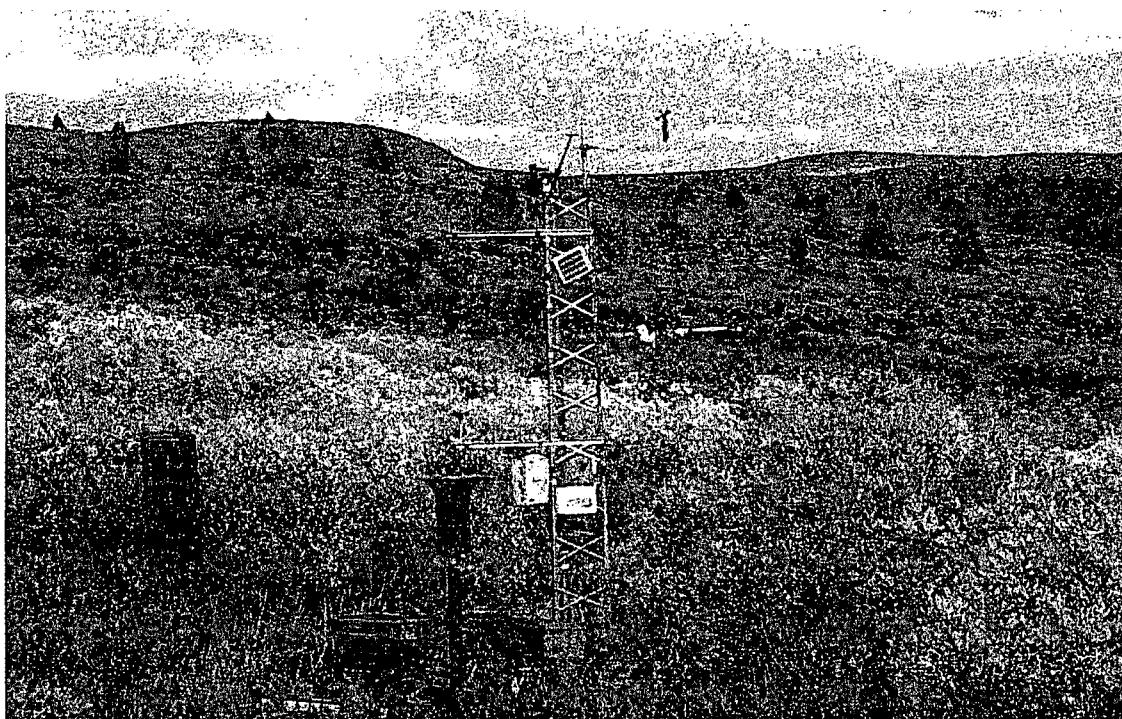
### Description:

Area is near valley bottom between Mt. Granger and Coal Ridge on a drainage divide between the Coal Lake Basin and the highest headwater of Mt. Granger. Vegetation is bushy, consisting of tall willows and alders (1-3 m) with sparsely scattered spruce (spaced about 100 m apart). A sloping fetch extends NE and SW for several kilometers. To the NW, the valley slopes upwards and to the SE the valley drops somewhat before rising to Coal Ridge (Figures 4 and 5).

**Figure 4**      **Buckbrush Site (winter) looking northeast.**



**Figure 5** Looking north at Buckbrush site (summer).



### **1.3 White Spruce Forest**

#### **Soils:**

Top 10 - 15 cm moss organic, below this silt loam to 1.4 m and river gravel below this. Soil profile in Table 1.

**Area represented:** 43 km<sup>2</sup> of basin total (195 km<sup>2</sup>)

**Elevation:** 750 m

**Location:** 60°35.76 N 134°57.17 W

#### **Snow Course:**

Consists of 25 depth points spaced 5 m apart with a snow density every 5th depth (25 m apart). This course extends through the forest sampling between trees and under branches on a consistent line and is monitored monthly.

#### **Description:**

#### **Site 1 & 2**

A mature white spruce forest (15 -18 m) on a flat valley bottom located near the Wolf Creek basin outlet. The tower is located in dense canopy of similar sized trees (Figure 6). The Whitehorse Cadet camp is 50 m NE of the mast, white spruce forest covers the adjacent lands except for the camp.

### **Site 3**

A mature white spruce forest (12 -18 m) on a flat valley bottom located near the Wolf Creek basin outlet. The tower is located in dense canopy amongst trees with a wider range of heights (Figure 7). A 10 m wide clearing, 15 m west of the tower allows for canopy free precipitation measurements.

**Figure 6      Forest site (winter) looking towards top of tower.**



**Figure 7      Forest 3 (spring) site looking down from top of tower.**



**Table 1 Soil Analysis**

sample description	total sand (%)	total silt (%)	total clay (%)	texture	location
Ap 0 - 5 cm	46.7	36.3	17.0	L	Alpine
Ap 5 - 15 cm	62.2	28.5	9.3	SL	Alpine
Ap 15 - 30 cm	76.7	19.5	3.8	LS	Alpine
BB 0 - 15 cm	21.0	57.7	21.4	SiLBuckbrush	
BB 15 - 30 cm	49.2	29.6	21.2	L	Buckbrush
F1 0 - 30 cm	63.6	29.3	7.1	SL	Forest 1-main tower
F2 10 - 30 cm	72.7	19.8	7.5	SL	Forest 2-main tower
F2 30 - 40 cm	47.4	45.0	7.6	L	Forest 2-main tower
F3 0 - 10 cm	37.4	41.0	21.6	L	Forest 3-main tower
F3 10 - 30 cm	66.9	28.1	5.0	SL	Forest 3-main tower
F3 30 - 40 cm	48.2	40.9	10.9	L	Forest 3-main tower
F4 0 - 30 cm	51.1	41.7	7.2	L	Forest 4-main tower

L loam

SL sandy loam

LS loamy sand

SiL silty loam

## 2. METEOROLOGICAL SENSOR DESCRIPTION

All sites use solid state Campbell Scientific Inc. dataloggers with data storage modules. The power is supplied by 12V DC batteries and charged by solar modules.

### 2.1 Alpine Tundra – 3m tower

Sensor	Data Type	Units
Net radiometer	net radiation	W/m <sup>2</sup>
Solarimeter - incoming	direct radiation	W/m <sup>2</sup>
Solarimeter - outgoing	diffuse radiation	W/m <sup>2</sup>
Soil heat flux plate	soil heat flux	W/m <sup>2</sup>
Type E thermocouple	air-snow interface temperature	°C
Barometer	air pressure	mb
Temperature and humidity gauge (2)	air temperature and humidity	°C and %
Infrared surface temperature	surface temperature	°C
Soil thermistor	soil temperature	°C
Cup anemometer (2)	wind speed	m/s
Propeller anemometer	wind speed and direction	m/s and °
Sonic snow gauge	snow depth	mm
Snow particle detector	snowfall particles	hertz
Tipping bucket rain gauge	rainfall precipitation	mm
Nipher shielded snow gauge	snowfall precipitation	mm
Standard rain gauge	rainfall precipitation	mm
Soil thermilinear (2)	soil temperature	°C
TDR (2)	soil moisture	WC
Wind vane	wind direction	°

## 2.2 Buckbrush Taiga – 5.2m tower

Sensor	Data Type	Units
Net radiometer	net radiation	W/m <sup>2</sup>
Solarimeter - incoming	direct radiation	W/m <sup>2</sup>
Solarimeter - outgoing	diffuse radiation	W/m <sup>2</sup>
Soil heat flux plate	soil heat flux	W/m <sup>2</sup>
Type E thermocouple	air-snow interface temperature	°C
Temperature and humidity gauge	air temperature and humidity	°C and %
Infrared surface temperature	surface temperature	°C
Soil thermistor	soil temperature	°C
Cup anemometer (2)	wind speed	m/s
Propeller anemometer	wind speed and direction	m/s and °
Sonic snow gauge	snow depth	mm
Snow particle detector	snowfall particles	hertz
Tipping bucket rain gauge	rainfall precipitation	mm
Nipher shielded snow gauge	snowfall precipitation	mm
Standard rain gauge (2)	rainfall precipitation	mm
Soil thermilinear (4)	soil temperature	°C
TDR (4)	soil moisture	WC

## 2.3 White Spruce Forest – 22m and 15m towers

Sensor	Data Type	Units
<b>Site1</b>		
Net radiometer	upper and lower net radiation	W/m <sup>2</sup>
Tube net radiometer	below canopy net radiation	W/m <sup>2</sup>
Solarimeter - incoming	direct radiation	W/m <sup>2</sup>
Solarimeter - outgoing	diffuse radiation	W/m <sup>2</sup>
Soil heat flux plate	soil heat flux	W/m <sup>2</sup>
Type E thermocouple	air-snow interface temperature	°C
Temperature and humidity gauge (3)	air temperature and humidity	°C and %
Infrared surface temperature	surface temperature	°C
Soil thermistor	soil temperature	°C
Cup anemometer (2)	wind speed	m/s
Sonic snow gauge	snow depth	mm
Snow particle detector	snowfall particles	hertz
Tipping bucket rain gauge	rainfall precipitation	mm
Standard rain gauge (2)	rainfall precipitation	mm
Fotoman	digital image	JPEG
<b>Site 2</b>		
Soil thermilinear (4)	soil temperature	°C
TDR (4)	soil moisture	WC
<b>Site 3</b>		
Propeller wind anemometer (2)	wind speed and direction	m/s and °
Load cell hanging tree	snow weight (tree)	grams
Load cell weighing nipher	snow weight (nipher)	grams
Type E thermocouple	air temperature (tree)	°C
Nipher shielded snow gauge	snowfall precipitation (clearing)	mm
Standard rain gauge (1)	rainfall precipitation (clearing)	mm

### 3. SENSOR INFORMATION AND YEARS OF OPERATION

#### 3.1 Alpine Tundra

##### Sensors:

Manufacturer	Model	Data Type	Years of Operation									
REBS	Q6.0	net radiation	1993	1994	1995	1996	1997	1998	1999	2000	2001	
LiCor	Li200S	direct radiation	1993	1994	1995	1996	1997	1998	1999	2000	2001	
LiCor	Li200S	diffuse radiation	1993	1994	1995	1996	1997	1998	1999	2000	2001	
REBS	HFT-3	soil heat flux	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Omega	Type E	air-snow interface temperature	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Vaisala	PTA 427	air pressure	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Vaisala	HMP35CF	air temperature and humidity (high)	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Everest	60° FOV	surface temperature		1994	1995	1996	1997	1998	1999	2000	2001	
CSI	107B	soil temperature	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Lambrect		wind speed (2)	1993	1994								
NRG	40	wind speed (2)		1994	1995	1996	1997	1998	1999	2000	2001	
RM Young	5103	wind speed and direction					1997	1998	1999	2000	2001	
CSI	UDG01	snow depth	1993	1994	1995	1996	1997	1998	1999	2000	2001	
NWRI	PD32	snowfall particles	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Texas	TE525M	rainfall precipitation	1993	1994	1995	1996	1997	1998	1999	2000	2001	
YSI	40328	soil temperature (2)				1996	1997	1998	1999	2000	2001	
CSI	CS615	soil moisture (2)				1996	1997	1998	1999	2000	2001	
NRG	200P	wind direction	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Nipher		snowfall precipitation	1993	1994	1995	1996	1997	1998	1999	2000	2001	
SRG		rainfall precipitation				1996	1997	1998	1999	2000	2001	
Vaisala	HMP35CF	air temperature and humidity (low)					1998	1999	2000	2001		

### 3.2 Buckbrush Taiga

#### Sensors:

Manufacturer	Model	Data Type	Years of Operation										
REBS	Q6.0	net radiation	1993	1994	1995	1996	1997	1998	1999	2000	2001		
LiCor	Li200S	direct radiation		1995	1996	1997	1998	1999	2000	2001			
LiCor	Li200S	diffuse radiation		1995	1996	1997	1998	1999	2000	2001			
REBS	HFT-3	soil heat flux	1993	1994	1995	1996	1997	1998	1999	2000	2001		
Omega	Type E	air-snow interface temperature	1993	1994	1995	1996	1997	1998	1999	2000	2001		
Vaisala	HMP35CF	air temperature and humidity	1993	1994	1995	1996	1997	1998	1999	2000	2001		
Everest	60° FOV	surface temperature		1994	1995	1996	1997	1998	1999	2000	2001		
CSI	107B	soil temperature	1993	1994	1995	1996	1997	1998	1999	2000	2001		
Lambrect		wind speed (2)	1993	1994									
NRG	40	wind speed (2)		1994	1995	1996	1997	1998	1999	2000	2001		
RMYoung	5103	wind speed and direction					1997	1998	1999	2000	2001		
CSI	UDG01	snow depth	1993	1994	1995	1996	1997	1998	1999	2000	2001		
NWRI	PD32	snowfall particle	1993	1994	1995	1996	1997	1998	1999	2000	2001		
Texas	TE525M	rainfall precipitation	1993	1994	1995	1996	1997	1998	1999	2000	2001		
YSI	40328	soil temperature (4)				1996	1997	1998	1999	2000	2001		
CSI	CS615	soil moisture (4)				1996	1997	1998	1999	2000	2001		
Nipher		snowfall precipitation	1993	1994	1995	1996	1997	1998	1999	2000	2001		
SRG (2)		rainfall precipitation				1996	1997	1998	1999	2000	2001		

### 3.3 White Spruce Forest

#### Sensors:

Manufacturer	Model	Data Type	Years of Operation									
<b>Site 1</b>												
REBS	Q6.0	net radiation - upper	1993	1994	1995	1996	1997	1998	1999	2000	2001	
REBS	Q7.1	net radiation - lower					1997	1998				
Delta-T	TRL	tube net radiation							1999	2000	2001	
LiCor	Li200S	direct radiation			1995	1996	1997	1998	1999	2000	2001	
LiCor	Li200S	diffuse radiation		1994	1995	1996	1997	1998	1999	2000	2001	
REBS	HFT-3	soil heat flux	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Omega	Type E	air-snow interface temperature	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Vaisala	HMP35CF	air temperature and humidity (low)	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Vaisala	HMP35CF	air temperature and humidity (mid)				1996	1997	1998	1999	2000	2001	
Vaisala	HMP35CF	air temperature and humidity (high)		1994	1995	1996	1997	1998	1999	2000	2001	
Everest	60° FOV	surface temperature		1994	1995	1996	1997	1998	1999	2000	2001	
CSI	107B	soil temperature	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Lambrect		wind speed (2)	1993	1994								
NRG	40	wind speed (2)		1994	1995	1996	1997	1998	1999	2000	2001	
CSI	UDG01	snow depth	1993	1994	1995	1996	1997	1998	1999	2000	2001	
NWRI	PD32	snow particles	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Texas	TE525M	rainfall precipitation	1993	1994	1995	1996	1997	1998	1999	2000	2001	
SRG (2)		rainfall precipitation				1996	1997	1998	1999	2000	2001	
Logitech	Fotoman	digital image			1995	1996	1997	1998	1999			
<b>Site 2</b>												
YSI	40328	soil temperature (4)				1996	1997	1998	1999	2000	2001	
CSI	CS615	soil moisture (4)			1996	1997	1998	1999	2000	2001		
<b>Site 3</b>												
RM Young	5103	wind speed and direction (2)				1997	1998	1999	2000	2001		
Sensotec	model 82	snow weight (tree)				1997	1998	1999				
Sensotec	model 31	snow weight (nipher)				1997	1998	1999				
Omega	Type E	air temperature (tree)				1997	1998	1999				
Nipher		snowfall precipitation (clearing)	1993	1994	1995	1996	1997	1998	1999	2000	2001	
SRG		rainfall precipitation (clearing)			1996	1997	1998	1999	2000	2001		

## 4. SENSOR HEIGHTS

### 4.1 Alpine Tundra

All measurements are from ground surface and are in meters.

Data Type	Years of Operation										
	1993	1994	1995	1996	1996 Aug	1997 Sept	1998 Mar	1999	2000	2001	
Net radiation	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	
Direct radiation	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	2.93	
Diffuse radiation	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	
Soil heat flux	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	-0.08	
Soil temperature	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	
Air-snow interface temperature	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Air pressure	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
Air temperature and humidity (high)	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	2.05	
Infrared surface temperature	N/A	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	1.60	
Wind speed (low)	0.66	0.66	0.66	0.66	0.66	0.66	0.85	0.85	0.85	0.85	
Wind speed (high)	2.33	2.33	2.33	2.33	2.33	2.33	2.75	2.75	2.75	2.75	
Wind speed and direction	N/A	N/A	N/A	N/A	N/A	2.79	2.79	2.79	2.79	2.79	
Snow depth	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	1.65	
Snow particles	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	
Soil temperature (5cm)	N/A	N/A	N/A	N/A	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	
Soil temperature (15cm)	N/A	N/A	N/A	N/A	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	
Soil moisture (5cm)	N/A	N/A	N/A	N/A	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	
Soil moisture (15cm)	N/A	N/A	N/A	N/A	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	
Wind direction	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	
Rainfall precipitation	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	1.87	
Air temperature and humidity (low)	N/A	N/A	N/A	N/A	N/A	N/A	0.30	0.30	0.30	0.30	
Nipher	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	
Standard rain gauge	N/A	N/A	N/A	N/A	0.50	0.50	0.50	0.50	0.50	0.50	

## 4.2 Buckbrush Taiga

All measurements are from ground surface and are in meters.

Data Type	Years of Operation								
	1993	1994	1995	1996	1997	1998	1999	2000	2001
Net radiation:	3.10	3.10	3.10	3.10	3.18	3.18	3.18	3.18	3.18
Direct radiation	N/A	N/A	4.80	4.80	4.98	4.98	4.98	4.98	4.98
Diffuse radiation	N/A	N/A	4.40	4.40	4.40	4.40	4.40	4.40	4.40
Soil heat flux	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06	-0.06
Soil temperature	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
Air-snow interface temperature	0.10	0.10	0.10	0.21	0.21	0.21	0.21	0.21	0.21
Air temperature and humidity	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Surface temperature	N/A	3.10	3.18	3.18	3.18	3.18	3.18	3.18	3.18
Wind speed (low)	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25	2.25
Wind speed (high)	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60	4.60
Wind speed and direction	N/A	N/A	N/A	N/A	4.98	4.98	4.98	4.98	4.98
Snow depth	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67
Snow particles	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21	2.21
Soil temperature (5cm)	N/A	N/A	N/A	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Soil temperature (15cm)	N/A	N/A	N/A	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15
Soil temperature (30cm)	N/A	N/A	N/A	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30
Soil temperature (80cm)	N/A	N/A	N/A	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80
Soil moisture (5cm)	N/A	N/A	N/A	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Soil moisture (15cm)	N/A	N/A	N/A	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15
Soil moisture (30cm)	N/A	N/A	N/A	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30
Soil moisture (80cm)	N/A	N/A	N/A	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80
Rainfall precipitation	4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.76	4.76
Nipher	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Standard rain gauge (2)	N/A	N/A	N/A	0.50	0.50	0.50	0.50	0.50	0.50

### 4.3 White Spruce Forest

All measurements are from ground surface and are in meters. In 1996 a new main tower was installed in a different location.

#### Forest 1 and 2

Data Type	Years of Operation											
	1993	1994	1994	1995	1996	1996	1997	1998	1998	1999	2000	2001
Net radiation-upper	12.10	12.10	14.63	14.63	14.63	19.82	19.82	19.82	19.82	19.82	19.82	19.82
Net radiation-lower	N/A	N/A	N/A	N/A	N/A	N/A	2.00	2.00	N/A	N/A	N/A	N/A
Tube net radiation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.00	1.00	1.00
Direct radiation	N/A	N/A	N/A	14.33	14.33	20.43	20.43	20.43	20.43	20.43	20.43	20.43
Diffuse radiation	N/A	N/A	4.40	4.40	4.40	4.40	14.33	14.33	14.33	14.33	14.33	14.33
Soil heat flux	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16	-0.16
Soil temperature	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11	-0.11
Air-snow interface temperature	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Air temperature and humidity (low)	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Air temperature and humidity (mid)	N/A	N/A	N/A	N/A	N/A	14.63	14.63	14.63	14.63	14.63	14.63	14.63
Air temperature and humidity (high)	N/A	N/A	14.56	14.56	14.56	20.12	20.12	21.34	21.34	21.34	21.34	21.34
surface temperature	N/A	N/A	14.94	14.94	14.94	19.82	19.82	19.82	19.82	19.82	19.82	19.82
Wind speed (low)	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80
Wind speed (high)	11.81	11.81	14.48	14.48	14.48	19.82	19.82	19.82	19.82	19.82	19.82	19.82
Snow depth	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
Snow particles	4.95	4.95	4.95	4.95	4.95	8.71	4.95	4.95	4.95	4.95	4.95	4.95
Soil temperature (5cm)	N/A	N/A	N/A	N/A	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Soil temperature (15cm)	N/A	N/A	N/A	N/A	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15
Soil temperature (30cm)	N/A	N/A	N/A	N/A	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30
Soil temperature (80cm)	N/A	N/A	N/A	N/A	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80
Soil moisture (5cm)	N/A	N/A	N/A	N/A	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05	-0.05
Soil moisture (15cm)	N/A	N/A	N/A	N/A	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15	-0.15
Soil moisture (30cm)	N/A	N/A	N/A	N/A	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30
Soil moisture (80cm)	N/A	N/A	N/A	N/A	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80	-0.80
Digital image	N/A	N/A	N/A	10.67	10.67	10.67	10.67	10.67	10.67	10.67	N/A	N/A
Rainfall precipitation	14.56	14.56	14.56	14.56	14.56	20.12	20.12	21.34	21.34	21.34	21.34	21.34
Standard rain gauge (2)	N/A	N/A	N/A	N/A	N/A	0.50	0.50	0.50	0.50	0.50	0.50	2.00

### **4.3 White Spruce Forest (continued)**

All measurements are from ground surface and are in meters.

#### **Forest 3**

Data Type	Year of Installation								
	1993	1994	1995	1996	1997	1998	1999	2000	2001
Weight (tree)	N/A	N/A	N/A	N/A	June	Feb.	July	N/A	N/A
Air temperature (tree)	N/A	N/A	N/A	N/A	12.00	12.00	12.00	N/A	N/A
Wind speed and direction (low)	N/A	N/A	N/A	N/A	7.47	7.47	7.47	7.47	7.47
Wind speed and direction (high)	N/A	N/A	N/A	N/A	11.89	11.89	11.89	11.89	11.89
Weight (nipher)	N/A	N/A	N/A	N/A	1.50	1.50	1.50	N/A	N/A
Nipher (clearing)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Standard rain gauge(clearing)	N/A	N/A	N/A	0.50	0.50	0.50	0.50	0.50	0.50

## 5. MONTHLY METEOROLOGICAL DATA AVERAGES

### 5.1 Alpine Tundra

Year	Month	Global	Soil Temperature	Air Temperature	Vapour Pressure	Wind Speed	Precipitation.
1993	9	79.148	-0.194	0.478	0.474	M	0.0
1993	10	53.749	-0.304	-1.389	0.489	M	0.3
1993	11	18.172	-4.468	-8.600	0.279	M	68.0
1993	12	7.927	-6.722	-8.862	0.267	0.641	23.2
1994	1	12.631	-9.042	-14.144	0.184	0.640	28.7
1994	2	26.482	-15.346	-21.118	0.102	0.980	28.7
1994	3	116.227	-9.554	-8.549	0.268	1.000	14.6
1994	4	208.208	-2.364	-2.166	0.356	1.000	2.1
1994	5	242.742	0.880	1.317	0.445	1.000	0.3
1994	6	250.670	5.875	6.951	0.650	3.924	1.7
1994	7	252.014	9.553	10.350	0.816	3.880	19.4
1994	8	216.780	10.637	12.767	0.884	3.588	14.0
1994	9	99.030	1.742	1.074	0.573	5.334	42.0
1994	10	52.553	-0.544	-4.024	0.414	4.960	16.4
1994	11	15.257	-5.701	-15.683	0.163	4.112	23.7
1994	12	8.561	-9.759	-12.640	0.202	2.847	16.4
1995	1	15.877	-9.198	-9.309	0.224	2.855	10.3
1995	2	43.955	-10.597	-13.229	0.197	3.442	24.6
1995	3	116.370	-11.959	-12.790	0.210	4.507	35.6
1995	4	219.164	-6.616	-2.564	0.362	5.119	0.1
1995	5	248.395	3.384	4.599	0.436	1.585	1.3
1995	6	241.727	7.392	8.209	0.623	3.771	18.2
1995	7	202.864	9.413	8.756	0.777	3.394	41.8
1995	8	156.817	6.352	6.093	0.702	3.647	39.7
1995	9	113.164	3.970	15.824	0.641	5.079	27.1
1995	10	53.357	-0.385	-3.790	0.399	3.603	5.6
1995	11	13.493	-3.285	-14.288	0.173	5.057	34.7
1995	12	4.146	-8.469	-15.329	0.198	4.169	55.9

## 5.1 Alpine Tundra (continued)

Year	Month	Global	Soil Temperature	Air Temperature	Vapour Pressure	Wind Speed	Precipitation
1996	1	20.349	-11.377	-19.199	0.101	3.102	15.0
1996	2	46.042	-10.750	-12.456	0.199	4.305	4.6
1996	3	126.773	-10.239	-11.161	0.181	5.763	8.3
1996	4	217.446	-5.762	-5.185	0.290	4.527	6.8
1996	5	269.298	0.892	0.820	0.367	3.801	16.5
1996	6	244.898	6.048	5.884	0.548	4.113	11.9
1996	7	229.827	8.941	8.799	0.712	3.645	27.8
1996	8	150.932	5.526	5.444	0.679	4.232	53.4
1996	9	110.781	1.441	-0.176	0.461	4.495	10.7
1996	10	53.128	-0.712	-7.414	0.305	2.967	6.8
1996	11	25.307	-5.079	-12.775	0.186	2.960	8.6
1996	12	5.393	-7.471	-15.883	0.152	2.622	23.4
1997	1	14.268	-10.277	-15.545	0.181	3.528	13.6
1997	2	43.021	-8.230	-8.326	0.271	4.110	21.5
1997	3	99.794	-9.219	-14.962	0.155	4.466	33.4
1997	4	279.652	-4.509	-2.075	0.345	3.922	5.6
1997	5	251.705	-0.645	1.838	0.450	4.488	4.1
1997	6	238.629	6.787	7.343	0.660	3.850	73.1
1997	7	201.306	9.674	8.917	0.864	2.983	85.4
1997	8	184.354	8.322	8.794	0.800	3.897	31.7
1997	9	105.069	3.259	3.181	0.635	3.983	29.4
1997	10	57.386	-1.008	-7.100	0.317	2.605	1.5
1997	11	M	M	M	M	M	19.6
1997	12	M	M	M	M	M	37.7
1998	1	13.695	-8.322	-13.439	0.198	5.291	11.9
1998	2	M	M	M	M	M	16.5
1998	3	134.423	-7.869	-8.364	0.245	5.119	7.0
1998	4	200.994	-4.949	-3.813	0.329	5.675	0.8
1998	5	235.863	1.938	3.403	0.491	4.992	17.4
1998	6	257.450	8.312	8.914	0.670	2.787	0.6
1998	7	220.309	9.378	8.910	0.750	3.531	13.6
1998	8	177.037	6.521	6.375	0.634	4.468	10.7
1998	9	98.759	1.654	1.976	0.559	4.188	15.6
1998	10	53.239	-0.779	-4.679	0.387	3.627	6.7
1998	11	22.390	-2.942	-9.493	0.253	1.801	81.1
1998	12	9.271	-7.838	-16.676	0.123	2.112	0.0

## 5.1 Alpine Tundra (continued)

Year	Month	Global	Soil Temperature	Air Temperature	Vapour Pressure	Wind Speed	Precipitation
1999	1	15.672	-9.545	-16.585	0.142	2.959	25.2
1999	2	44.044	-10.104	-13.923	0.174	3.228	21.9
1999	3	122.303	-9.022	-10.801	0.220	4.919	13.6
1999	4	195.954	-5.116	-5.307	0.321	5.398	22.9
1999	5	234.963	-1.524	-1.085	0.436	4.017	21.4
1999	6	242.255	5.762	7.979	0.634	3.680	19.6
1999	7	224.951	9.427	8.938	0.757	3.613	37.4
1999	8	169.225	7.802	8.251	0.777	3.605	41.6
1999	9	96.907	1.924	1.403	0.568	4.945	16.7
1999	10	56.283	-0.768	-2.915	0.429	5.008	33.7
1999	11	7.969	-3.410	-7.453	0.356	5.253	36.4
1999	12	6.070	-4.614	-9.673	0.271	5.237	17.4
2000	1	16.463	-12.818	-13.816	0.186	2.552	19.2
2000	2	46.430	-8.616	-8.113	0.247	3.457	9.2
2000	3	101.109	-8.327	-9.246	0.234	3.821	8.0
2000	4	230.438	-5.394	-5.385	0.288	4.888	4.1
2000	5	238.453	0.731	-0.145	0.466	3.528	25.0
2000	6	235.486	6.675	6.540	0.647	3.641	51.9
2000	7	228.222	8.725	7.968	0.843	3.683	1.1
2000	8	144.210	6.511	5.335	0.767	3.672	107.1
2000	9	85.115	1.165	1.090	0.586	4.640	10.5
2000	10	58.186	-0.556	-4.857	0.393	3.297	5.9
2000	11	21.372	-2.170	-6.924	0.319	3.040	67.7
2000	12	8.717	-6.663	-9.432	0.249	2.323	21.4
2001	1	14.273	-6.979	-7.976	0.289	4.025	14.6
2001	2	49.541	-8.997	-10.803	0.182	3.532	M
2001	3	120.264	-9.999	-11.748	0.210	5.620	M
2001	4	194.473	-4.553	-4.764	0.308	4.161	3.7
2001	5	234.402	-0.228	-1.018	0.406	4.566	14.6
2001	6	246.575	6.447	6.880	0.687	3.016	70.6
2001	7	189.827	8.627	7.632	0.837	3.475	28.5
2001	8	174.987	8.253	8.294	0.824	3.223	50.6
2001	9	104.827	1.865	1.909	0.614	4.306	18.5
2001	10	44.998	-0.578	-5.140	0.370	4.424	1.0
2001	11	18.713	-1.297	-9.342	0.264	1.876	23.4
2001	12	3.704	-4.665	-11.700	0.252	0.690	29.9

## 5.2 Buckbrush Taiga

Year	Month	Global	Soil Temperature	Air Temperature	Vapour Pressure	Wind Speed	Precipitation
1993	9	M	1.956	2.420	0.490	M	5.1
1993	10	M	0.566	0.158	0.503	M	0.0
1993	11	M	-1.312	-7.424	0.282	M	61.6
1993	12	M	-1.553	-5.126	0.392	0.642	21.8
1994	1	M	-1.683	1.370	0.615	0.641	38.1
1994	2	M	-2.786	-20.188	0.099	0.964	23.8
1994	3	M	-2.230	9.921	0.364	0.901	0.9
1994	5	M	3.248	3.579	0.447	1.001	0.0
1994	6	M	7.700	9.053	0.673	2.613	2.3
1994	7	M	9.563	11.893	0.852	2.207	16.9
1994	8	M	10.469	13.926	0.917	2.003	22.9
1994	9	M	4.331	3.046	0.585	2.542	50.6
1994	10	M	0.447	-2.118	0.429	2.163	33.3
1994	11	M	-0.769	-14.242	0.164	2.732	30.1
1994	12	M	-1.409	-13.119	0.189	1.912	30.2
1995	1	M	-2.235	-11.155	0.208	1.233	5.2
1995	2	M	-1.887	-12.104	0.197	2.481	18.7
1995	3	M	-1.905	-10.895	0.209	3.283	47.0
1995	4	M	-0.651	-0.317	0.368	2.352	0.9
1995	5	240.104	2.852	6.666	0.472	0.973	4.8
1995	6	231.973	6.459	9.913	0.686	0.624	17.9
1995	7	203.186	9.216	10.675	0.852	1.194	32.5
1995	8	150.339	7.785	7.815	0.762	1.852	43.2
1995	9	109.291	5.881	7.409	0.686	1.919	23.8
1995	10	49.292	0.339	-2.466	0.422	0.898	17.8
1995	11	17.145	-1.340	-12.759	0.191	1.697	48.2
1995	12	6.522	-2.416	-14.762	0.201	1.349	16.8

## 5.2 Buckbrush Taiga (continued)

Year	Month	Global	Soil Temperature	Air Temperature	Vapour Pressure	Wind Speed	Precipitation
1996	1	17.409	-2.604	-20.711	0.095	0.647	20.0
1996	2	51.053	-2.313	-11.503	0.210	2.182	36.3
1996	3	121.638	-2.279	-9.358	0.193	2.755	6.4
1996	4	213.432	-1.005	-3.103	0.308	1.883	3.8
1996	5	253.376	1.614	3.213	0.392	2.047	13.5
1996	6	236.863	5.753	7.746	0.588	1.981	14.2
1996	7	233.600	8.324	10.627	0.766	2.214	29.5
1996	8	151.521	7.171	7.190	0.729	1.922	54.5
1996	9	125.484	5.323	3.996	0.579	1.860	14.0
1996	10	54.725	-0.522	-6.031	0.322	1.171	12.3
1996	11	24.132	-2.642	-12.327	0.188	0.899	8.7
1996	12	6.085	-3.327	-15.363	0.151	1.890	21.5
1997	1	16.172	-4.597	-15.594	0.180	1.016	15.1
1997	2	44.127	-2.915	-7.386	0.279	1.341	13.7
1997	3	108.429	-2.565	-12.783	0.166	2.176	40.6
1997	4	M	M	M	M	M	5.6
1997	5	242.061	2.100	4.569	0.501	2.618	6.7
1997	6	238.544	6.430	9.316	0.723	2.027	65.7
1997	7	207.962	8.378	10.537	0.930	1.679	67.9
1997	8	169.164	8.867	10.339	0.857	2.035	26.7
1997	9	104.063	5.656	4.891	0.668	1.659	29.2
1997	10	49.776	-0.040	-5.038	0.358	1.469	2.2
1997	11	30.888	-1.404	-5.893	0.324	0.970	20.5
1997	12	19.176	-1.331	-6.351	0.354	1.274	38.6
1998	1	28.060	-2.581	-4.012	0.396	1.532	7.4
1998	2	50.682	-2.762	-7.190	0.280	0.949	11.0
1998	3	121.205	-2.671	-7.898	0.234	1.778	6.0
1998	4	203.146	-0.717	-1.595	0.353	2.608	1.3
1998	5	233.536	2.477	5.517	0.520	2.586	18.2
1998	6	251.221	6.193	10.533	0.728	2.049	15.5
1998	7	215.905	7.898	10.501	0.812	1.807	26.7
1998	8	173.969	6.934	8.113	0.679	2.257	11.1
1998	9	99.864	3.540	3.591	0.586	1.804	16.3
1998	10	74.419	0.582	-2.329	0.421	1.280	3.5
1998	11	17.885	-3.838	-10.691	0.237	0.525	0.1
1998	12	11.328	-3.757	-12.554	0.190	0.998	0.0

## 5.2 Buckbrush Taiga (continued)

Year	Month	Global	Soil Temperature	Air Temperature	Vapour Pressure	Wind Speed	Precipitation
1999	1	14.494	-5.313	-16.276	0.143	1.634	34.6
1999	2	41.111	-5.026	-13.762	0.160	1.306	27.6
1999	3	123.193	-3.918	-8.829	0.233	2.280	11.2
1999	4	189.006	-1.771	-3.183	0.339	2.777	5.2
1999	5	220.966	0.404	1.285	0.463	2.004	29.9
1999	6	236.704	5.413	9.414	0.700	2.199	36.3
1999	7	226.653	7.593	11.015	0.809	2.359	41.3
1999	8	166.151	7.729	9.536	0.841	1.782	35.6
1999	9	97.676	3.987	3.366	0.606	2.165	15.9
1999	10	54.582	0.213	-1.665	0.437	2.273	18.3
1999	11	16.410	-0.800	-9.469	0.254	1.006	7.7
1999	12	6.536	-1.479	-10.812	0.226	M	2.5
2000	1	17.795	-3.983	-12.962	0.197	2.010	5.7
2000	2	49.810	-2.944	-7.331	0.255	1.596	4.5
2000	3	110.649	-2.694	-6.731	0.267	2.126	5.2
2000	4	209.520	-1.260	-3.771	0.306	2.082	10.6
2000	5	230.637	0.595	2.084	0.490	2.029	22.6
2000	6	224.367	5.546	8.306	0.691	2.212	54.2
2000	7	205.442	7.505	10.688	0.906	1.808	0.0
2000	8	137.488	6.972	6.952	0.815	1.734	107.3
2000	9	80.234	4.052	3.039	0.623	1.996	9.7
2000	10	57.557	0.447	-3.173	0.416	1.573	13.6
2000	11	18.548	-0.268	-6.043	0.328	1.654	59.0
2000	12	7.994	M	-10.795	0.230	1.318	23.0
2001	1	15.715	M	-6.863	0.298	1.927	14.6
2001	2	51.297	M	-10.616	0.183	1.897	1.7
2001	3	119.219	M	-9.796	0.222	2.647	1.3
2001	4	191.761	-0.687	-2.931	0.324	1.955	6.4
2001	5	234.517	0.625	1.188	0.436	2.506	15.1
2001	6	242.905	5.501	8.464	0.720	1.712	71.1
2001	7	190.261	7.589	9.469	0.904	1.942	55.2
2001	8	178.031	8.682	9.692	0.888	1.713	25.6
2001	9	101.444	4.408	3.426	0.653	1.732	27.1
2001	10	47.457	0.233	-3.735	0.391	1.735	5.7
2001	11	13.626	-1.373	-6.203	0.347	0.670	19.1
2001	12	6.220	-2.450	-11.401	0.258	0.879	32.4

### 5.3 White Spruce Forest

Year	Month	Global	Soil Temperature	Air Temperature	Vapor Pressure	Wind Speed	Precipitation
1993	9	M	3.278	M	M	0.640	0.0
1993	10	M	1.611	M	M	0.640	0.0
1993	11	M	-3.605	M	M	0.638	34.5
1993	12	M	-6.063	M	M	0.640	16.0
1994	1	M	-7.442	M	M	0.641	27.8
1994	2	M	-8.432	M	M	0.954	22.3
1994	3	M	-4.010	M	M	1.002	1.0
1994	4	M	-0.046	M	M	1.001	0.1
1994	5	M	2.195	M	M	1.001	0.0
1994	6	M	7.061	12.398	0.748	1.549	0.9
1994	7	M	9.600	15.714	0.884	1.690	4.5
1994	8	M	10.764	17.079	0.962	1.419	8.1
1994	9	M	4.749	5.918	0.641	1.368	38.0
1994	10	M	0.982	1.018	0.488	1.220	21.5
1994	11	M	-3.619	-13.578	0.176	1.040	23.0
1994	12	M	-7.870	-16.459	0.158	1.000	14.1
1995	1	M	-8.568	-16.761	0.150	1.002	7.0
1995	2	M	-6.380	-12.548	0.197	1.026	17.3
1995	3	M	-6.715	-9.980	0.212	1.116	19.6
1995	4	M	-0.414	3.452	0.395	1.403	1.7
1995	5	243.525	3.002	10.120	0.544	0.866	2.7
1995	6	251.939	7.578	13.403	0.736	0.756	19.6
1995	7	4.115	10.127	14.227	0.928	0.685	27.6
1995	8	161.220	7.923	11.038	0.864	0.557	15.5
1995	9	110.513	6.562	9.627	0.755	0.585	26.1
1995	10	46.336	0.387	0.247	0.495	0.222	13.2
1995	11	11.716	-6.122	12.584	0.202	0.318	46.9
1995	12	2.188	-9.187	-17.206	0.185	0.138	11.7

### 5.3 White Spruce Forest (continued)

Year	Month	Global	Soil Temperature	Air Temperature	Vapor Pressure	Wind Speed	Precipitation.
1996	1	4.127	-12.771	-31.330	0.049	0.123	11.6
1996	2	41.571	-7.431	-11.697	0.219	0.592	0.4
1996	3	119.655	-6.500	-11.671	0.128	0.527	29.9
1996	4	185.136	-2.593	0.216	0.335	0.620	4.3
1996	5	238.555	2.096	6.511	0.431	0.726	18.0
1996	6	251.065	6.699	11.367	0.645	1.318	17.0
1996	7	226.082	9.619	14.251	0.843	1.745	15.4
1996	8	158.644	7.725	10.669	0.813	1.646	30.0
1996	9	112.526	4.340	5.287	0.601	1.449	9.4
1996	10	47.434	-1.557	-4.029	0.381	1.217	19.5
1996	11	19.420	-10.324	-14.520	0.190	0.743	6.4
1996	12	2.858	-12.254	-19.015	0.130	0.816	11.5
1997	1	2.586	-14.689	-20.906	0.139	0.986	9.4
1997	2	28.519	-6.183	-6.577	0.309	1.071	12.6
1997	3	95.023	-6.548	-9.407	0.206	1.624	19.1
1997	4	168.273	-0.810	1.266	0.368	1.813	2.0
1997	5	233.760	3.056	7.636	0.516	1.806	2.7
1997	6	242.102	8.810	12.967	0.775	1.670	26.5
1997	7	212.110	10.730	14.178	1.009	1.512	43.8
1997	8	183.092	9.519	13.440	0.911	1.503	13.3
1997	9	112.414	5.552	8.183	0.731	1.641	18.3
1997	10	49.365	-1.880	-2.890	0.384	0.955	7.1
1997	11	16.613	-5.908	-6.656	0.316	0.680	15.3
1997	12	3.810	-7.331	-7.758	0.305	0.910	21.7
1998	1	7.330	-13.419	-19.469	0.134	1.009	13.8
1998	2	39.487	-7.190	-8.078	0.282	0.746	5.8
1998	3	111.968	-6.647	-6.189	0.254	1.471	4.2
1998	4	183.443	-0.770	2.456	0.377	2.048	2.8
1998	5	227.617	4.895	9.034	0.571	2.159	13.6
1998	6	252.794	9.279	14.156	0.747	1.857	14.6
1998	7	228.377	10.204	14.544	0.839	1.879	18.6
1998	8	170.625	8.010	11.656	0.721	2.227	11.2
1998	9	103.520	4.569	6.723	0.641	1.614	11.6
1998	10	44.245	-0.139	-0.503	0.477	1.112	24.7
1998	11	8.945	-5.300	-9.221	0.267	0.710	34.3
1998	12	4.516	-11.201	-15.992	0.167	0.650	21.0

### 5.3 White Spruce Forest (continued)

Year	Month	Global	Soil Temperature	Air Temperature	Vapor Pressure	Wind Speed	Precipitation
1999	1	11.971	-11.936	-20.054	0.122	1.214	9.6
1999	2	44.520	-10.746	-16.677	0.134	1.324	17.9
1999	3	113.202	-5.664	-5.886	0.253	1.826	10.0
1999	4	162.690	-1.497	0.750	0.383	1.878	11.8
1999	5	207.423	1.602	4.920	0.514	1.770	25.4
1999	6	238.051	8.466	12.748	0.739	1.865	16.2
1999	7	226.990	9.921	14.170	0.842	1.862	33.7
1999	8	177.521	9.740	13.354	0.869	1.711	26.1
1999	9	96.417	5.235	6.700	0.674	1.890	15.0
1999	10	47.358	1.113	1.611	0.519	1.563	22.4
1999	11	9.778	-4.946	-9.140	0.275	0.764	21.9
1999	12	2.921	-6.805	-9.555	0.270	0.979	23.2
2000	1	13.004	-12.902	-17.259	0.162	1.281	15.1
2000	2	43.780	-6.860	-7.918	0.245	1.083	2.7
2000	3	99.196	-4.555	-3.404	0.303	1.566	5.8
2000	4	177.910	-1.458	0.244	0.335	1.677	10.8
2000	5	200.944	2.131	5.441	0.529	1.583	23.2
2000	6	235.948	7.988	11.913	0.725	1.832	49.5
2000	7	211.613	9.930	12.827	0.921	1.588	46.4
2000	8	148.192	9.123	10.192	0.920	1.055	70.5
2000	9	88.907	4.977	5.374	0.701	1.275	24.9
2000	10	56.476	0.050	-0.153	0.529	1.415	30.7
2000	11	12.395	-2.919	-5.900	0.357	0.644	26.0
2000	12	3.974	-9.233	-13.688	0.198	0.327	11.7
2001	1	9.326	-7.166	-7.132	0.321	0.788	12.3
2001	2	36.751	-8.700	-12.526	0.188	1.264	13.6
2001	3	107.951	-6.140	-6.737	0.242	1.713	1.2
2001	4	172.736	-1.792	1.033	0.345	1.662	3.5
2001	5	218.309	1.168	5.159	0.465	1.922	23.3
2001	6	251.067	7.993	11.903	0.803	1.429	84.3
2001	7	204.676	9.938	13.034	0.951	1.635	36.0
2001	8	183.036	10.522	13.054	0.944	1.304	35.1
2001	9	106.924	5.664	6.638	0.711	1.413	15.2
2001	10	46.982	0.189	-1.049	0.458	1.099	15.9
2001	11	11.631	-5.605	-9.795	0.275	0.661	12.6
2001	12	1.713	-10.512	-17.349	0.169	0.634	28.3

## **6. DESCRIPTION OF RELATED WORK AND SHORT TERM EXPERIMENTS IN WOLF CREEK RESEARCH BASIN**

In conjunction with major programs and existing projects being conducted at the Alpine, Buckbrush and Forest sites in the Wolf Creek Research Basin, there are several separate studies. Some were specifically designed to enhance existing studies while other experiments explored new but related areas of interest.

### **6.1 Granger Basin**

Project consists of measuring the various components of the vertical energy and water balances at three representative levels on Granger Basin, a sub-basin ( $4.3\text{km}^2$ ) of the Wolf Creek watershed. The purpose of this study is to examine the energy and water balances on sloped surfaces. It is necessary to understand the processes occurring on slopes, and how these differ from the "classic infinite flat plane" for which most energy transfer theories have been developed.

The data collected are used to develop parameterizations for the improvement of an evapotranspiration model developed by the researcher, as well as for the development and testing of remote sensing approaches for the estimate of Aerial evapotranspiration.

The data are also used by other researchers at the National Hydrology Research Center and at DIAND. This work complements other field work carried out in the southern boreal forest near Prince Albert Saskatchewan.

There are four 3 meter towers in Granger Basin collecting meteorological data. Towers are located on north and south facing slopes, valley bottom and in the headwaters of the basin. Data has been collected since the spring of 1998.

Contact: Dr. Raoul Granger or Newell Hedstrom.

### **6.2 Snow Depletion**

Research to better characterize melt energetics and spatial distribution in a northern boreal forest. This project examined small to medium-scale snow and melt rate distribution and sub-catchment spring discharge over Wolf Creek and improve infiltration to frozen soil characterization. It was also designed to characterize the dynamics of nitrogen in and carbon dioxide from melting snow, snowmelt water and frozen soils in a northern boreal forest. A roving albedometer was deployed and snow chemistry was also performed for this study.

The study took place in Spring of 1998, 1999 and 2001.

Contact: Dr. John Pomeroy.

### **6.3 Partitioning of Energy and Water in Boreal and Alpine Ecosystems**

Energy and water balance studies help to characterize the evaporation loss and climate of the basin as affected by its vegetation cover. These studies help to determine the role of northern vegetation in controlling hydrology and climate and the sensitivity of northern basins to disturbance from forest clearing and climate change.

A tethered dirigible was deployed to collect meteorological information up to 1000 metres above the ground. The study was conducted over several one week periods in July 1997, July 1998 and May 1999. Data was collected at the Alpine, Buckbrush and Forest sites and in Granger basin.

Contact: Dr. Raoul Granger or Newell Hedstrom.

#### **6.4 Parameterization of Evapotranspiration Using Remotely Sensed Data**

Arctic/alpine environments are known for low evapotranspiration rates. Vapour transfer characteristics, soil heat storage relationships, radiation balance and surface temperature relationships have been developed for ecosystem meteorological stations and aggregated over the watershed using remotely sensed data.

Ground truthing measurements and surface temperature (Coal Lake) monitoring for use with satellite imagery was conducted in July 1996, summers of 1999, 2000 and 2001. Data was collected throughout the Wolf Creek Watershed and surrounding area.

Contact: Dr. Raoul Granger.

#### **6.5 Contribution to the Development of the Boreal Component of the Cold Regions Hydrological Model**

Designed primarily from Canadian Prairie hydrology research, the accuracy and transferability of the Cold Regions Hydrological Model (CRHM) is being tested using data from open sites in prairie, boreal forest and alpine tundra environments. CRHM is a spatially distributed, modular, numerical modelling system created from recent process-based hydrology research. Modules represent algorithms to transform input data, to interpret basin characteristics and to represent physically-based hydrological processes; these modules are linked and compiled by CRHM into a customised 'Simulation'. The simulations use standard climate data, land use and basin characteristics in internal data assimilation routines to provide appropriately distributed parameters and boundary conditions for the process algorithms and to calculate and graphically display hydrological parameters of interest. Results from the simulations have proven useful for the assessment of land use change and climate variability on water balance, snow accumulation, soil freezing and streamflow and in making recommendations for improved land use practices for water management.

An experiment was set up in spring/summer 2001 in two watersheds (Wolf and Contact Creek) in the southern Yukon Territory at the northern edge of the boreal forest. Data from these sites will be run through CRHM to assess the impacts of landuse change. The study is designed to link with existing programs contributing to the development of CRHM..

Contact: Newell Hedstrom.

#### **6.6 Response of Alpine Tundra Communities to Manipulations of Temperature and Snow Accumulation**

Contributed to the International Tundra Experiment (ITEX) site established in conjunction with the Alpine meteorological station. The experimental was designed to include small-scale temperature manipulation and herbivore exclusion. As part of the snow manipulation component, soil and snow temperatures were monitored from 1995-2001.

Contact: Newell Hedstrom or Dr. John Pomeroy.

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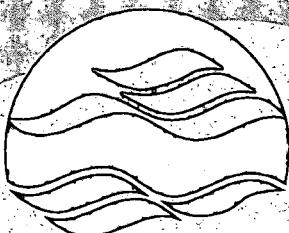
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