Hydrological Data
1998-1999 Water Year

Havikpak Creek Research Basin

NWRI Contribution to the Mackenzie GEWEX Study (MAGS)

Principal Investigator:
Dr. Philip Marsh

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Cuyler Onclin
Mark Russell
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Dr. W.L. Quinton

November 2000
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ABSTRACT
Hydrological Data, 1998-1999 Water Year

Havikpak Creek Research Basin: An NWRI Contribution to the Mackenzie GEWEX Study (MAGS)

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Abstract

This report presents a summary of data collected by the National Water Research Institute (NWRI) at the Havikpak Creek (HPC) research basin near Inuvik, NWT as part of our Mackenzie GEWEX Study (MAGS) activities, and accompanies a CD-ROM containing the full data sets. Havikpak Creek is a 17 km² basin located approximately 5 km’s north of the Inuvik airport. The basin is predominately covered by northern boreal forest, with occasional shrub zones and tundra vegetation in the upper portions of the basin. HPC is located in the zone of continuous permafrost. A separate report and CD-ROM contains information and data for our Trail Valley Creek research basin, located approximately 45 km’s north of Inuvik.

Included on the accompanying CD-ROM are the following data sets: snow surveys, satellite images showing the depletion of snowcovered area during the melt period, stream discharge, standard micro-meteorological data including air temperature, relative humidity, radiation, wind and precipitation for example, surface energy fluxes including sensible and latent heat, and calculated daily water balance for the basin. In addition, there is a reference list containing relevant publications stemming from our MAGS research in the lower Mackenzie basin. Although this report and the accompanying CD concentrate on the Canadian GEWEX Enhanced Study (CAGES) 1998/99 water year, there are also accompanying data sets for the 1994/95 water year as presented in a paper by Marsh et al. (in press).

When utilizing all of the provided data sets, it is important to realize that the HPC research site is only manned during intense field periods, generally during the spring melt
period, and with occasional winter and fall visits. As the stations are not manned year round, there are potential problems with certain sensors. For example, since Havikpak Creek is located in a northern environment, snow, ice and extreme temperatures are common and can greatly affect the data quality. As a result, many of the instruments are prone to significant errors. This is especially true during the long winter period. All users of these data should use caution.

The primary purpose of the data sets presented in this report are to provide background information on the water balance and energy fluxes for the Havikpak Creek area for the two water years under consideration. As such they present an excellent data set for testing and validating a variety of hydrologic and atmospheric models. The presented data fall into three main categories. First there are “final” research data sets prepared for publication. These include the snow survey, satellite image analysis, energy balance, and water balance data sets. All of these data have undergone a quality control check. The second category, include operational data sets that again have undergone a full quality control process. Only the preliminary Water Survey of Canada stream discharge data falls into this category. In addition to these quality controlled data sets, we have also included “raw” micro-meteorological research data. In all cases, the documentation notes potential problems that users must consider. This data set has not undergone the “normal” practice of removing data that is outside of standard limits. For example, relative humidity above a given value are often removed, based on the assumption that they are in error. However, such limits are often arbitrary and it was felt that for this research data set, it was more appropriate that quality control would be limited only to the checking of time stamps to ensure that the time sequence was correct and to the removal of data where it was known that the instruments were not operating (during periods of maintenance or if an instrument was broken for example). Other than these simple checks, the micro-meteorological data is as it came off the data loggers. Final quality control will therefore be the responsibility of the final user. Given our experience with such data, it was felt that such a “raw” data set will be of greater use to future researchers, as they will be best able to decide on the quality control required for their individual analysis.
INTRODUCTION
Havikpak Creek

Site description:
Havikpak Creek is located 10 km's South-east of Inuvik, and immediately North of the Inuvik Airport, within the boreal forest/tundra transition zone. The landscape of the basin consists of sparse black spruce, with some lakes, and areas of open tundra in the upper portions of the basin. The entire basin is underlain by continuous permafrost.

Basin Location:
Co-ordinates of the main instrument tower:

NAD 83: Zone 8W  560,985 E  7,579,271 N
or
68.32°N  133.50°W

Elevation Range:
15 m amsl to 230 m amsl

Basin Size:
17 km²

Vegetation:
Open (exposed, water, tundra, sparse and open shrub): 29.6 %
Closed shrub: 3.7 %
Forest (sparse, open, closed): 66.8 %
LOCATION
MAP
SNOW SURVEYS
End of Winter Snow Survey Results for Havikpak Creek:
National Water Research Institute - Surveys done on April 22, 1999

Snow surveys were done within each of the major landclasses / terrain types of the basin. The landclasses were determined from prior NWRI work in the basin which included ground surveys, analysis of landsat imagery and ground truthing. Snow survey transects were then chosen to fall within a specific landclass from which a representative snow water equivalence could be determined for that class. For landclasses with more than one representative snow survey, the class snow water equivalence was determined by averaging the results of all surveys within the class.

<table>
<thead>
<tr>
<th>Havikpak Creek Landclass Surveyed</th>
<th>Average SWE: (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest Area</td>
<td>102</td>
</tr>
<tr>
<td>Drift Area</td>
<td>292</td>
</tr>
<tr>
<td>Closed Shrub Area</td>
<td>118</td>
</tr>
<tr>
<td>Tundra Area</td>
<td>111</td>
</tr>
<tr>
<td>Forest Area (Main Met)</td>
<td>88</td>
</tr>
<tr>
<td>Forest/Open Area (Main Met)</td>
<td>86</td>
</tr>
<tr>
<td>Nipher:(to April 15)</td>
<td>97</td>
</tr>
</tbody>
</table>

**Total Area of the Basin:**
Havikpak Creek = 17 km²

**Percentage of Basin covered by Landclass / terrain type & the average Snow Water Equivalence determined for each class**

<table>
<thead>
<tr>
<th>HPC: Class</th>
<th>%</th>
<th>(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>27.9</td>
<td>111</td>
</tr>
<tr>
<td>Closed Shrub</td>
<td>3.7</td>
<td>118</td>
</tr>
<tr>
<td>Forest</td>
<td>66.8</td>
<td>93</td>
</tr>
<tr>
<td>Drift</td>
<td>1.7</td>
<td>292</td>
</tr>
</tbody>
</table>

**Havikpak Acoustic Snow Depth Sensor (SR50)**

<table>
<thead>
<tr>
<th>DATE</th>
<th>SR50 READING (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15-Sep-98</td>
<td>3.9</td>
</tr>
<tr>
<td>15-Oct-98</td>
<td>9.1</td>
</tr>
<tr>
<td>13-Nov-98</td>
<td>28.1</td>
</tr>
<tr>
<td>15-Dec-98</td>
<td>28.9</td>
</tr>
<tr>
<td>15-Jan-99</td>
<td>35.7</td>
</tr>
<tr>
<td>15-Feb-99</td>
<td>43.0</td>
</tr>
<tr>
<td>15-Mar-99</td>
<td>49.5</td>
</tr>
<tr>
<td>15-Apr-99</td>
<td>53.2</td>
</tr>
</tbody>
</table>

**Total Water Available from each Landclass / terrain type:**

<table>
<thead>
<tr>
<th>HPC: Class</th>
<th>(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open</td>
<td>31</td>
</tr>
<tr>
<td>Closed Shrub</td>
<td>4</td>
</tr>
<tr>
<td>Forest</td>
<td>62</td>
</tr>
<tr>
<td>Drift</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>103</td>
</tr>
</tbody>
</table>
SATELLITE IMAGE ANALYSIS

(PROGRESS OF SNOW DEPLETION)
Satellite Image Analysis

SPOT and Landsat satellite images were obtained for the melt and early summer periods for Havikpak Creek. These images show the progress of snow depletion and provide information on surface conditions during the observation period.

<table>
<thead>
<tr>
<th>Image Date</th>
<th>Satellite</th>
<th>Sensor</th>
<th>Bands</th>
<th>Spatial Resolution (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 12/99</td>
<td>SPOT2</td>
<td>Panchromatic</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>May 20/99</td>
<td>SPOT2</td>
<td>Panchromatic</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>May 23/99</td>
<td>SPOT2</td>
<td>Multispectral</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>May 28/99</td>
<td>SPOT2</td>
<td>Multispectral</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>June 11/99</td>
<td>Landsat5</td>
<td>Thematic Mapper</td>
<td>7</td>
<td>30 TM</td>
</tr>
<tr>
<td>July 5/99</td>
<td>Landsat7</td>
<td>Enhanced Thematic Mapper</td>
<td>8</td>
<td>60 thermal</td>
</tr>
</tbody>
</table>

Each image was georeferenced individually to existing hydrological vectors, and the snow covered area (SCA) was determined using the surface spectral reflectance characteristics. Snow is a strong reflector in the visible range, and pixels dominated by snow have higher reflectance (albedo) than those dominated by tundra or water. Using this information each image was converted to a binary map of “snow” and “snow-free” pixels. A distinction was made between snow on the ground (terrestrial ecosystems) and snow and ice on lakes (aquatic ecosystems).

<table>
<thead>
<tr>
<th>Date</th>
<th>Snow on Ground (%)</th>
<th>Snow and Ice on Lakes (%)</th>
<th>Total SCA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 12/99</td>
<td>90.3</td>
<td>4.5</td>
<td>94.8</td>
</tr>
<tr>
<td>May 20/99</td>
<td>56.4</td>
<td>3.9</td>
<td>60.3</td>
</tr>
<tr>
<td>May 23/99</td>
<td>15.1</td>
<td>3.0</td>
<td>18.1</td>
</tr>
<tr>
<td>May 28/99</td>
<td>0.6</td>
<td>1.9</td>
<td>2.5</td>
</tr>
<tr>
<td>June 11/99</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>July 5/99</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

The following maps are organised with each original image followed immediately by its associated snow map, in chronological order.
Havikpak Creek Basin
Snow Cover Map
May 12, 1999
Snow is shown as white, snow-free as black and blue denotes snow and ice on lakes.
Havikpak Creek Basin
Snow Cover Map
May 20, 1999
Snow is shown as white, snow-free as black and blue denotes snow and ice on lakes.
Havikpak Creek Basin
Snow Cover Map
May 28, 1999

Snow is shown as white, snow-free as black and blue denotes snow and ice on lakes.
STREAM
DISCHARGE
Preliminary Water Survey of Canada Data

HPC 1999 Discharge

HPC 1999 Water Levels
MICRO-METEOROLOGICAL DATA
HAVIKPAK CREEK, N.W.T.

FILE NAME = HPC_SUMMARY1998-99.XLS
Havikpak Main Meteorological Site
National Water Research Institute Contribution
Principal Investigator: Dr. Philip Marsh
Technical & Science Contributors: Cuyler Ondin, Natasha Neumann, Mark Russell, & Dr. W.L. Quinton

DATA IN THIS FILE IS UNEDITED

Site Description: The Havikpak Main Meteorological Site is located in the Basin of Havikpak Creek, approximately 10 km's South-East of Inuvik. The site falls within the boreal forest / tundra transition zone. The landscape of the basin consists of sparse black spruce, with some lakes, and areas of open tundra in the upper portions of the basin. The entire basin is underlain by continuous permafrost.

Havikpak Creek is a Research Basin of N.W.R.I.'s which was incorporated into the GEWEX CAGES program. There are a total of 4 dataloggers running the various sensors at the Havikpak Main Meteorology Site. The 4 loggers are code named HM1, HM2, HM3 & HDS. HM1 is the core station, constructed and operated jointly by NWRI/MAGS/CAGES/ & Prairie & Northern Region of Environment Canada. The HM1 datalogger uses a N.W.R.I. Program modified to incorporate some of the MSC remote station program features.

- Water Survey of Canada has been monitoring the discharge of Havikpak Creek for several years.

GPS Coordinate:

<table>
<thead>
<tr>
<th>NAD 83</th>
<th>Zone 8W</th>
<th>560,985 E</th>
<th>7,579,271 N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude:</td>
<td>66.32° N</td>
<td>Longitude:</td>
<td>133.5° W</td>
</tr>
</tbody>
</table>

Basin Size: 17 km²

Station Elevation: 87 m a.m.s.l.

Equipment:

Dataloggers Used:

HM1: - CR10X (produced by Campbell Scientific)
-55 degree C tested; S/N X931; 1 Meg extended Memory; housed inside a white plastic enclosure.

HM2: - 21X (produced by Campbell Scientific)
-55 degree C tested; S/N 6933; PROMs 574-2, 575-3, 576-3; EDR# A49585; housed inside a white fiberglass enclosure.

HM3: - 21X (produced by Campbell Scientific)
-55 degree C tested; S/N 9454; PROMs 6145,6146,6147; EDR# X00355 housed inside a white fiberglass enclosure.

HDS: - 21X (produced by Campbell Scientific)
-55 degree C tested; S/N 12680; PROMs 6148,6149,6070-65; EDR# X01330 housed inside a white fiberglass enclosure.
**Data Transmission / Storage:**

| HM1: | - TGT1 GOES transmitter (produced by Telonics Inc.)  
  - CR10X internal memory (produced by Campbell Scientific) |
|------|------------------------------------------------------|
| HM2: | - SM716 (produced by Campbell Scientific)  
  S/N 4915; EDR # X01332; -55 degree C tested; placed in Ring configuration. |
| HM3: | - SM716 (produced by Campbell Scientific)  
  S/N 3653; EDR # X00910; -55 degree C tested; placed in Ring configuration. |
| HDS: | - SM192 (produced by Campbell Scientific)  
  S/N 2397; -55 degree C tested; placed in Ring configuration. |

**Solar Panels: Wind Generators and Regulators being Used:**

| HM1: | - Solarex MSX 60 (60W) Solar Panel, S/N FW95C28568934; EDR# X01579.  
  Solarex Solarstat SRX-6/12 12Volt, 5.5amp Regulator.  
  - Rutland Model FM910 12V Wind Generator (50W at 9.8m/s), S/N 074336, EDR# X00072  
  Rutland Model WG910 12Volt Shunt Regulator |
|------|----------------------------------------------------------------------------------------------------------------------------------|
  Solarex Solarstat SRX-6/12 12Volt, 5.5amp Regulator. |
| HM3: | - Solarex MSX 30 (30W) Solar Panel, S/N FW96414763336; EDR# X01550.  
  Solarex Solarstat SRX-6/12 12Volt, 5.5amp Regulator. |
| HDS: | - Siemens Model SP36 (36W) Solar Panel, Sunsaver 12Volt, 10amp Regulator. |

**Power Sources being Used:**

<table>
<thead>
<tr>
<th>HM1:</th>
<th>- Two lead acid, 80 amp/hr 12Volt batteries in Parallel, being recharged by Solar Panel &amp; Wind Generator.</th>
</tr>
</thead>
<tbody>
<tr>
<td>HM2:</td>
<td>- One lead acid, 80 amp/hr 12Volt battery being recharged by Solar Panel.</td>
</tr>
<tr>
<td>HM3:</td>
<td>- One lead acid, 80 amp/hr 12Volt battery being recharged by Solar Panel.</td>
</tr>
<tr>
<td>HDS:</td>
<td>- One lead acid, 80 amp/hr 12Volt battery being recharged by Solar Panel.</td>
</tr>
</tbody>
</table>

**Air Temperature and RH Sensor Used:**

| HM1: | - Model HMP35CF (produced by Vaisala)  
  50ft Lead; S/N C1446; sensor mounted inside a 12 plate Gill Shield.  
  Sensor is mounted 200cm above ground surface. |
Wind Speed and Direction Sensors Used:

HM1: - Model 05103-10A Wind Monitor (produced by RM Young)
  50ft. Lead; FINSMTY; S/N C1321
  Sensor is mounted 12.8 m a.g.s. (01/09/98 to 27/04/99) then at 13.5 m a.g.s.
- Model #40 Maximum Anemometer (produced by NRG Systems)
  30ft. Lead.
  Sensor is mounted 200 cm a.g.s.

Net Radiation Sensor Used:

HM1: - Model Q7.1 Net Pyrradiometer (produced by Radiation & Energy Balance Systems, Inc.)
  50ft. Lead; S/N Q95301
  Rigid radiometer domes (require no inflation); External Ventilator used to reduce dome heating when battery power was sufficient. Sensor is mounted 10 m a.g.s.

  50ft. Lead; S/N Q95055
  Rigid radiometer domes (require no inflation).
  Sensor is mounted 150 cm a.g.s.

Short Wave Radiation Sensor Used:

HM1: - Model PDS7.1 Pyranometer (produced by Radiation & Energy Balance Systems, Inc.)
  until 27/04/99 then HDS: 50ft. Lead; S/N P95005
  External Ventilator used to reduce dome heating when battery power was sufficient.
  Sensor is mounted 10 m a.g.s.

Barometric Pressure Sensor Used:

HM1: Model SBP270 Barometric Pressure Sensor (produced by GETRA)
  Mounted inside the datalogger enclosure; S/N 896352
  Sensor is 158 cm a.g.s.

Snow Depth Sensor Used:

HM1: Model SR50 (produced by Campbell Scientific)
  -45 degree C tested; S/N C1119; 50ft. Lead.
  The snow depth sensor is mounted off of a horizontal arm clamped to the tower.
  The face of the sensor is 151 cm a.g.s.
**Thermistors Used:**

HM3:

<table>
<thead>
<tr>
<th>S/N</th>
<th>Lead length (m)</th>
<th>Depth below ground surfac (cm)</th>
<th>Medium measured</th>
</tr>
</thead>
<tbody>
<tr>
<td>C2574</td>
<td>15</td>
<td>10</td>
<td>Mineral</td>
</tr>
<tr>
<td>C2600</td>
<td>15</td>
<td>20</td>
<td>Mineral</td>
</tr>
<tr>
<td>C2635</td>
<td>15</td>
<td>30</td>
<td>Mineral</td>
</tr>
<tr>
<td>C2639</td>
<td>15</td>
<td>45</td>
<td>Mineral</td>
</tr>
<tr>
<td>C2645</td>
<td>15</td>
<td>60</td>
<td>Mineral</td>
</tr>
</tbody>
</table>

**TDR Probe Used:**

HM3:
- CS615 (produced by Campbell Scientific) (Probe #1 - in Organic Soil) #8688, 50ft. Lead, Lf#429720 8221-07
  Sensor is buried horizontally at 10 cm b.g.s.
- CS615 (produced by Campbell Scientific) (Probe #2 - in Organic Soil) #8688, 50ft. Lead, Lt#429720 8221-07
  Sensor is buried horizontally at 11 cm b.g.s.

**Soil Thermocouple Array Used:**

HM3:
- TCAV averaging soil thermocouple probe (produced by Campbell Scientific)
  Sensor is buried within a zone from 0 to 8 cm b.g.s.

**Soil Heat Flux Plates Used:**

HM3:
- HFT-3 Soil Heat Flux Plate (produced by Radiation & Energy Balance Systems, Inc.)
  S/N H953269; 50ft. Lead.
  Sensor is buried at 10 cm b.g.s. in the mineral soil.
## Equipment on Site provided by:

### HM1:
- Datalogger & Enclosure
- GOES Antenna, transmitter and hardware
- Solar Panel
- Power Regulator for Solar Panel
- Wind Generator
- Power Regulator for Wind Generator
- Two batteries
- 40ft. tapered triangular tower, centre mast & Hardware
- Air Temp. & R.H. Sensor
- Gill Shield
- Wind Monitor Sensor (RMYoung)
- Anemometer (NRG40)
- Net Radiometer (above canopy)
- Short Wave Radiometer (until 27/04/99)
- Barometric Pressure Sensor
- Snow Depth Sensor
- Tipping Bucket
- 12 Volt Relay Driver
- Radiometer Ventilators

### HM2:
- Datalogger & Enclosure
- Storage Module
- Solar Panel
- Power Regulator for Solar Panel
- Battery
- Tower and hardware
- Fine Wire Thermocouple
- Vertical Prop Anemometer
- Net Radiometer (below canopy)

### HM3:
- Datalogger & Enclosure
- Storage Module
- Solar Panel
- Power Regulator for Solar Panel
- Battery
- Thermistors
- Averaging Thermocouple Array (Soil)
- Heat Flux Plate
- TDR Probes
- Hypodermic Thermocouple (Snow/Air)

### HDS:
- Datalogger & Enclosure
- Storage Module
- Solar Panel
- Power Regulator for Solar Panel
- Battery
- Tower and hardware
- Short Wave Radiometer (after 27/04/99)
Data:

1) Units for some sensor readings are in non-SI form. Such units were chosen by Meteorological Survey of Canada for the sake of consistency with historical records. N.W.R.I. prefers to use the SI units, and does so for all sensors that were not connected to the GOES (HM1) station.

2) There are five data spreadsheets (Microsoft Excel 5.0/95) in this file which contain the raw, unedited data collected for Havikpak Main Meteorological Site. Three of the data spreadsheets contain the half-hourly data over the period of record, the other two data spreadsheets contain the six hourly records. The final two spreadsheets in this file elaborate on the titles of the data columns, attempting to clarify exactly what the data records represent.

3) Any person using the data from this file should be fully aware that the data is collected at an unmanned site. That is to say that sensors are often frost, snow, or rain covered. Sensor readings must be scrutinized carefully before being used, as they may falsely report conditions due to a lack of servicing / maintenance. Field personnel from N.W.R.I. will ultimately edit the data to a final form as time permits. Please contact the Principal Investigator for details on the progression of the editing.

**Further to Data Point #3:**

We are suspicious of the readings from the Thermistors. We believe they may no longer be in good contact with the soil, and disturbance of the area during their installation (i.e. compaction of insulating moss layer) several years earlier may have led to them existing within an anomalous location compared to the region around them. The frost table was almost certainly disturbed in the immediate area surrounding the thermistors.

Unmanned site considerations:

- Gill shields may fill with snow and rime, or be heavily frosted at various times - severe affect on RH and Air Temperature
- Domes on Radiometers covered by snow, ice, rime, frost, dew or raindrops - severe affect on radiometer readings (both incoming and outgoing radiation sensing domes can be affected).
- Anemometer cups and propellers covered in snow, ice, rime, frost, dew or raindrops - can cause small to very large reductions in measured wind speeds by the sensors (often reducing measured speeds to zero).
- Wind Direction sensors are often covered in snow, ice, rime, frost, dew or raindrops - can cause small to very large errors in measured directions (often a vane can be frozen into one direction).
- Frost heaving, heat conduction by cables, and altering of the frost table by compression of overlying moss layers can result in affected of faulty readings by thermistors, thermocouples, TDR probes and Heat Flux plates located in the soil.
- Wind and precipitation events can cause false readings from the Snow Depth Sensor. Blowing snow can mislead one to believe more or less snow exists in the area depending on whether the sensor is in an area of drifting or in an area of erosion.

4) All relative humidity readings are with respect to water, and not ice. With respect to water is done through the standard calibration and programming set out by Vaisalla and Campbell Scientific. Conversion to, with respect to ice, may be appropriate as required by individual users.
HALF-HOURLY DATA
# Half-Hourly Data outputs for the Havikpak Creek Main Meteorology Site:

**See last page of output listing for Special Notes and Definitions.**

<table>
<thead>
<tr>
<th>DATE</th>
<th>(MST)</th>
<th>= Calendar date and time for the row of data values (in Mountain Standard Time).</th>
</tr>
</thead>
<tbody>
<tr>
<td>YEAR</td>
<td>(MST)</td>
<td>= Year for the row of data values (in Mountain Standard Time).</td>
</tr>
<tr>
<td>DAY OF YEAR</td>
<td>(GMT)</td>
<td>= Day of the year for the row of data values (in Greenwich Mean Time).</td>
</tr>
<tr>
<td>24 HOUR TIME</td>
<td>(GMT)</td>
<td>= Hour and Minute of the year for the row of data values (in Greenwich Mean Time).</td>
</tr>
<tr>
<td>DAY OF YEAR</td>
<td>(MST)</td>
<td>= Day of the year for the row of data values (in Mountain Standard Time).</td>
</tr>
<tr>
<td>24 HOUR TIME</td>
<td>(MST)</td>
<td>= Hour and Minute of the year for the row of data values (in Mountain Standard Time).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>all 60 sec. periods</th>
<th>Air Temp. (HM1)</th>
<th>HMP35CF</th>
<th>2.0m a.g.s.</th>
<th>average</th>
<th>(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

The datalogger measures the instantaneous air temperature recorded by the HMP35CF every 60 seconds. The logger then uses all thirty of the 60-second readings collected during the half-hour to determine an average air temperature for the half-hour. This column shows that half-hour average value.

<table>
<thead>
<tr>
<th>all 60 sec. periods</th>
<th>R.H. (HM1)</th>
<th>HMP35CF</th>
<th>2.0m a.g.s.</th>
<th>average</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

The datalogger measures the instantaneous relative humidity recorded by the HMP35CF every 60 seconds. The logger then uses all thirty of the 60-second readings collected during the half-hour to determine an average relative humidity for the half-hour. This column shows that half-hour average value.

<table>
<thead>
<tr>
<th>all 60 sec. periods</th>
<th>Horizontal Wind Speed (HM1)</th>
<th>RM Young 05103</th>
<th>12.8m a.g.s.</th>
<th>average</th>
<th>(m/s)</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

The datalogger measures the average wind speed (Hz) recorded by the RMYoung Anemometer for each successive 60-second period. The Logger then uses all thirty of the 60-second averages collected during the half-hour to determine an average wind speed for the half-hour. This column shows that half-hour average value.

<table>
<thead>
<tr>
<th>all 60 sec. periods</th>
<th>Unit Vector Wind Direction (HM1)</th>
<th>RM Young 05103</th>
<th>12.8m a.g.s.</th>
<th>average</th>
<th>(0 to 360°)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

The datalogger measures the average wind speed (Hz) and instantaneous direction recorded by the RMYoung for each successive 60-second period. The logger then uses all thirty of the 60 second readings, of both speed and direction, collected during the half hour to determine a resulting unit vector direction for the half hour. This column shows the unit vector direction (wind direction) obtained for that half-hour.
| all 60 sec. periods | Std. Dev. of Wind Direction (HM1) | RM Young 05103 | 12.8 m a.g.s. | standard deviation | (degrees) |
| all 60 sec. periods | Horizontal Wind Speed (HM1) | RM Young 05103 | 13.5 m a.g.s. | average | (m/s) |
| all 60 sec. periods | Unit Vector Wind Direction (HM1) | RM Young 05103 | 13.5 m a.g.s. | average | (0 to 360°) |
| all 60 sec. periods | Std. Dev. of Wind Direction (HM1) | RM Young 05103 | 13.5 m a.g.s. | standard deviation | (degrees) |
| all 60 sec. periods | Horizontal Wind Speed (HM1) | NRG 40 | 2.0 m a.g.s. | average | (m/s) |

The datalogger measures the average wind speed (Hz) and instantaneous direction recorded by the RMYoung for each successive 60 second period. The logger then uses all thirty of the 60-second readings collected during the half-hour to determine a standard deviation of wind direction for the half-hour. This column shows the standard deviation of the wind direction obtained for that half-hour.

The datalogger measures the average wind speed (Hz) recorded by the RMYoung Anemometer for each successive 60-second period. The Logger then uses all thirty of the 60-second averages collected during the half-hour to determine an average wind speed for the half-hour. This column shows that half-hour average value.

The datalogger measures the average wind speed (Hz) and instantaneous direction recorded by the RMYoung for each successive 60 second period. The logger then uses all thirty of the 60 second readings, of both speed and direction, collected during the half hour to determine a resulting unit vector direction for the half hour. This column shows the unit vector direction (wind direction) obtained for that half-hour.

The datalogger measures the average wind speed (Hz) and instantaneous direction recorded by the RMYoung for each successive 60 second period. The logger then uses all thirty of the 60-second readings collected during the half-hour to determine a standard deviation of wind direction for the half-hour. This column shows the standard deviation of the wind direction obtained for that half-hour.

The datalogger measures the average wind speed (Hz) recorded by the NRG40 Anemometer for each successive 60 second period. The Logger then uses all thirty of the 60-second averages collected during the half-hour to determine an average wind speed for the half-hour. This column shows that half-hour average value.
<table>
<thead>
<tr>
<th>all 60 sec. periods</th>
<th>Snow Depth (HM1)</th>
<th>SR50</th>
<th>1.51 m a.g.s.</th>
<th>average</th>
<th>(m)</th>
<th>= The datalogger measures the instantaneous snow depth recorded by the SR50 every 60 seconds. The logger then uses all thirty of the 60-second readings collected during the half-hour to determine an average snow depth for the half-hour. This column shows that half-hour average value.</th>
</tr>
</thead>
<tbody>
<tr>
<td>all 60 sec. periods</td>
<td>Barometric Pressure (HM1)</td>
<td>SBP270</td>
<td>1.58 m a.g.s.</td>
<td>average</td>
<td>(mbar -800)</td>
<td>= The datalogger measures the instantaneous barometric pressure recorded by the Setra every 60 seconds. The logger then uses all thirty of the 60-second readings collected during the half-hour to determine an average barometric pressure for the half-hour. This column shows that half-hour average value. Add 800 to this value to get pressure in mbar.</td>
</tr>
<tr>
<td>all 10 sec. periods</td>
<td>Above Canopy Net Radiation (HM1)</td>
<td>Q7.1</td>
<td>10.0 m a.g.s.</td>
<td>average</td>
<td>(W/m2)</td>
<td>= The datalogger measures the instantaneous Net Radiation recorded by the Q7.1 every 10 seconds. The logger then uses all one hundred eighty of the 10-second readings collected during the half-hour to determine an average Net Radiation for the half-hour. This column shows that half-hour average value.</td>
</tr>
<tr>
<td>all 60 sec. periods</td>
<td>Below Canopy Net Radiation (HM2)</td>
<td>Q7.1</td>
<td>1.5 m a.g.s.</td>
<td>average</td>
<td>(W/m2)</td>
<td>= The datalogger measures the instantaneous Net Radiation recorded by the Q7.1 every 60 seconds. The logger then uses all thirty of the 60-second readings collected during the half-hour to determine an average Net Radiation for the half-hour. This column shows that half-hour average value.</td>
</tr>
<tr>
<td>all 10 sec. periods</td>
<td>K incoming Radiation (HDS)</td>
<td>PDS7.1</td>
<td>10.0 m a.g.s.</td>
<td>average</td>
<td>(W/m2)</td>
<td>= The datalogger measures the instantaneous Incoming Short Wave Radiation recorded by the PDS7.1 every 10 seconds. The logger then uses all one hundred eighty of the 10-second readings collected during the half-hour to determine an average Incoming Short Wave Radiation for the half-hour. This column shows that half-hour average value.</td>
</tr>
<tr>
<td>all 10 sec. periods</td>
<td>K outgoing Radiation (HDS)</td>
<td>PDS7.1</td>
<td>10.0 m a.g.s.</td>
<td>average</td>
<td>(W/m2)</td>
<td>= The datalogger measures the instantaneous Outgoing Short Wave Radiation recorded by the PDS7.1 every 10 seconds. The logger then uses all one hundred eighty of the 10-second readings collected during the half-hour to determine an average Outgoing Short Wave Radiation for the half-hour. This column shows that half-hour average value.</td>
</tr>
<tr>
<td>Time Periods</td>
<td>Measurement Description</td>
<td>Units</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>-----------------</td>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>---------------</td>
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<tr>
<td>all 2 sec.</td>
<td>The datalogger measures the instantaneous ground temperature recorded by the Averaging Thermocouple Array every 2 seconds. The logger then uses all nine hundred of the 2-second readings collected during the half-hour to determine an average soil temperature for the half-hour. This column shows that half-hour average value.</td>
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<tr>
<td>periods</td>
<td></td>
<td>(°C)</td>
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<tr>
<td>Min. Soil Heat</td>
<td>The datalogger measures the instantaneous heat flux recorded by the Soil Heat Flux Plate every 2 seconds. The logger then uses all nine hundred of the 2-second readings collected during the half-hour to determine an average soil heat flux for the half-hour. This column shows that half-hour average value.</td>
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<tr>
<td>Flux</td>
<td></td>
<td>(W/m²)</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>(HM3)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>All 15 min.</td>
<td>The datalogger measures the instantaneous soil moisture recorded by the TDR probe at the end of each 15-minute period within each half-hour. The logger then uses the two readings within each half-hour period to determine average soil moisture for that half-hour period. This column shows the average soil moisture obtained for the half-hour period.</td>
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<tr>
<td>periods</td>
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<tr>
<td>Organic Vol.</td>
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<tr>
<td>Water Content</td>
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<td></td>
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<tr>
<td>(HM3)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>CS 615 TDR Probe (#1)</td>
<td></td>
<td>(fraction H₂O)</td>
<td>[based on Camp.Sc. average soil type - 0.8dS/m]</td>
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<tr>
<td>10 cm b.g.s.</td>
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<tr>
<td>sample</td>
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</tr>
<tr>
<td>CS 615 TDR Probe (#2)</td>
<td></td>
<td>(fraction H₂O)</td>
<td>[based on Camp.Sc. average soil type - 0.8dS/m]</td>
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<tr>
<td>11 cm b.g.s.</td>
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<tr>
<td>sample</td>
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<td></td>
<td></td>
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</tr>
</tbody>
</table>

**Special Notes & Definitions:**

All time stamps refer to period ending (i.e. a 1030 time stamp on a half-hourly average means the data is averaged from essentially one second past 10:00am to 10:30am).

Time is recorded as a 24-hour clock, with the minutes always occupying the last two digits of the value.

Horizontal wind speed and Wind Direction refer to values determined by averaging all the instantaneous readings from the sensor over the period being analyzed. They do not involve vector determinations.

Resultant wind speed and Resultant wind direction involve vector calculations. They are essentially the vector length and direction from time zero to the end of the period being analyzed.

The units in which the various measurements are recorded are often not in the International System of Units (SI). This is contrary to N.W.R.I.'s normal practice. Meteorological Survey of Canada has chosen to maintain some non-SI units for historical purposes. We have presented the non-SI units in this case only, for consistency with MSC protocol.

a.g.s. = above ground surface  b.g.s. = below ground surface
### Six-Hourly Data outputs for the Havikpak Creek Main Meteorology Site:

**See end of output listing for Special Notes & Definitions.**

<table>
<thead>
<tr>
<th>DATE (MST)</th>
<th>YEAR (MST)</th>
<th>DAY OF YEAR (MST)</th>
<th>24 HOUR TIME (MST)</th>
<th>= Calendar date and time for the row of data values (in Mountain Standard Time).</th>
</tr>
</thead>
</table>

#### 24 Hour Time Periods

- **All 2 sec. periods**
  - Soil Temp. (HM3): 107B Thermistor
  - 10 cm b.g.s.
  - average (°C)
  - The datalogger measures the instantaneous soil temperature recorded by the 107B thermistor every 2 seconds. The logger then uses all the 2-second readings within the six-hour period to determine an average soil temperature for that period. This column shows that six hour average soil temperature at 10 cm below ground surface.

- **All 2 sec. periods**
  - Soil Temp. (HM3): 107B Thermistor
  - 20 cm b.g.s.
  - average (°C)
  - The datalogger measures the instantaneous soil temperature recorded by the 107B thermistor every 2 seconds. The logger then uses all the 2-second readings within the six-hour period to determine an average soil temperature for that period. This column shows that six hour average soil temperature at 20 cm below ground surface.

- **All 2 sec. periods**
  - Soil Temp. (HM3): 107B Thermistor
  - 30 cm b.g.s.
  - average (°C)
  - The datalogger measures the instantaneous soil temperature recorded by the 107B thermistor every 2 seconds. The logger then uses all the 2-second readings within the six-hour period to determine an average soil temperature for that period. This column shows that six hour average soil temperature at 30 cm below ground surface.

- **All 2 sec. periods**
  - Soil Temp. (HM3): 107B Thermistor
  - 45 cm b.g.s.
  - average (°C)
  - The datalogger measures the instantaneous soil temperature recorded by the 107B thermistor every 2 seconds. The logger then uses all the 2-second readings within the six-hour period to determine an average soil temperature for that period. This column shows that six hour average soil temperature at 45 cm below ground surface.

- **All 2 sec. periods**
  - Soil Temp. (HM3): 107B Thermistor
  - 60 cm b.g.s.
  - average (°C)
  - The datalogger measures the instantaneous soil temperature recorded by the 107B thermistor every 2 seconds. The logger then uses all the 2-second readings within the six-hour period to determine an average soil temperature for that period. This column shows that six hour average soil temperature at 60 cm below ground surface.

### Special Notes & Definitions:

All time stamps refer to period ending (i.e. a 1000 time stamp on an hourly average means the data is averaged from essentially one second past 09:00am to 10:00am). Time is recorded as a 24-hour clock, with the minutes always occupying the last two digits of the value.

Horizontal wind speed and Wind Direction refer to values determined by averaging all the instantaneous readings from the sensor over the period being analyzed. They do not involve vector determinations.

Resultant wind speed and Resultant wind direction involve vector calculations. They are essentially the vector length and direction from time zero to the end of the period being analyzed.

The units in which the various measurements are recorded are often not in the International System of Units (SI). This is contrary to N.W.R.I.'s normal practice. Meteorological Survey of Canada has chosen to maintain some non-SI units for historical purposes. We have presented the non-SI units in this case only, for consistency with MSC protocol.

*a.g.s. = above ground surface  b.g.s. = below ground surface*
ENERGY BALANCE CALCULATIONS
1999 Havikpak Creek (HPC) Energy Balance Calculations

HPC daily energy balance

Experimental details:
All components of the surface energy balance (Net radiation, ground, sensible and latent heat fluxes) were measured at the Havikpak Creek main meteorological station (68.32°N 133.5°W) during the spring and summer of 1999.

Net radiation and ground heat flux were measured directly, while latent and sensible heat fluxes were determined with an eddy correlation system consisting of a 3-axis sonic anemometer, a fine-wire thermocouple and a Krypton hygrometer.

From these data, daily energy accumulations and the daily residual of the energy balance were calculated.
DAILY WATER BALANCES
The spring-summer daily water balance for Havikpak Creek basin was reconstructed using measured rainfall and discharge and estimates of evaporation and snow melt. Rainfall data was available from the tipping bucket at the main met station, while discharge was measured in the spring by NWRI and monitored during the remainder of the year by Water Survey of Canada (please note: discharge data is preliminary - for final values please contact Water Survey of Canada). Evaporation was calculated using the Priestley-Taylor equations with an alpha-coefficient of 0.55 and measurements from the main met station. During the spring evaporation was weighted by the fraction of the basin that was snow-free. Snowmelt was estimated using the energy balance at the main met station, where net radiation and ground heat flux were measured and the turbulent fluxes were estimated using the bulk aerodynamic equations. When air temperatures were above freezing, the residual of the energy balance was assumed to be the melt component. Melt was weighted by the fraction of the basin which was snow-free.

While preliminary in nature, the results of the daily water balance indicate the distribution of water during the melt and summer periods at Havikpak Creek.
ACKNOWLEDGEMENTS
Acknowledgements

The investigators would like to acknowledge the field and technical assistance provided by Newell Hedstrom, Dell Bayne, Drs. John Pomeroy and Richard Essery, Stefan Pohl, Steven McCartney, and Mark Jurca in the collection and preparation of this data.

Thanks to the Aurora Research Institute, Inuvik, and especially Les Kutny, for logistical support in the field. Thanks also to the Polar Continental Shelf Project for aircraft and logistical support that is so critical to our ability to continue working in the north.

Financial contributions from NWRI, MARGS, Dr. Peter Schuepp and McGill University, the Program of Energy Research and Development, the Climate Change Action Fund, the Natural Sciences and Engineering Research Council of Canada, and the Northern Scientific Training Program are much appreciated.

Technical and data support was provided by the Water Survey of Canada, especially George Lennie in the Inuvik office, and Randy Wedel and Wade Hanna in Yellowknife.

Many thanks to Robert Crawford who provided essential data support, and to Bob Kochtubajda and the group at MSC in Edmonton for data and technical support for the MARGS-dedicated micrometeorological stations.
REFERENCE LIST
Reference List:

Articles directly stemming from MAGS funded research by P. Marsh between 1993 and 2000 and additional references of interest to MAGS. Ordered by Year and Author.

1991


1993


1994


1995


1996


1997


1998


1999


2000


Graduate Thesis related to MAGS-1 Studies by P. Marsh
