# Snow Survey Data for the Sagavanirktok River / Bullen Point Hydrology Study: Spring 2008

*Repeater site in the Brooks Range, photo by Ken Irving*


by

Sveta Berezovskaya, Jeff Derry, Douglas Kane, Michael Lilly, and Dan White


June 2008

Sagavanirktok River/Bullen Point Hydrology Project

Report No. INE/WERC 08.15

Water and Environmental Research Center

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A report on research sponsored by the

**Alaska Department of Transportation and Public Facilities, and the Alaska Department of Natural Resources.**

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**Recommended Citation:**

Berezovskaya, S.L., Derry, J.E., Kane, D.L., Lilly, M.R., and White, D.M., 2008. Snow survey data for the Sagavanirktok River / Bullen Point Hydrology Study: Spring 2008. June 2008, University of Alaska Fairbanks, Water and Environmental Research Center, Report INE/WERC 08.15, Fairbanks, Alaska, 30 pp.

Fairbanks, Alaska

June 2008

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# DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the accuracy of the data presented herein This research was funded by the Alaska Department of Natural Resources (ADNR) and the Alaska Department of Transportation and Public Facilities (AKDOT&PF). This work does not constitute a standard, specification, or regulation.

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# UNITS, CONVERSION FACTORS, WATER QUALITY UNITS, VERTICAL AND HORIZONTAL DATUM, ABBREVIATIONS AND SYMBOLS

## Conversion Factors

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| inch (in) | 25.4 | millimeter (mm) |
| inch (in) | 2.54 | centimeter (cm) |
| foot (ft) | 0.3048 | meter (mm) |
| mile (mi) | 1.609 | kilometer (km) |
| | Area | |
| Acre | 43559.826 | square feet ($ft^2$) |
| Acre | 0.407 | hectare (ha) |
| square foot ($ft^2$) | 2.590 | square mile ($mi^2$) |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| | Volume | |
| gallon (gal) | 3.785 | liter (L) |
| gallon (gal) | 3785 | milliliter (mL) |
| cubic foot ($ft^3$) | 23.317 | liter (L) |
| Acre-ft | 1233 | cubic meter ($m^3$) |
| | Velocity and Discharge | |
| foot per day (ft/d) | 0.3048 | meter per day (m/d) |
| Square foot per day ($ft^2/d$ ) | 0.0929 | square meter per day ($m^2/d$) |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second ($m^3/sec$) |
| | Hydraulic Conductivity | |
| foot per day (ft/d) | 0.3048 | meter per day (m/d) |
| foot per day (ft/d) | 0.00035 | centimeter per second (cm/sec) |
| meter per day (m/d) | 0.00115 | centimeter per second (cm/sec) |
| | Hydraulic Gradient | |
| foot per foot (ft/ft) | 5280 | foot per mile (ft/mi) |
| foot per mile (ft/mi) | 0.1894 | meter per kilometer (m/km) |
| | Pressure | |
| pound per square inch ($lb/in^2$ ) | 6.895 | kilopascal (kPa) |
| | Density | |
| Slugs per cubic foot ($slug/ft^3$) | 515.464 | Kilograms per cubic meter ($kg/m^3$) |

## UNITS

For the purposes of this report, both English and Metric (SI) units were employed. The choice of "primary" units employed depended on common reporting standards for a particular property or variable measured. Whenever possible, the approximate value in the "secondary" units was also provided in parentheses. Thus, for instance, snow density was reported in kilograms per cubic meter (kg $m^{-3}$) followed by the approximate value in slugs per cubic feet (slug $ft^{-3}$) in parentheses.

Vertical Datum:

In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called *Sea Level Datum of 1929*.

Horizontal Datum:

The horizontal datum for all locations in this report is the North American Datum of 1983.

## Abbreviations, Acronyms, and Symbols

| | |
|---|---|
| AAS | Alaska's Arctic Slope |
| ADOT&PF | Alaska Department of Transportation and Public Facilities |
| DNR | Department of Natural Resources |
| F | Fahrenheit ($^{o}$F). |
| ft | feet |
| GWS | Geo-Watersheds Scientific |
| kg | kilograms |
| km$^2$ | square kilometers |
| m | meters |
| NGVD | National Geodetic Vertical Datum |
| NRCS | Natural Resources Conservation Service |
| NWIS | National Water Information System |
| QA | quality assurance |
| QC | quality control |
| Sag | Sagavanirktok River |
| Slug | slug |
| SWE | snow water equivalent |
| UAF | University of Alaska Fairbanks |
| USGS | U.S. Geological Survey |
| WERC | Water and Environmental Research Center |
| WWW | World Wide Web |
| YSI | Yellow Springs Instruments |

## ACKNOWLEDGEMENTS

This project is funded by Alaska Department of Natural Resources and the Alaska Department of Transportation and Public Facilities. Ken Irving, Dan Reichardt, Greta Myerchin, Bill Schnabel, Robert Gieck, Emily Youcha, Amy Tidwell, Bob Busey and many others participated in snow water equivalent data collection. Peter Prokein assisted with map preparations.

# Snow Survey Data for the Sagavanirktok River Bullen Point Hydrology Study: Spring 2008

## 1. INTRODUCTION

This report follows 2006 and 2007 snow survey data reports (Kane et al, 2006, Berezovskaya et al., 2007) and discusses snow conditions that were observed during the 2008 end-of-winter snow surveys in the study area of the Sagavanirktok, Kadleroshilik, Shaviovik and Kavik River basins. Field studies primarily focused on assessment of maximum snow water equivalent (SWE) that accumulated during the 2007 - 2008 winter. Field activities started at the end of April because the snowpack at that point in time virtually binds all precipitation falling during the period from October to April, with no winter melt occurring on the Alaska's Arctic Slope (AAS) (Benson et al., 1986). Deficiencies in determining snow precipitation and sublimation imply that measurements of snow accumulated on the ground provide the most reliable observational component of the net winter water budget.

Assessment of maximum snow accumulation is critical input to snow hydrology studies. Seasonal snowpack constitutes winter detention storage for precipitation, induces considerable differences in surface energy balance, and impacts the amount of soil desiccation that occurs in the organic layer overlying permafrost (Kane et al., 1978). Snowmelt is also a major hydrological event that occurs each year due to the abundant water contained in the snowpack. Peak discharge of the annual flows is generally highest during snowmelt for many rivers on the North Slope, particularly for the basins of the Sagavanirktok, Colville and Kuparuk Rivers. These rivers drain a large area that extends from the Brooks Range through the Northern Foothills and across the Coastal Plain before discharging into the Arctic Ocean. Generally snow starts contributing to runoff in the southern foothills in May and a month later it melts on the Coastal Plain. Due to extremely high snowpack heterogeneity, knowledge on SWE spatial distribution is critical for understanding a river's hydrologic response during ablation.

This report presents snow water equivalent observational data for the eastern part of the Alaskan Arctic. It summarizes data collection procedures, accuracy of observations and their spatial distribution.

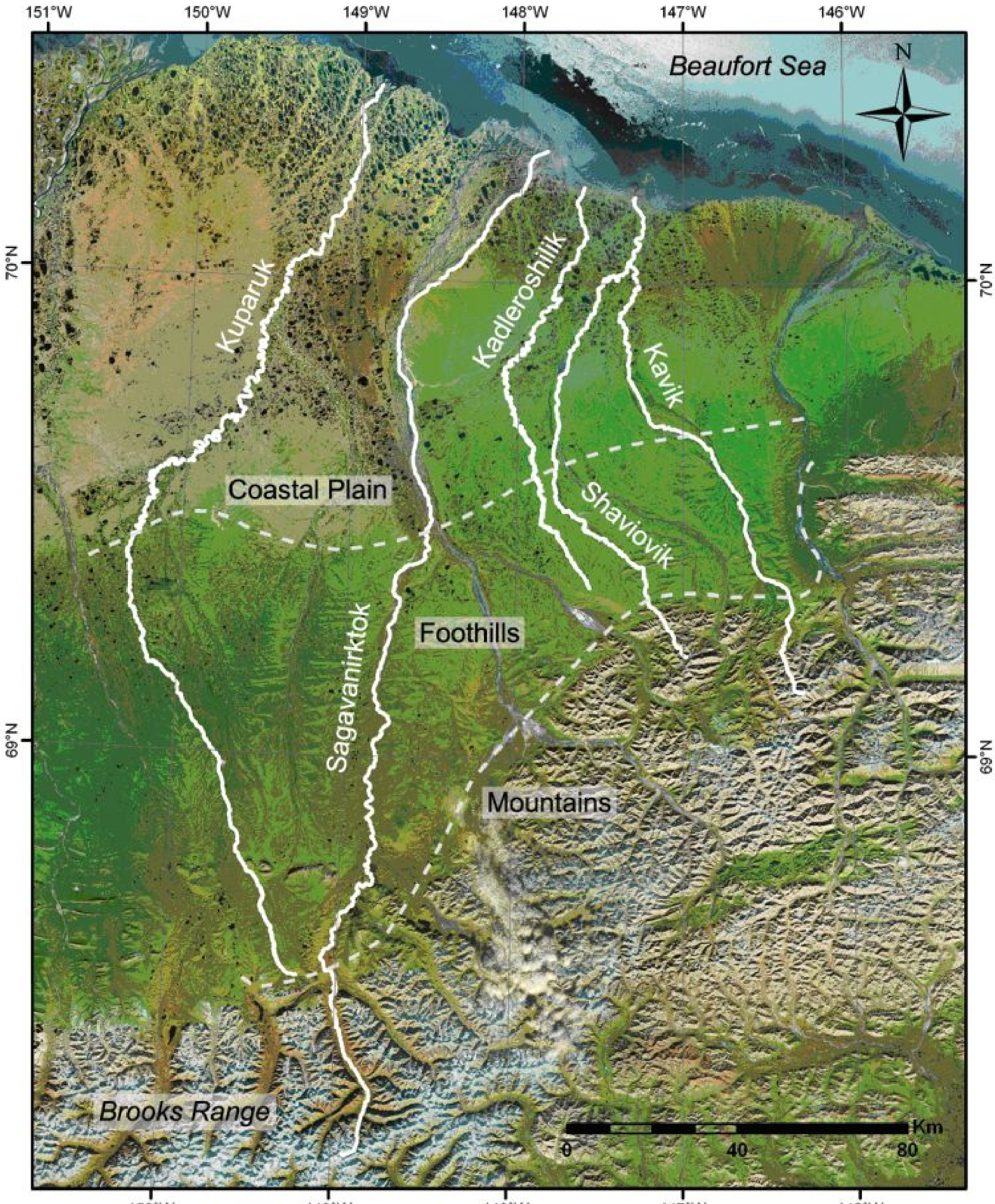


**Figure 1. Geographical map of the study area. Solid lines show major rivers; dashed lines represent approximate boundaries of the Coastal Plain, Foothills and Mountains regions.**

## 2. STUDY AREA

The study domain covers a 120 by 240 km region of the AAS that is bounded by the Brooks Range on the south and the Arctic Ocean on the north and includes the Sagavanirktok, Kadleroshilik, Shaviovik and Kavik River basins. The Sagavanirktok River is about 290 km long and has a drainage area of about 14,900 $km^2$. More than half (54 %) of the basin area occurs in the Brooks Range, and an additional 29% lies within the Foothills region. Only 17% of the basin falls within the Coastal Plain. The Sagavanirktok River is confined between the Kuparuk River basin to the east and Kadleroshilik and Shaviovik River basins to the west.

Approximately 90 % of the Kadleroshilik River basin consists of the Coastal Plain with the remaining 10 % in the Foothills. The river is approximately 113 km in length encompassing over 1,500 $km^2$ in drainage area. The Shaviovik River is located west of the Kadleroshilik River and is the largest river between the Sagavanirktok and Canning Rivers. The river is 137 km in length extending into the Brooks Range. The Shaviovik River drainage basin is approximately 4,028 $km^2$ in size which includes the watershed of the Kavik River. The confluence of the Shaviovik and Kavik Rivers is located 18 km from the coast. The Kavik River extends 122 km to the south from this confluence reaching into the Brooks Range.

The southern and northern boundaries of the domain are at 68° 10' and 70° 15' N latitude, respectively. The western and eastern boundaries of the domain are at 150° 00' and 146° 30' W longitude, respectively. The total elevation range within the study area is sea level to 2675 m (0 to 8025 ft). The topography is characterized by a flat northern portion, generally referred to as "Coastal Plain", followed by gently rolling hills and valleys ("Foothills") extending to the south and mountain ridges of the Brooks Range ("Mountains") (Figure 1). More than half of the domain occurs in the Brooks Range.

Vegetation falls within a large region of sedge tussocks and mosses that cover much of northern Alaska. Occasional groupings of willows, approximately 40 cm (15.8 in) high, occur in hillside water tracts and in the valley bottom. The surface organic soils vary from live organic material at the surface to partially decomposed organic matter between 10 and 20 cm (3.9 in – 7.9 in) in depth. Silt, overlying a glacial till, makes up the mineral soil in the glaciated areas (Kane et al, 1989). Overall, the topography and vegetation of the domain are representative of the AAS region.

## 3. SAMPLING METHODS

Snow surveys are made at designated sites throughout the domain to determine the depth, as well as vertically integrated density and water equivalent (Figure 2). Most of the sites, except for ablation measurements (see section 3.2), are visited once a year near the peak of snow accumulation, the last week of April. Our observations in the Foothills show that the onset of ablation is typically in May, so the end of April is a good time to capture end-of-winter SWE. Also, March, April and May are typically the months of lowest precipitation and, therefore, there is little accumulation between the surveys and ablation.

In addition to snow surveys, meteorological stations are equipped with snow sensors that operate during the cold season and collect snow depth data at a point. Data can be collected in near real time or downloaded in the field directly from data logger.

### 3.1 Snow Survey

Our snow surveys includes snow density and snow depth measurements collected over a 25 m by 25 m area; this technique is often referred to as “double sampling”. The Alaskan snowpack is extremely heterogeneous with Snow Depth being more variable than density (Benson and Sturm, 1993). Usually, double sampling yields an areal SWE estimate with a lower variance than is possible by collecting snow cores only. Rovansek et al. (1993) showed that double sampling provides improved SWE estimates and recommended sampling 12 to 15 snow depths for each snow core. However, this optimal ratio of snow depths to water equivalent appeared to vary greatly (from 1 to 23), depending on weather and snow conditions. Currently, we use an optimal ratio of 10; that is, 50 depths accompany five snow cores.

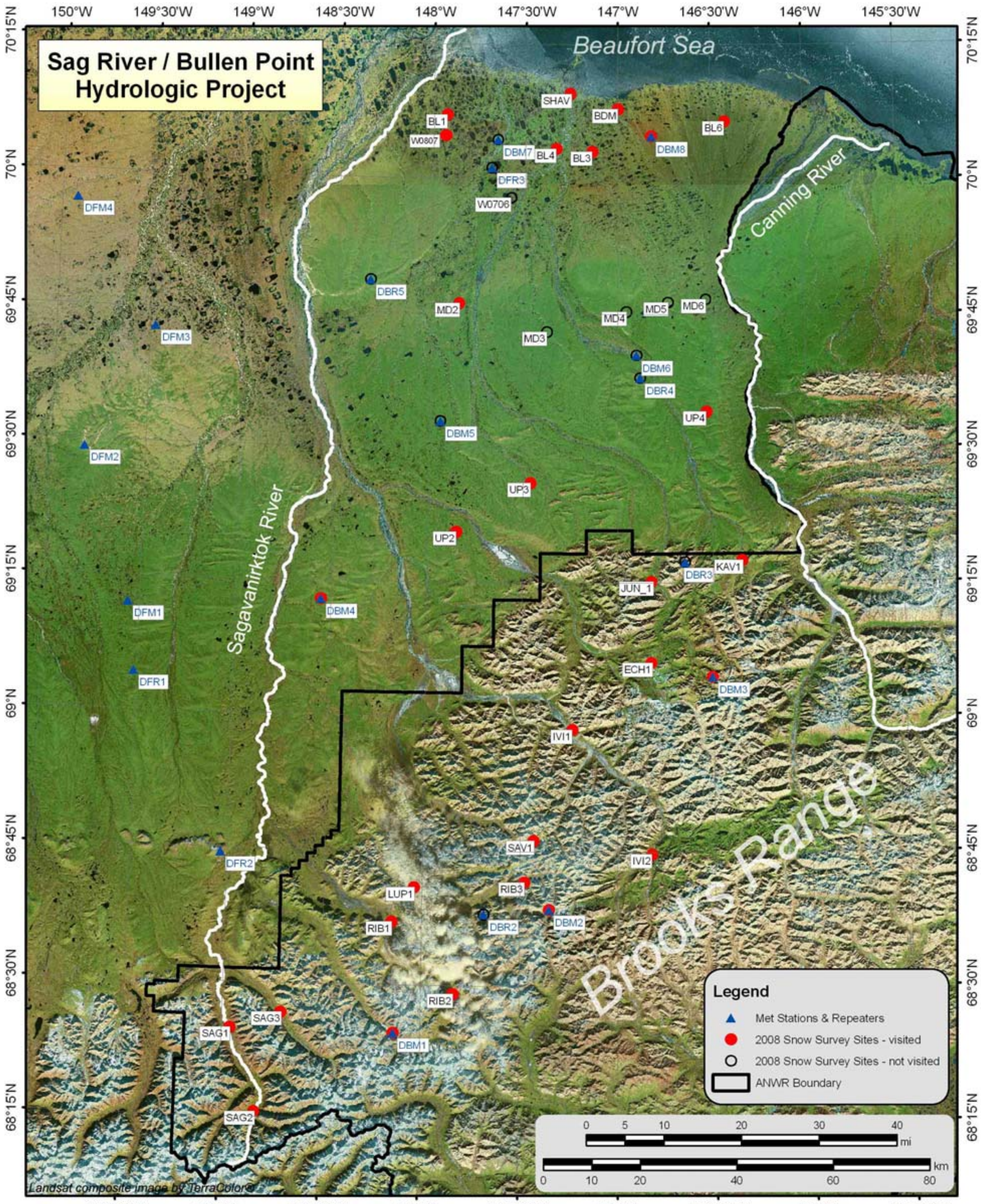


**Figure 2. Location map of 2008 snow survey sites and meteorological stations.**

Snow cores are sampled using a fiberglass tube (“Adirondack”) with an inside area of 35.7 $cm^2$, equipped with metal teeth on the lower end to cut through dense layers of snow. The advantage of the Adirondack for shallow snowpack is that it has a larger diameter than many other types of snow tubes and thus provides a larger sample for the shallow Arctic snowpack. To obtain a complete snow core, the Adirondack tube is pushed vertically through the snow while turning until soil is encountered; at this point the snow depth is recorded. The tube is then driven further into the organic layer and tipped sideways, retaining a vegetation plug that ensures the complete snow column was sampled. The vegetation plug is then removed and the snow is collected to be weighed later in the laboratory. Five snow cores are usually taken to estimate the average snow density.

We use a constant 50 m length for the snow depth course with a 1 m sampling interval along an L-shaped transect. Twenty five depth measurements are made on each leg of the L; this strategy is used to account for the presence of snowdrifts in the area of measurement. The directions of measurement are chosen randomly. Snow depth measurements are collected using a T-shaped graduated rod (T-probe). The probe is simply pushed through the snow to the snow-ground interface.

Snow water equivalent is defined as

$$SWE = (SD * \rho_s) / \rho_w \qquad (1)$$

where $\rho_s$ is average snow density from the 5 snow core samples, $\rho_w$ is water density and *SD* is an average of 50 snow depths.

## 3.2 Snow Depth Sensors

Eight meteorological stations located in the Sagavanirktok River /Bullen Point Project area are equipped with a Sonic Ranger 50 (SR50) or SR50(A) snow-depth sensor (Figure 2). The only difference between the SR50 and SR50(A) is the housing encasing the ultrasonic sensor. The sensor emits a 50 kHz sound pulse and measures the time the pulse takes to return to the sensor.

Ultrasonic sensors can measure the distance to any reflective surface like the ground or water, but sensitivity of the SR50(A) is designed for measuring distance to a snow surface.

The method for measuring snow depth with the SR50(A) is simple subtraction. When there is no snow on the ground, the distance measured is the sensor's height above the ground. When snow has accumulated under the sensor the distance measured is to the snow surface. The difference between distance-to-ground and distance-to-snow surface yields snow depth. For example, if the sensor's height above the ground is 50 inches and 10 inches of snow accumulates, the new distance to surface will be 40 inches. Hence, 40 inches subtracted from 50 inches gives a snow depth of 10 inches under the sensor.

The SR50(A) has an ultrasonic pulse measurement cone of 22º from the bottom of the sensor. It records measurements at one minute intervals, and reports hourly averages. The SR50(A) yields low spatial coverage with a high temporal resolution, while snow surveys yield higher spatial coverage with a low temporal resolution. Thus, snow sensor data used in conjunction with snow survey data can enhance and expand the limitations of each sampling method.

# 4. ACCURACY OF OBSERVATIONS

This section reports the problems of measuring and processing observational snow data, so the reported dataset can be used properly.

## 4.1 Snow Water Equivalent

Snow density and SWE are estimated using snow core sampling. Woo et al. (1997) showed that a larger tube diameter increases the accuracy of density determination; he also showed that the Canadian sampler (similar to the Adirondack in diameter) captures snow density within 5% of snow pit estimates. Our comparison of Adirondack to snow pit density gave similar results.

The accuracy of a single snow-depth measurement is difficult to quantify. In an area of well-developed organics on top of mineral soils, snow depth is often overestimated (Berezovskaya and Kane, 2007). The probe can easily penetrate low-density organic material, so this additional depth is often inadvertently incorporated into the snow depth measurement. Any type of correction to existing snow depth records is difficult to perform, because the error varies strongly from observer to observer and varying snow and soil conditions exist at each site.

While snow depths show a systematic overestimation error, snow core densities tend either to be accurate or show an underestimation error. The difficulty in SWE accuracy interpretations is that the actual, accurate SWE is unknown. Comparing different sampling methods, Berezovskaya and Kane (2007) concluded that SWE of the tundra snow estimated with double sampling technique has an error of ± 10 %.

## 4.2 Snow-Depth Sensors

Diligent field practices are essential for accurate measurements. After the sensor is installed and subsequently every time the station is visited, the distance from the bottom of the sensor to five points (four distances at 22º angles around sensor, and one directly underneath) on the ground are measured. When snow is on the ground, five depth measurements are obtained as well as the distance from the sensor to the snow surface. This information is crucial for post processing data correction and QA/QC purposes.

Adjustments to data may vary according to the error tolerance and goals of the investigation, for this report QA/QC procedures are outlined below:

- Establish a baseline value that represents no snow on the ground.
- Manually review data (graphically), and replace erroneous values with the average from the first and last data value that is deemed reasonable.
- Adjust data to fit observed values in the field.
- Smooth the data and omit smaller, sporadic, data values. If the difference between a data point and the prior data point is greater than 1.5 cm, and/or if the difference between a data point and the following data point is greater than 1.5 cm, then replace the data point with the average of the prior 5 hours and following 5 hours of data values. A 10-hour

average helped smooth out blowing snow events and cold periods that may have altered readings.

- As to avoid an abrupt transition during accumulation and/or ablation periods, incrementally adjust data over a period of days.

Potential inherent errors exist. For example, since the speed of sound in air is affected by the temperature of the air it is traveling in, an air temperature measurement is required to correct the distance reading. Inaccuracies can be caused by poor calibration and/or neglecting periodic maintenance requirements. Physically related errors include blowing snow creating spurious data readings, difficulty in establishing a zero point due to tussocks, low shrubs, grass, etc., ground heave altering sensor height, changes in sensor height and angle, as well as cable breakages due to wildlife.

## 5. SPATIAL DISTRIBUTION OF SNOW SURVEY SITES

Snow survey sites are chosen to represent snow characteristics over a wide range of vegetation and terrain conditions. Snow water equivalents are measured at elevations from sea level to 4,434 ft (0 to 1,478 m) (Appendix A1-A3).

There are two distinctly different snow regimes across the domain, uplands, and coastal plain (Liston and Sturm, 2002). To determine regional SWE, snow sites are classified as the Coastal Plain and uplands, the latter is separated into Foothills and Mountains. The coastal sites are the sites located below elevation isolines of 500 ft (152 m) and those above are referred to as upland sites. Upland snow sites are, in turn, separated into Foothills and Mountains based on elevation and surrounding topography (Appendix A1-A3). Elevation alone is not always representative for this purpose. For example, in mountainous regions most of the snow survey sites are located in the valley bottoms where helicopters can safely access the site.

We also list the lake sites that are visited for the purpose of chemistry data collection (*e.g.* Chambers et. al., 2006). A snow survey is always conducted on the lake surface because the lake snow is thinner, denser, and harder and has less snow water equivalent than snow on the surrounding tundra (Sturm and Liston, 2003). If time allows, snow surveys are also taken on the surrounding tundra.

To compare SWE between years (i.e. Table 1), only those lake sites that have repeated snow surveys are used. The Bullen Point Hydrology study has repeated snow surveys on the Badami and Shaviovik Reservoirs. Snow surveys on the other lake sites are critical to the physical models to account appropriately for ice thickness and heat losses (Sturm and Liston, 2003). Snow survey measurements in 2008 were taken on the lake surface of 4 lakes (Appendix A3 and Appendix B3).

Overall, 113 sites were visited in 2008 on the North Slope. This number includes 84 sites within the framework of the Foothills project (80 snow survey sites and 4 lake sites) and 29 sites within the Bullen Point project (28 snow survey sites and 1 lake site). Sixteen of the Bullen project sites are located in the Mountains, 5 sites are in the Foothills and 8 sites are on the Coastal Plain

## 6. SNOW SURVEY DATA

The average Mountains snow density (0.599 slug ft$^{-3}$, 309 kg m$^{-3}$) is higher than the Foothills density (0.414 slug ft$^{-3}$, 213 kg m$^{-3}$) and Coastal Plain density (0.368 slug ft$^{-3}$, 190 kg m$^{-3}$) (Appendix B1-B3).

Table 1 shows regional average SWE. Figures 3 and 4 show the snow depth and SWE at each snow survey site in the AAS. The average Coastal Plain SWE is 3.9 in (10.0 cm), and snow depth is 12.0 in (30.5 cm), respectively. The Foothills average SWE is 2.7 in (6.8 cm), and snow depth average is 12.9 in (32.8 cm). The Mountains average SWE (2.1 in, 5.4 cm) and snow depths (10.8 in, 27.3 cm) are generally lower than those at the Coastal Plain and Foothills (Figures 3 and 4).

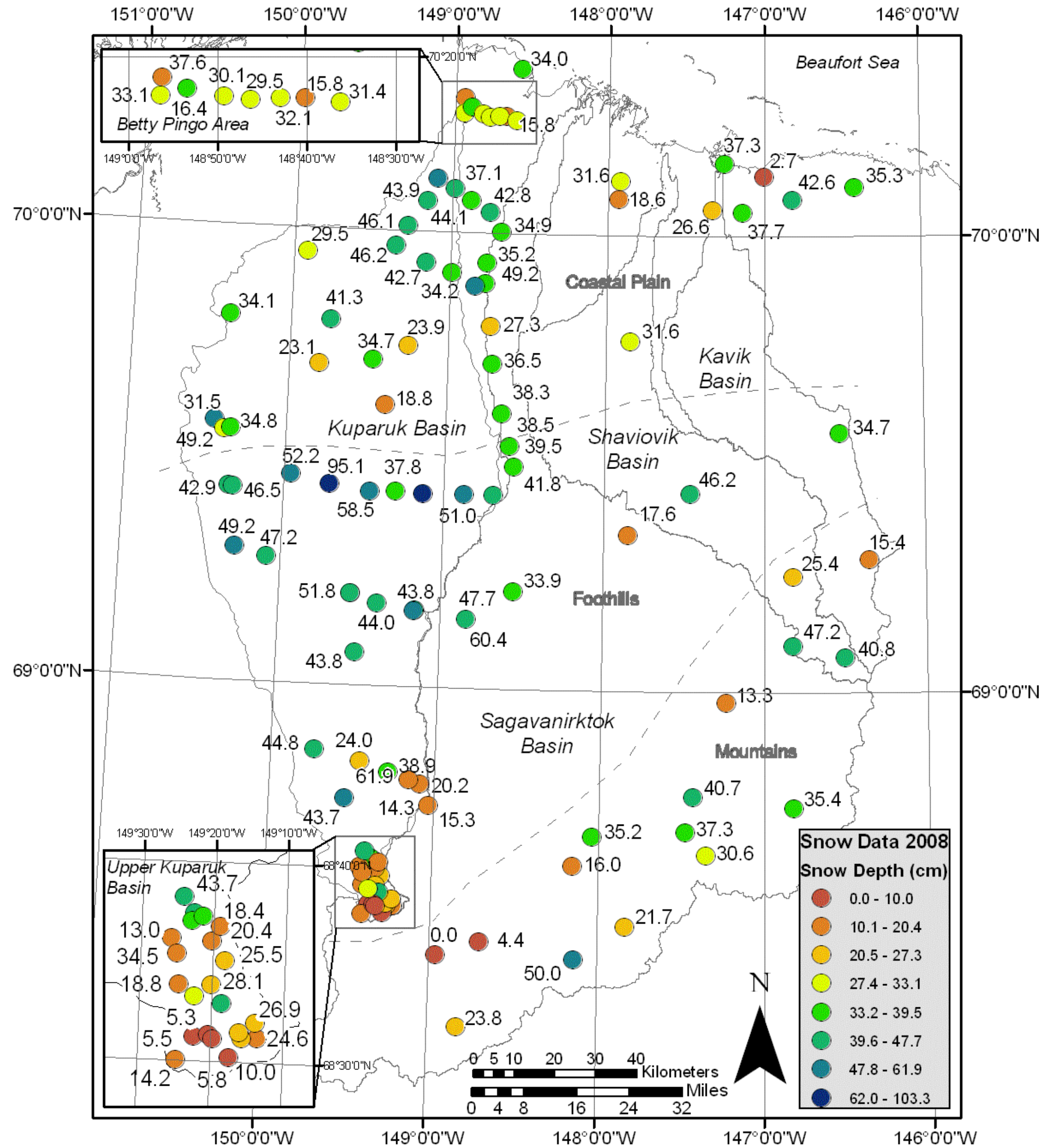


**Figure 3. End of winter snow depth (cm) collected from snow survey sites at the North Slope of Alaska in spring 2008. The colored circles represent the snow depth class that minimizes the sum of squared difference from the mean within the class. Dashed lines indicate the approximate boundary between the Mountains, Foothills, and Coastal Plains regions.**

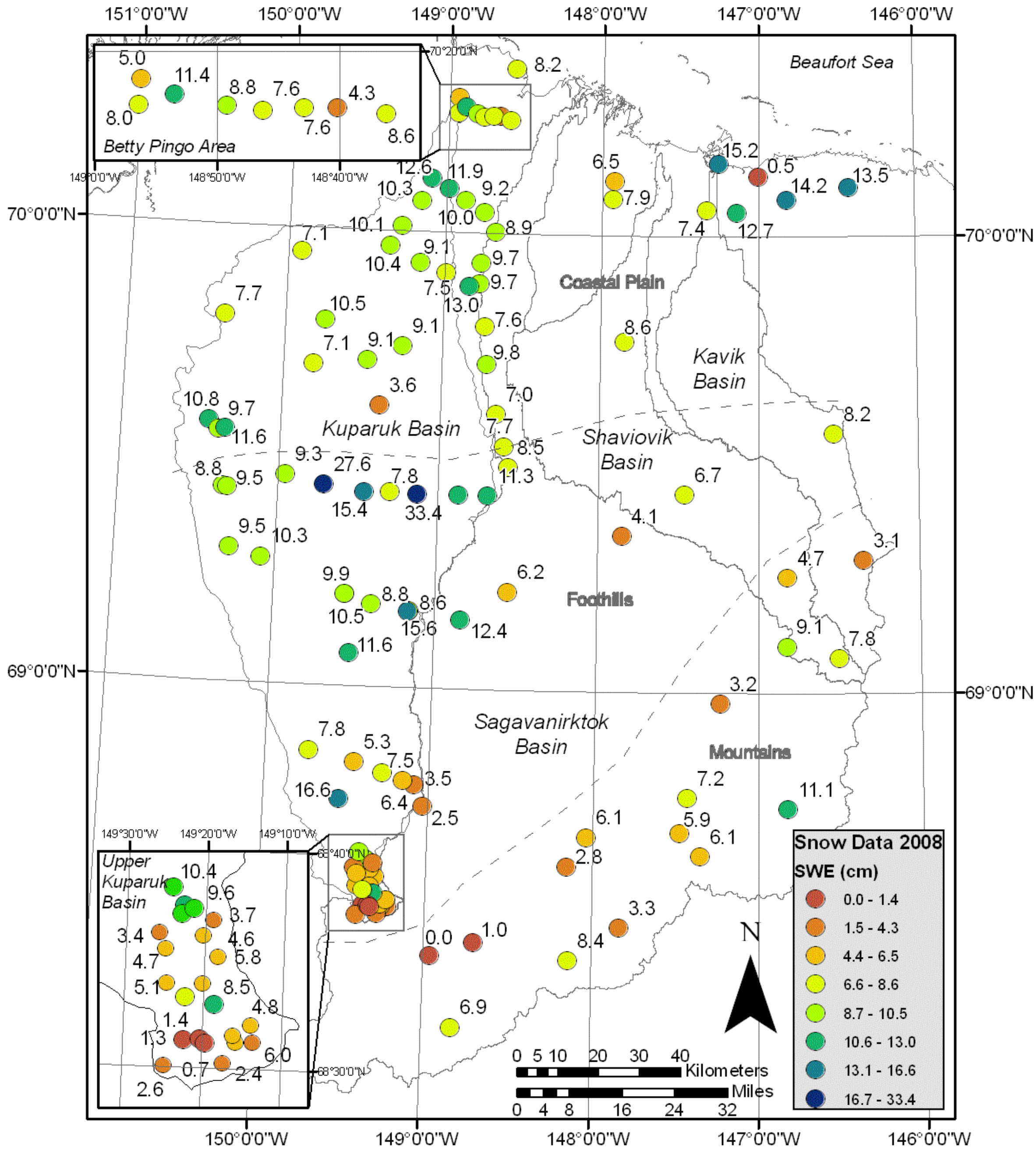


**Figure 4. End of winter snow water equivalent (cm) collected from snow survey sites at the North Slope of Alaska in spring 2008. The colored circles represent the snow water equivalent class that minimizes the sum of squared difference from the mean within the class. Dashed lines indicate the approximate boundary between the Mountains, Foothills, and Coastal Plains regions.**

**Table 1. Sagavanirktok, Kadleroshilik, Kavik and Shaviovik Rivers snow water equivalent: 2006 – 2008.**

| YEAR | Mountains | | | Foothills | | | Coastal Plain | | | Domain Average | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SWE | | Number of sites | SWE | | Number of sites | SWE | | Number of sites | SWE | | Number of sites |
| | cm | in | | cm | in | | cm | in | | cm | in | |
| 2006[1] | 7.3 | 2.9 | 14 | 7.6 | 3.0 | 8 | 8.9 | 3.5 | 10 | 7.9 | 3.1 | 32 |
| 2007[1] | 6.7 | 2.6 | 17 | 9.2 | 3.6 | 9 | 5.9 | 2.3 | 2 | 7.3 | 2.9 | 38 |
| 2008 | 5.4 | 2.1 | 16 | 6.8 | 2.7 | 5 | 10 | 3.9 | 8 | 7.4 | 2.9 | 28 |
| Average | 6.5 | 2.5 | | 7.9 | 3.1 | | 8.3 | 3.2 | | 7.5 | 3.0 | 6.5 |

Overall, average SWE over the domain is similar between the years of 2006, 2007 and 2008 (Table 1, Table 2). However, distribution of average SWE within the domain is different from year to year (Table 2). In 2008 the Mountains had less SWE when compared to 2006 and 2007, whereas the Coastal Plain shows a higher SWE in 2008 compared to previous years. The Mountains average SWE in 2008 accounts for 75% of SWE in 2006 and 81% of SWE in 2007. The Coastal Plain average SWE in 2008 accounts for 113% of the SWE in 2006 (Table 2).

[1] Note the 2007 and 2006 Coastal Plain and Basin average are slightly different from those reported in Kane et al., 2006 and Berezovskaya et al., 2007. This table contains averages only from 'long-term' snow survey sites, i.e. most of the lake snow survey sites are excluded from 2006 and 2007 averages.

**Table 2. 2008 snow water equivalent analysis.**

| Region | Number of sites | SWE | | Percent of 2007 | Percent of 2006 |
|---|---|---|---|---|---|
| | | cm | in | % | % |
| Mountains | 16 | 5.4 | 2.1 | 81 | 75 |
| Foothills | 5 | 6.8 | 2.7 | 73 | 90 |
| Coastal Plain | 7 | 10.0 | 3.9 | n/d * | 113 |
| Domain summary | 28 | 7.4 | 2.9 | 101 | 94 |

* Not defined. Due to weather conditions only 2 snow survey sites were visited in 2007

## 7. SONIC SNOW DEPTH DATA

Seven of the eight meteorological stations in the Sagavanirktok River/Bullen Point region reported continuous, good quality sensor snow depths from the accumulation/ablation season (Figures 3-9). The Lower Kadleroshilik Met (DBM7) data is not shown because of a malfunctioning SR50 sensor and the site was unable to be visited because of bad weather during the snow surveys to collect manual snow depths.

Sonic snow depth records are adjusted to account for field observations and anomalous data points (section 4.2). Transition periods, particulary the transition from fall to winter, are difficult periods to assertain accurate snow depths. For instance, Ribdon and Bullen stations (DBM2 and DBM8) reported sensor snow depths that agreed very well with measured snow depths when sites were visited on April 28 and May 1 (Figures 6 and 11). Yet, data indicated a snow depth of 10 cm (3.9 in) the first of October when it is known that no snow was on the ground. This is likely due to vegetation at these sites, grass and shrubs, which can create a false surface which the ultrasonic sensor measures. Typically, however, snow is quickly captured by the vegetation and accumulates to the top of the vegetation height during the first snow events of the season. Data is corrected for these erronous readings during the beginning of the season when reporting in real-time.

Manual snow depths from snow surveys conducted near the stations show a depth range from 20 to 105 cm (7.9 in to 41.3 in) for Accomplishment Creek, 7.2 to 72.2 cm (2.8 in to 28.4 in) for Ribdon, 21 to 74 cm (8.3 in to 29.1 in) for Juniper, 16.4 to 50 cm (6.5 in to 19.7 in) for Sag-Ivishak, and 23 to 59 cm (9.0 in to 23.2 in) for Bullen station (Figures 5-8, and 11).

Since sensor snow depth measurements are made at a point, knowledge of the representativeness of sensor data with the surrounding area is useful. Accomplishment Creek and Juniper Met sensors show a much shallower snow depth compared to the 50 snow survey depth measurements made locally (Figure 7). Sensor data represent less than 0.01 (Accomplishment Creek) and in the 0.06 (Juniper Creek) percentile - fraction of data that are less than or equal to the given sensor value – compared to the 50 snow survey depths. Sensor readings for Ribdon, Sag-Ivishak, and Bullen station are in the 0.78, 0.31, and 0.62 percentiles, respectively, compared to collocated snow survey depths. These comparisons are informative when making inferences about the surrounding area when inspecting data in real-time.

The advantage of snow sensor information is its high temporal resolution, which can capture the timing and magnitude of snow events, plus wind events that transport snow on the ground. Records show that snow accumulation began approximately in the middle of October at all of the Sagavanirktok River/Bullen Point meteorological sites. Snow depth was inconsistent in terms of comparisons between stations. Ribdon, Sag-Ivishak, Upper Kadleroshilik, Kavik, and Bullen showed a steady accumulation from the beginning of winter until approximately April 1$^{st}$ (Figures 4 and 6-9). Juniper station showed large erosion events throughout the winter with no snow being reported the last week of November and mid-January (Figure 5); Ribdon station also experienced the same erosion event in mid-January. Accomplishment Creek station had little or no snow present (Figure 5). All stations respond, to some degree, to a large storm the end of April after which all stations, with the exception of Kavik, reported their highest snow depth of the season. The maximum snow depth during the winter was recorded at Bullen (75 cm, 29.5 in) at the end of April (Figure 11). No snow was reported on the ground during the second week of May for the mountain stations (Accomplishment Creek, Ribdon, and Juniper station) or during the latter part of May for the Foothill and Coastal stations.

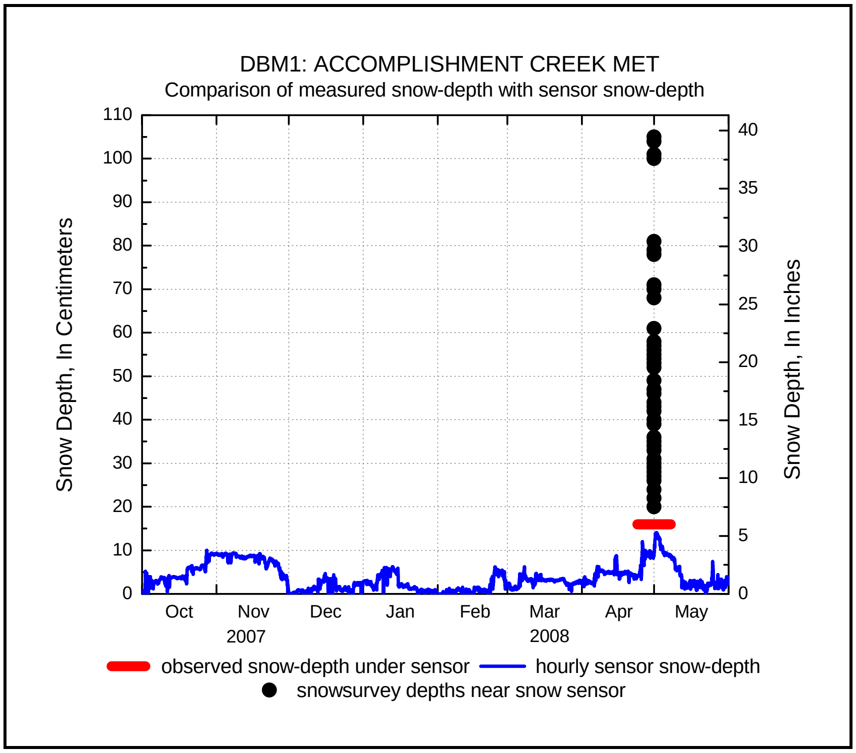


**Figure 5. Accomplishment Creek station sensor snow depth over the winter with a comparison to manual snow depth measurements in the spring.**

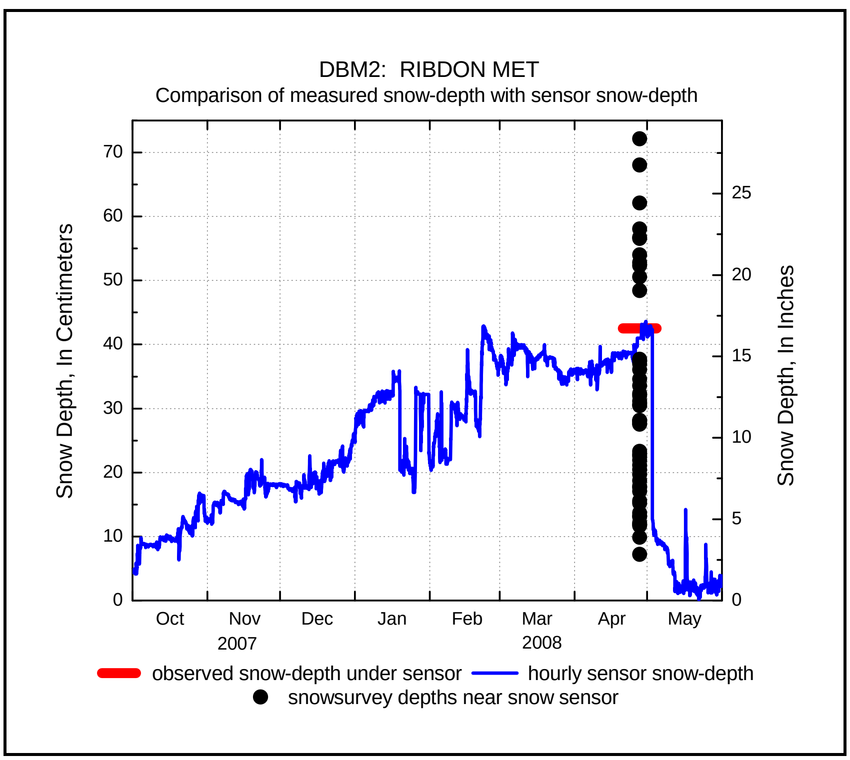


**Figure 6. Ribdon station sensor snow depth over the winter with a comparison to manual snow depth measurements in the spring.**

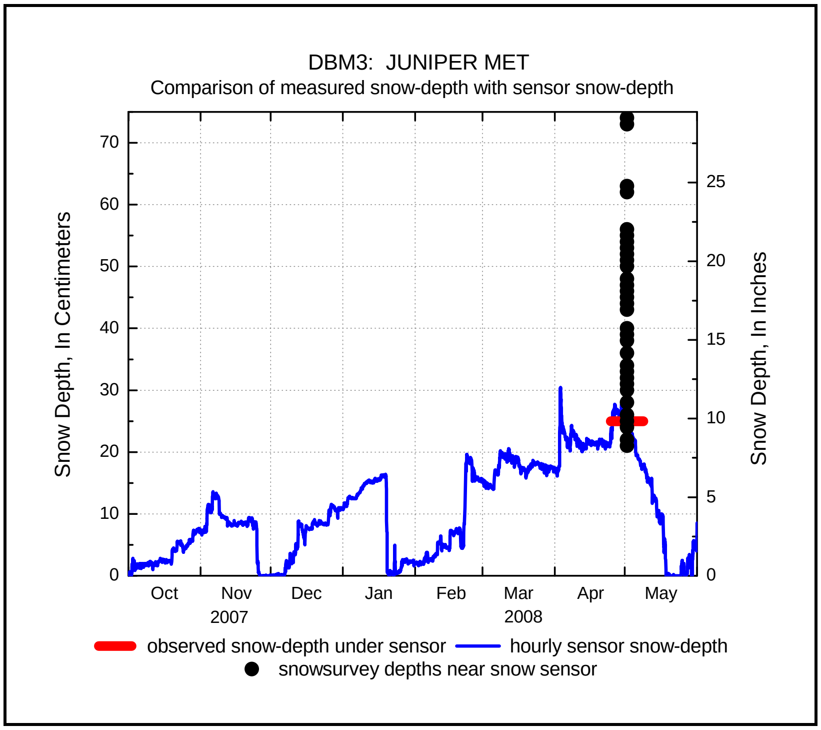


**Figure 7. Juniper station sensor snow depth over the winter with a comparison to manual snow depth measurements in the spring.**

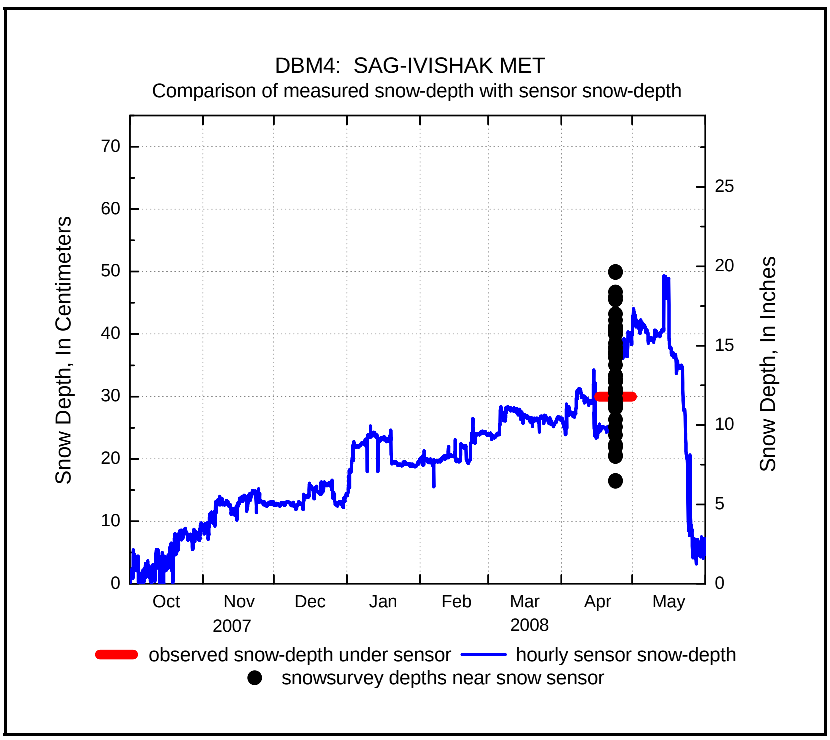


**Figure 8. Sag-Ivishak station sensor snow depth over the winter with a comparison to manual snow depth measurements in the spring.**

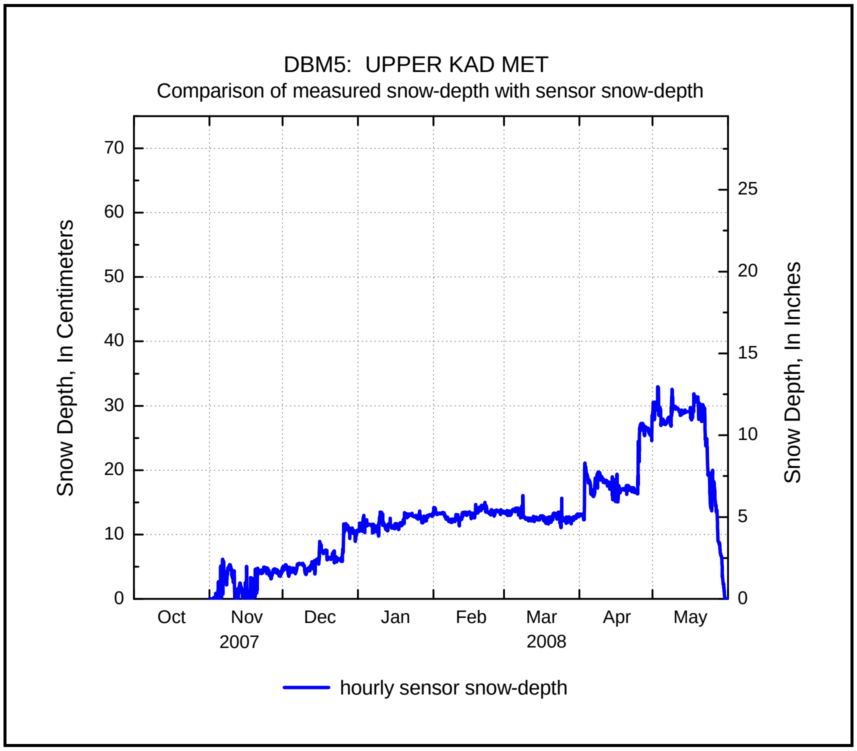


**Figure 9. Upper Kadleroshilik station hourly SR50 sensor snow depth throughout the winter.**

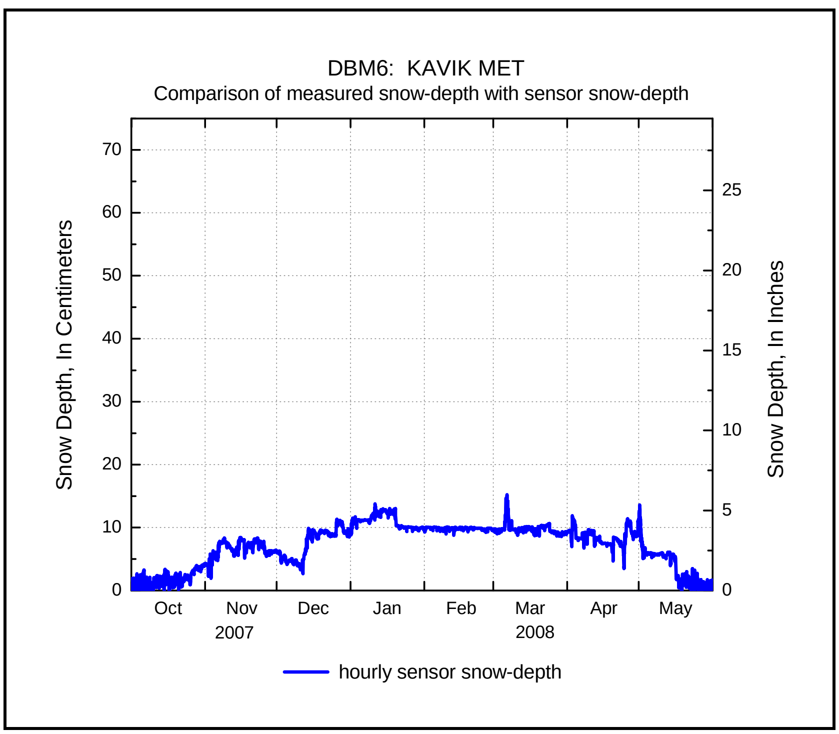


**Figure 10. Kavik station hourly SR50 sensor snow depth throughout the winter.**

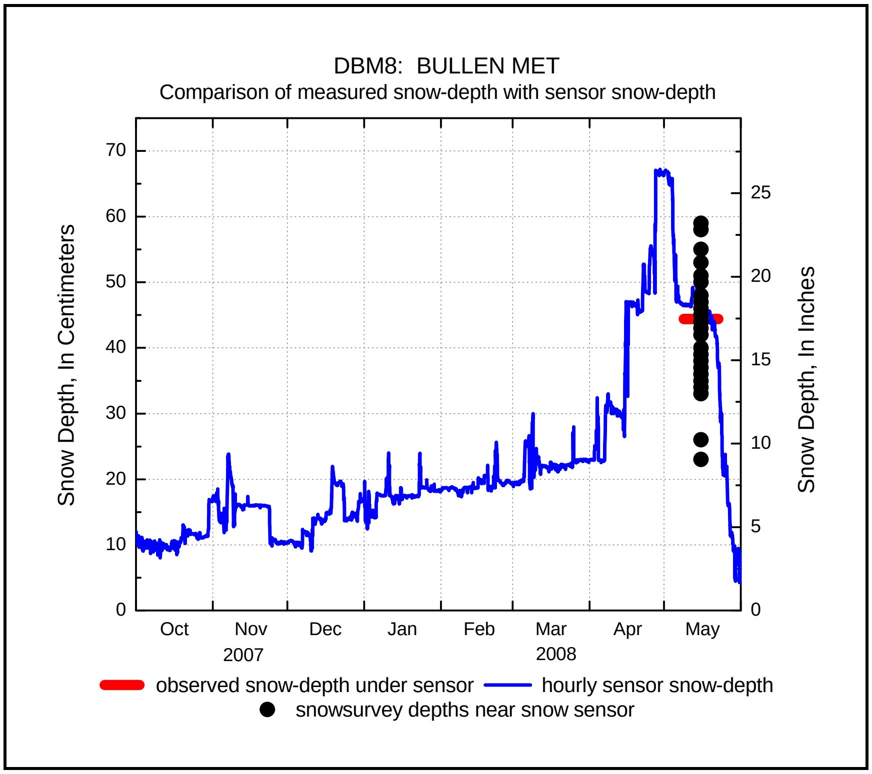


**Figure 11. Bullen station sensor snow depth over the winter with a comparison to manual snow depth measurements in the spring.**

# 8. SUMMARY

SWE, averaged for the Sagavanirktok, Kadleroshilik, Kavik and Shaviovik basin, is similar between the years of 2006, 2007 and 2008. Regional SWE in 2008 differs from previous years. The Mountains have less SWE when compared to 2006 and 2007 and the Coastal Plain has a higher SWE in 2008 when compared to previous years. The Mountains average SWE in 2008 accounts for 75% of SWE in 2006 and 81% of SWE in 2007. The Coastal Plain average SWE in 2008 accounts for 113% of the SWE in 2006.

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## LIST OF APPENDICES

## APPENDIX A. LIST OF THE SNOW SURVEY SITES IN 2008

Appendix A1. Elevation and coordinates of the sites located in the Mountains

| № | ID | ELEV m | LAT decimal degree | LON decimal degree |
|---|---|---|---|---|
| 1 | RIB1 | 609 | 68.6174 | -148.153 |
| 2 | RIB2 | 800 | 68.4848 | -147.836 |
| 3 | RIB3 | 918 | 68.6931 | -147.478 |
| 4 | SAG1 | 730 | 68.2667 | -148.967 |
| 5 | SAG2 | 868 | 68.2597 | -148.826 |
| 6 | SAG3 | 830 | 68.4462 | -148.704 |
| 7 | SAV1 | 955 | 68.7705 | -147.432 |
| 8 | ECH1 | 868 | 69.1022 | -146.825 |
| 9 | IVI1 | 521 | 68.9767 | -147.234 |
| 10 | IVI2 | 810 | 68.7464 | -146.823 |
| 11 | JUN_1 | 615 | 69.2526 | -146.823 |
| 12 | KAV1 | 733 | 69.2920 | -146.348 |
| 13 | LUP1 | 747 | 68.6817 | -148.041 |
| 14 | *DBM1* | 1474 | 68.4116 | -148.137 |
| 15 | *DBM2* | 1478 | 68.6425 | -147.352 |
| 16 | *DBM3* | 1319 | 69.0762 | -146.505 |

Appendix A2. Elevation and coordinates of the sites located in the Foothills

| № | ID | ELEV m | LAT decimal degree | LON decimal degree |
|---|---|---|---|---|
| 1 | *DBM4* | 431 | 69.2156 | -148.552 |
| 2 | UP2 | 318 | 69.3439 | -147.850 |
| 3 | UP3 | 393 | 69.4356 | -147.460 |
| 4 | UP4 | 350 | 69.5689 | -146.530 |
| 5 | MD2 | 334 | 69.7688 | -147.849 |

Appendix A3. Elevation and coordinates of the sites located on the Coastal Plain (A) and Lake Sites (B).

Table A. Coastal Plain.

| № | ID | ELEV m | LAT decimal degree | LON decimal degree |
|---|---|---|---|---|
| 1 | BL1 | 10 | 70.1184 | -147.925 |
| 2 | BL3 | 43 | 70.0516 | -147.137 |
| 3 | BL4 | 62 | 70.0566 | -147.333 |
| 4 | BL6 | 29 | 70.1073 | -146.421 |
| 5 | DBM8 | 26 | 70.0799 | -146.819 |

Table B. Lake sites[1].

| № | ID | ELEV m | LAT decimal degree | LON decimal degree |
|---|---|---|---|---|
| 1 | SHAV | 5 | 70.1586 | -147.259 |
| 2 | BDM | 4 | 70.1310 | -147.000 |
| 3 | W0807 | | 70.0805 | -147.933 |

[1] Lake sites are separated because not all them represent repeated on yearly basis measurements.

## APPENDIX B. AVERAGE SNOW DENSITY, SNOW DEPTH AND SNOW WATER EQUIVALENT

Appendix B1. Summary for the sites located in the Mountains

| № | ID | SWE | | SNOW DEPTH | | SNOW DENSITY | |
|---|---|---|---|---|---|---|---|
| | | cm | in | cm | in | $kg/m^3$ | $slug/ft^3$ |
| 1 | RIB1 | 2.8 | 1.1 | 16.0 | 6.3 | 180 | 0.349 |
| 2 | RIB2 | 3.3 | 1.3 | 21.7 | 8.5 | 150 | 0.291 |
| 3 | RIB3 | 5.9 | 2.3 | 37.3 | 14.7 | 157 | 0.305 |
| 4 | SAG1 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0.000 |
| 5 | SAG2 | 6.9 | 2.7 | 23.8 | 9.4 | 290 | 0.563 |
| 6 | SAG3 | 1 | 0.4 | 4.4 | 1.7 | 217 | 0.421 |
| 7 | SAV1 | 7.2 | 2.8 | 40.7 | 16.0 | 177 | 0.343 |
| 8 | ECH1 | 9.1 | 3.6 | 47.2 | 18.6 | 193 | 0.374 |
| 9 | IVI1 | 3.2 | 1.3 | 13.3 | 5.2 | 242 | 0.469 |
| 10 | IVI2 | 11.1 | 4.4 | 35.4 | 13.9 | 313 | 0.607 |
| 11 | JUN_1 | 4.7 | 1.9 | 25.4 | 10.0 | 184 | 0.357 |
| 12 | KAV1 | 3.1 | 1.2 | 15.4 | 6.1 | 200 | 0.388 |
| 13 | LUP1 | 6.1 | 2.4 | 35.2 | 13.9 | 175 | 0.340 |
| 14 | *DBM1* | 8.4 | 3.3 | 50.0 | 19.7 | 168 | 0.326 |
| 15 | *DBM2* | 6.1 | 2.4 | 30.6 | 12.0 | 200 | 0.388 |
| 16 | *DBM3* | 7.8 | 3.1 | 40.8 | 16.1 | 192 | 0.372 |
| | **Average** | **5.4** | **2.1** | **27.3** | **10.8** | **190** | **0.368** |

Appendix B2. Summary for the sites located in the Foothills.

| № | ID | SWE | | SNOW DEPTH | | SNOW DENSITY | |
|---|---|---|---|---|---|---|---|
| | | cm | in | cm | in | $kg/m^3$ | $slug/ft^3$ |
| 1 | DBM4 | 6.2 | 2.4 | 33.9 | 13.3 | 182 | 0.353 |
| 2 | UP2 | 4.1 | 1.6 | 17.6 | 6.9 | 230 | 0.446 |
| 3 | UP3 | 6.7 | 2.6 | 46.2 | 18.2 | 145 | 0.281 |
| 4 | UP4 | 8.2 | 3.2 | 34.7 | 13.7 | 237 | 0.460 |
| 5 | MD2 | 8.6 | 3.4 | 31.6 | 12.4 | 273 | 0.530 |
| | **Average** | **6.8** | **2.7** | **32.8** | **12.9** | **213.4** | **0.414** |

Appendix B3. Summary for the sites located in the Coastal Plain (A) and Lake sites (B).

Table A. Coastal Plain

| № | ID | SWE | | SNOW DEPTH | | SNOW DENSITY | |
|---|---|---|---|---|---|---|---|
| | | cm | in | cm | in | $kg/m^3$ | $slug/ft^3$ |
| 1 | BL1 | 6.5 | 2.6 | 31.6 | 12.4 | 207 | 0.402 |
| 2 | BL3 | 12.7 | 5.0 | 37.7 | 14.8 | 338 | 0.656 |
| 3 | BL4 | 7.4 | 2.9 | 26.6 | 10.5 | 279 | 0.541 |
| 4 | BL6 | 13.5 | 5.3 | 35.3 | 13.9 | 381 | 0.739 |
| 5 | DBM8 | 14.2 | 5.6 | 42.6 | 16.8 | 335 | 0.650 |
| | **Average** | **10.9** | **4.3** | **35** | **13.7** | **308** | **0.598** |

Table B. Lake Sites[2].

| № | ID | SWE | | SNOW DEPTH | | SNOW DENSITY | |
|---|---|---|---|---|---|---|---|
| | | cm | in | cm | in | $kg/m^3$ | $slug/ft^3$ |
| 1 | SHAV | 15.2 | 6.0 | 37.3 | 14.7 | 408 | 0.792 |
| 2 | BDM | 0.6 | 0.2 | 2.7 | 1.1 | 214 | 0.415 |
| 3 | W0807 | 7.9 | 3.1 | 18.6 | 7.3 | 426 | 0.826 |
| | **Average** | **7.9** | **3.1** | **19.5** | **7.7** | **349** | **0.678** |

[2] Lake sites are separated because not all them represent repeated on yearly basis measurements.