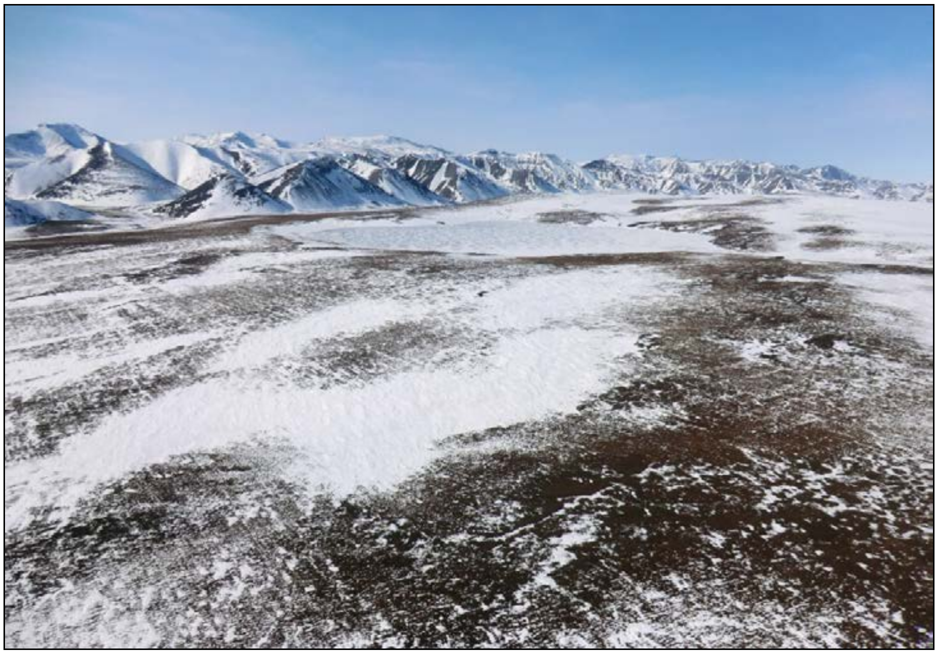
Snow Survey Data for the Central North Slope Watersheds: Spring 2012



Windblown region near the White Lake meteorological station (Chandler River basin) on April 19, 2012

by

Sveta L. Stuefer, Joel W. Homan, Emily K. Youcha, Douglas L. Kane and Robert E. Gieck

Water and Environmental Research Center

December 2012

Umiat Corridor Hydrology Projects

Report No. INE/WERC 12.22

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CONVERSION FACTORS, UNITS, 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 purpose of this report, both English and international engineering metric unit system (SI) units were employed. The choice of “primary” units employed depended on common reporting standards for a particular property or variable measured. In most cases, 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.

Datum:

The horizontal and vertical datum for all locations in this report is the World Geodetic System 1984 (WGS84).

Abbreviations, Acronyms, and Symbols

AAS	Alaska’s Arctic Slope
AKDOT&PF	Alaska Department of Transportation and Public Facilities
cm	centimeters
F	Fahrenheit (°F).
ft	feet
in	inches
kg	kilograms
km^2	square kilometers
m	meters
mph	miles per hour
NGVD	National Geodetic Vertical Datum
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
QA	quality assurance
QC	quality control
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

ACKNOWLEDGMENTS

This project was funded by grant ADN #2522154, Alaska Department of Transportation and Public Facilities. Ken Irving, Joel Bailey and many others from WERC/UAF participated in snow data collection. We thank Matthew Sturm for sharing the ablation data at Imnavait Creek collected in 2012 through the National Science Foundation SnowNet project. Contribution of Michael Lilly and Jeff Derry to the earlier snow reports (2008, 2009, 2010) is greatly appreciated.

Snow Survey Data for the Central North Slope Watersheds: Spring 2012

1. INTRODUCTION

This report is the seventh in a series of annual snow survey data reports, published each year since 2006 (Kane et al., 2006; Berezovskaya et al., 2007a and 2007b; Berezovskaya et al., 2008a and 2008b; Berezovskaya, et al., 2009; Berezovskaya et al., 2010; and Stuefer et al., 2011). Discussed in this report are the snow conditions observed during the 2012 end-of-winter snow surveys in the following watersheds: Chandler, Anaktuvuk, Itkillik, Kuparuk and western Sagavanirktok River . Snowpack field studies focused primarily on the maximum snow water equivalent (SWE) accumulation of the 2011–2012 winter and subsequent ablation. Field activities started at the end of April because, by then, the snowpack reflects nearly the maximum precipitation that has fallen minus sublimation (Benson et al., 1986) from October to April. Difficulties in quantifying 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 for use in hydrologic studies.

Assessment of maximum snow accumulation at winter's end is a critical component of snow hydrology studies, they provide necessary information for the prediction of runoff for the design of river and streams crossings. The seasonal snowpack constitutes cumulative winter storage of precipitation, induces considerable differences in surface energy balance, and affects the amount of soil desiccation that occurs within the organic layer overlying the permafrost (Kane et al., 1978). Snowmelt is a major hydrological event each year in the Arctic. For many larger river basins on Alaska's Arctic Slope, particularly in the larger basins like the Colville and Kuparuk Rivers, measured peak discharge of record is during snowmelt. These rivers drain a large area that extends from the Brooks Range on the south, through the northern foothills and finally across the coastal plain before flowing into the Arctic Ocean. Snow starts contributing to runoff in May in the southern foothills, and melting is usually complete within a month over the whole of the watershed. Due to extremely high snowpack heterogeneity, knowledge of SWE spatial distribution is critical for understanding a river basin's hydrologic response during ablation. This report presents snow depth, snow density and snow water equivalent observational data for the central part of the Alaska's Arctic Slope (AAS). It summarizes 2012 data collection procedures, accuracy of observations, and spatial distribution.

2. STUDY AREA

The study domain covers a 200-by-300-km region of Alaska's Arctic Slope (AAS) that is bound by the Brooks Range on the south and the Arctic Ocean on the north, and includes the Chandler, Anaktuvuk, Itkillik, Kuparuk and western part of the Sagavanirktok River basins. The Chandler River, located in the far west of the study area, drains from the high elevation Chandler Lake and is approximately 225 km long with a drainage area of 5800 km^2 (above our hydrologic observation station). It empties into the Colville River below Umiat. The Anaktuvuk River, which is 215 km long and has a drainage area of 7000 km^2 (above our hydrologic observation station), flows from a glacier in the Endicott Mountains to the Colville River. The upper Itkillik has a basin area of approximately 1900 km^2 and is 153 km long (above our hydrologic observation site, which is located in the upper part of basin near the proposed bridge crossing). The Kuparuk River is 240 km long and has a drainage area of about 8140 km^2. Headwaters of the Kuparuk River include a small area of the northern Brooks Range. Most of the watershed is located in the Foothills and on the Coastal Plain. The Sagavanirktok River is about 290 km long and has a drainage area of about 14,900 km^2, mainly in the Brooks Range. The Kuparuk and Sagavanirktok Rivers flow directly into the Beaufort Sea, while the other streams flow first into Colville River.

The southern and northern boundaries of the domain are at 68°10′N and 70°15′N latitude, respectively. The western and eastern boundaries of the domain are at 153°00′W and 146°00′W longitude, respectively. Elevation within the study area ranges from sea level to 2675 m (0 to 8025 ft). The topography is characterized by a flat northern portion (generally referred to as *Coastal Plain*) and by gently rolling hills and valleys (*Foothills*) and mountain ridges (*Mountains*) of the Brooks Range to the south (Figure 1).

Vegetation consists of sedge tussocks and mosses, which cover much of northern Alaska. Mountains vegetation consists of alpine communities, while the vegetation of the coastal plain is mostly grasses and sedge tussocks. Occasional groupings of willows, approximately 1 m (3 ft.) high, occur in hillside water tracts and in valley bottoms. The surface organic soils vary from live organic material at the surface to partially decomposed organic matter between 10 and 20 cm (4 in.–8 in.) in depth. The mineral soil in the glaciated areas is silt overlying glacial till (Kane et al., 1989). In the mountainous regions, weathered bedrock may be exposed at the surface.

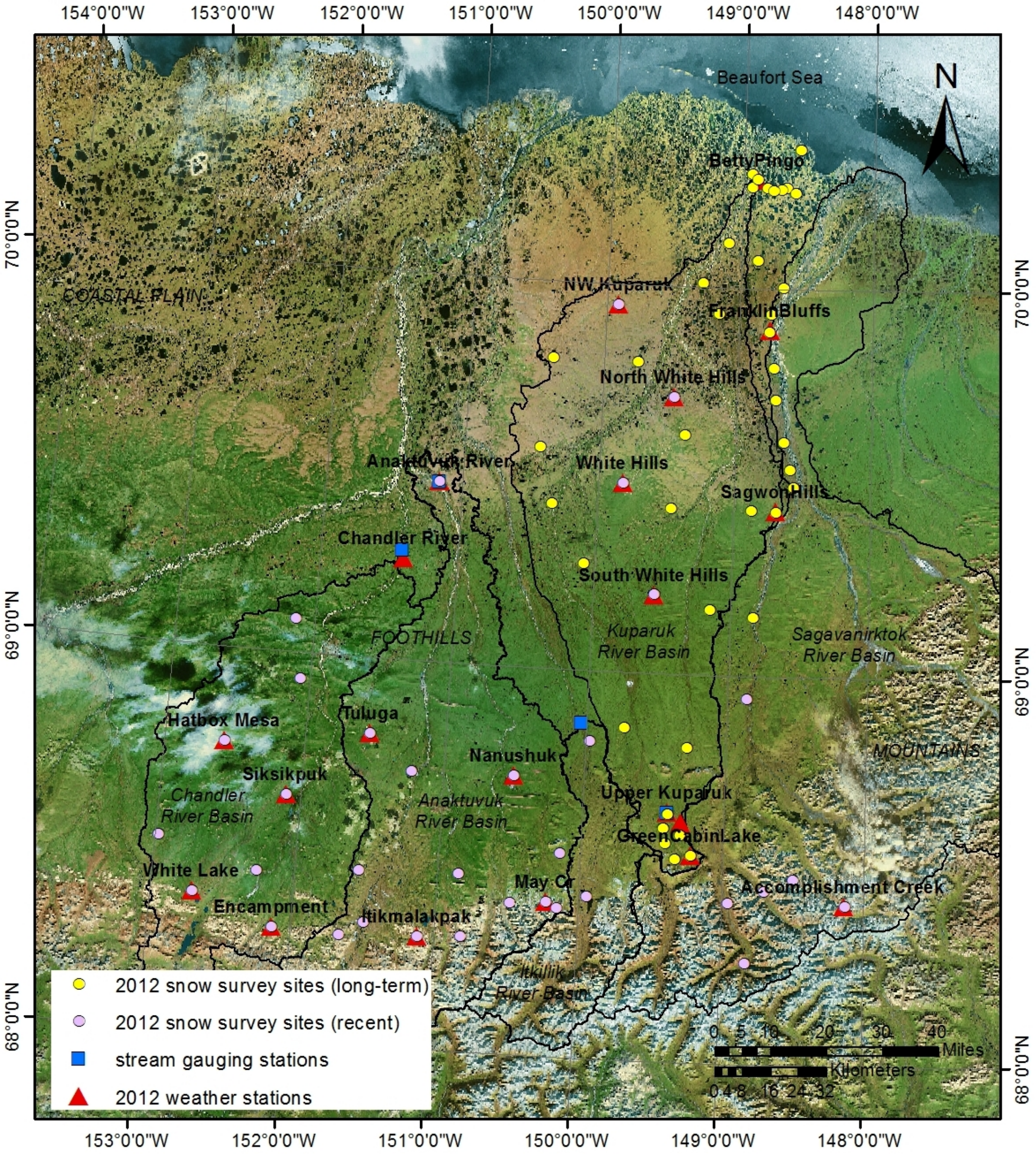

Figure 1. Geographical map of study area shows weather stations (they also double as snow survey sites) and snow survey sites visited in April, 2012. Long-term snow survey sites (10 or more years of data) are highlighted in yellow. Plotted watershed boundaries above hydrologic observation stations were derived from the digital elevation model by WERC researchers.

3. SAMPLING METHODS

Snow surveys are made at designated locations throughout the domain to determine snow depth, as well as vertically integrated density and snow water equivalent. Except when making ablation measurements (see Section 3.2), most of the sites are visited once a year near the peak of snow accumulation, generally the last week of April. Our observations show that the onset of ablation is typically in May. The end of April is a good time to capture end-of-winter SWE. March, April, and May are often the months of lowest precipitation, and therefore there is usually little accumulation between the end of winter snow surveys and the onset of ablation.

In addition to snow surveys, snow depths are collected continuously throughout the winter at meteorological stations, which are equipped with SR50 snow depth sensors. Snow depth sensor readings can be transmitted in near real time back to UAF/WERC or downloaded in the field directly from a data logger.

3.1 Snow Survey

Our snow surveys include gravimetric SWE sampling 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 using collected snow cores only. Rovansek et al. (1993) showed that double sampling provides improved SWE estimates; they recommended sampling 12 to 15 snow depths for each snow core. This optimal ratio of snow depths to water equivalent, however, appeared to vary greatly (from 1 to 23), depending on site, weather and snow conditions. Currently, we use an optimal ratio of 10; that is, 50 depths accompany 5 snow cores.

Snow cores are sampled using a fiberglass tube (“Adirondack” sampler) 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 its diameter is larger than many other types of snow tubes (like the Mt. Rose); thus, it provides a larger sample of 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, snow depth is recorded. The tube is then driven further into the organic layer and tipped sideways, retaining a vegetation plug; this ensures that the complete snow column was sampled. The vegetation plug is removed and the snow is either collected in a Ziploc bag for weighing later in the laboratory or weighed directly in the field. Five snow cores are usually taken at each site to estimate average snow density.

We use constant 50-m lengths 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 possible 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:

$$SWE = (SD * \rho_s) / \rho_w \tag{1}$$

where ρ_s is average snow density from the 5 snow core samples, ρ_w is water density, and SD is an average of 50 snow depths.

3.2 Snow Ablation

Starting with the 2007 Kuparuk Foothills snow survey data report, we have summarized long-term snow ablation observations (Table 1) that have been conducted continuously since 1985 from earlier funded National Science Foundation, Office of Polar Programs projects. The data is presented in Appendix B.

Table 1. Summary of snow ablation sites from north to south.

Site Name	Period of Record	Comments
Betty Pingo	1993 to 2012	Surveyed near NRCS precipitation gauge.
West Dock	1999 to 2009	150 m east of West Dock–GC1 Road, approximately one mile south of West Dock Meteorological Site.
Franklin Bluffs	1988 to 2012	Surveyed near Met site 1988 to 1998 (with some missing years), snow site moved west 700 m along access road 1999 to 2010.
Anaktuvuk	2011	10 meters north (upstream) of Anaktuvuk hydro-meteorological station
Sagwon Hill	1988 to 2012	Adjacent to the Sagwon Meteorological Site
Chandler	2011	Helicopter landing area near Chandler River meteorological station on bluff above the river
Happy Valley	1999 to 2012	Survey site 150 m west of Dalton Highway from Happy Valley Airfield.
Oil Spill Hill	2010	Surveyed 250 m west of pullout on top of Oil Spill Hill along the Dalton Highway.
Itkillik	2011	Right bank on lower terrace, 200 meters north of Itkillik River surface-water observation station
Upper Kuparuk	1999 to 2012	Adjacent to the Upper Kuparuk Meteorological Site.
Imnavait basin	1985 to 2009	Snow ablation measured at 4 sites on west-facing slope at mid-basin 1985 to 1988, at a 6-site mid-basin transect 1989 to 1997 and at a 6-site transect along UTM 612800 northing from 1999 to 2010.
Galbraith	2010	West of Galbraith Airport, adjacent to gravel pit access road.
Atigun Pass	2010	30 meters north of NRCS precipitation gauge.

3.2.1 Observations from 1985 to 2011

Measurement methods have changed over time as techniques have been modified to improve sampling accuracy and as the study area has expanded. From 1985 to 1992, SWE was estimated from 10 randomly collected snow cores. These cores were sampled using Adirondack tubes and weighed using mechanical scales, calibrated in inches of water. To overcome the difficulty of weighing samples in frequent high-wind conditions, cores were placed in bags in the field and weighed later indoors, using the Adirondack mechanical scale and cradle; after 1999, digital scales were used when weighing samples back in the labratory. Following Rovansek et al. (1993), the double sampling technique, which was adopted in 1996, is still used (Section 3.1). During the transition period (1993–1995), 5 to 20 snow cores were taken, along with 50 snow depths. Snow depths have been measured using a variety of devices, such as the Adirondack snow tube, avalanche probes, T-handled graduated probes, MagnaProbe, and ski poles and rods with added graduated scales.

A number of observational sites have changed over time (Table 1). In 1985, SWE and ablation were observed only in the Imnavait Creek basin. Sagwon Hill (SH) and Franklin Bluffs (FR) sites were added in 1986 (although measurements were often lacking). Snow surveys at the Sagwon site were usually made just east of the meteorological site. The Franklin Bluffs sampling site was located from 1986 through 1998, adjacent to the meteorological site 1 km east of the Dalton Highway. In 1999, the snow survey and ablation site was moved west approximately 300 m from the highway. The Betty Pingo site on the Prudhoe Bay Oilfield was established in 1992. This snow survey site is located near the NRCS Wyoming snow gauge about 200 m north of the Kuparuk Pipeline Road between P-Pad and Gathering Center 2. Upper Kuparuk, Happy Valley, and West Dock snow survey and ablation sites were added in 1999. Three snow ablation sites at Oil Spill Hill, Galbraith and Atigun Pass were monitored only one year in 2010. Three new sites (Itkillik, Anaktuvuk, and Chandler) were monitored only one year in 2011.

Imnavait Creek basin (IB) differs from others in that it has the longest period of record and more detailed observations. Up to six sites sites were sampled across the basin to capture basin average SWE. From 1985 through 1997, the Imnavait basin SWE was determined from a transect made across the basin, perpendicular to the stream channel. At that time, snow ablation was tracked only at the west-facing slope adjacent to 4 runoff plots (Hinzman, 1990). In 1989, two additional sites were added: one in the valley bottom and one on the low east-facing slope of the basin. To provide consistent identification of sites, the transect has been aligned with the 7612800 northing (NAD27, UTM6) since 1999.

Many of the previously described snow ablation measurements were supported by the WERC/UAF project “Long-term measurements in the Kuparuk River Watershed” funded by National Science Foundation since 2003. Support from this NSF project was discontinued in 2010, which had resulted in the reduction of the snow survey and ablation sites. Ablation observations were discontinued at the West Dock (WD), and at 6 sites across the Imnavait basin (IB1–IB6) in 2010 and 2011. Some measurements were made by another party in 2012.

3.2.2 Observations from 2012

Ablation sites visited in 2012 include Betty Pingo, Franklin Bluffs, Happy Valley, Sagwon Hills, and Upper Kuparuk. These sites were visited daily or every other day to capture the net volumetric decrease in SWE. We took 5 snow density and 50 snow depth measurements at each site. The snow depth course during snowmelt has an assigned location because of daily repeated measurements.

3.3 Snow Depth Sensors

The study domain includes fifteen meteorological stations, each equipped with a sonic snow depth sensor. Five stations in the Sagavanirktok and Kuparuk River basin were established in August 2006 (Table 2, Figure 1). Five stations were established in the Anaktuvuk River basin in June 2009 and five stations were installed in the Chandler River basin in September 2010. The snow depth sensor type is Campbell Scientific Sonic Ranger SR50 or SR50(A). 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.

Table 2. Meteorological stations with an SR50 snow depth sensor included in this report. Site coordinates are listed in Appendix A.

	Site Name	General Location
1	Accomplishment Creek (DBM1)	Sagavanirktok River, Brooks Range
2	South White Hills (DFM1)	Kuparuk River, Foothills
3	White Hills (DFM2)	Kuparuk River, Foothills
4	North White Hills (DFM3)	Kuparuk River, Foothills
5	Northwest Kuparuk (DFM4)	Kuparuk River, Foothills
6	Itikmalakpak (DUM1)	Anaktuvuk River, Brooks Range
7	Upper May Creek (DUM2)	Anaktuvuk River, Brooks Range
8	Nanushuk (DUM3)	Anaktuvuk River, Foothills
9	Tuluga (DUM4)	Anaktuvuk River, Foothills
10	Anaktuvuk (DUS2)	Anaktuvuk River, Foothills
11	Encampment Creek (DUM5)	Chandler River, Brooks Range
12	White Lake (DUM6)	Chandler River, Brooks Range
13	Hatbox Mesa (DUM7)	Chandler River, Foothills
14	Siksikpuk (DUM8)	Chandler River, Foothills
15	Chandler River Bluff (DUS3)	Chandler River, Foothills

The method for measuring snow depth with the SR50 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 from the sensor 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 (127 cm) and 10 in (25.4 cm) of snow accumulates, the new distance to surface will be 40 in (101.6 cm). Hence, 40 in (101.6 cm) subtracted from 50 in (127 cm) gives a depth of 10 in (25.4 cm) under the sensor. The ultrasonic pulse has a measurement cone circumference of 22º from the bottom of the sensor. The program for the SR50 records measurements at one minute intervals and reports hourly averages.

4. ACCURACY OF OBSERVATIONS

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

4.1 Snow Water Equivalent

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

The accuracy of a single snow depth measurement depends on properties of underlying organic material. In the area of well-developed organics on top of the mineral soils, snow depth is often overestimated (Stuefer et al., 2013). While measuring, the probe can easily penetrate low-density organic material, so this additional depth often is incorporated inadvertently 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 depends on snow and soil conditions at each site.

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

4.2 Snow-Depth Sensors

High frequency, small amplitude noise is inherent in ultrasonic snow depth sensors and can be an impediment to accurate snow accumulation measurements (Brazenec, 2005). Since the speed of sound in air is affected by the temperature of the air it is traveling in, an air temperature is measured to correct distance readings. Sensor mounting height can influence data quality with higher mounting heights resulting in noisier data. Manufacture’s stated accuracy is ±1 cm or 0.4% of distance to snow surface, whichever is greater (Campbell, 2008). Inaccuracies can be caused by difficulty in establishing a zero point due to tussocks/uneven ground, vegetation growth, neglecting periodic maintenance requirements (replacement of sensor transducer), high wind, falling snow, low density snow, blowing snow, and change in sensor height due to ground heave.

Sonic snow depth records in this report were adjusted manually to account for both field observations and erroneous data points. Typically, erroneous data occurred during high wind/blowing snow events as well as beginning and end of seasonal transition periods. Just prior to the 2008-2009 snow season, the ground surface under the snow sensors was trimmed of vegetation and leveled with wood bark. This resulted in improved clarity when deciphering the timing and amount of snow accumulation at the beginning and end of the season.

Diligent field practices are essential for accurate measurements and post-processing data corrections and QA/QC purposes. Our field procedures during site visits include:

- Measuring distance from the sensor to the ground during the snow free season.
- Measuring snow depth under the sensor.
- Measuring distance from sensor to snow surface.
- Conduct snow survey near the sensor.
- Inspect sensor and supporting structure for proper leveling and structural soundness.
- Inspect sensor for corrosion and ice on sensor, replace if it is necessary.

We usually visit these sites twice per year, once in the fall when there is no significant snow and once in the spring about the time of maximum SWE. If we visit these sites in the winter, we take all of the measurements mentioned above. On-site checks during field visits ensure proper operation and better accuracy of the snow sensor.

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 (Figures 2 and 3). Snow water equivalents are measured at elevations from 5 m to 1478 m (16.4 ft to 4849 ft). To determine regional average SWE, snow sites are classified as Coastal Plain, Foothills and Mountains (Appendix A1–A3). This classification is based on elevation and surrounding topography. Coastal sites are generally located below an elevation contour of 500 ft (152 m). Foothills sites are located above 500 ft (152 m) and below elevation contour of 3300 ft (1000 m). Elevation alone is not always representative for the classification of Mountains sites, because many of them are located in lower elevation valley bottoms where a helicopter can safely access the site. We selected Mountains sites either based on elevation (above an elevation of ~3300 ft (1000 m)) or based on surrounding topography. If the mountain ridges around the snow survey site are above 3300 ft (1000 m), we classified this site as Mountains even if the site itself is located at the lower elevation (Appendix A1–A3).

Overall, 74 sites were visited in 2012. This number includes 14 sites located in the Mountains, 35 sites in the Foothills, and 25 sites on the Coastal Plain.

6. SNOW SURVEY DATA

We observed in 2012 that the average Coastal Plain snow density (0.515 slug ft^{-3}, 265 kg m^{-3}) is higher than the Foothill snow density (0.481 slug ft^{-3}, 248 kg m^{-3}) and Mountain snow density (0.493 slug ft^{-3}, 254 kg m^{-3}) (Appendix A1–A3). This is generally the case each year.

In 2012, the average Coastal Plain SWE was 4.3 in. (11.0 cm), and snow depth is 16.1 in. (41.0 cm). The average Foothills SWE was 4.3 in. (11.0 cm), and average snow depth was 18.0 in. (45.8 cm). The average Mountains SWE was 2.6 in. (6.5 cm), and average snow depth was 9.5

in. (24.1 cm); both these measurements are generally lower than those of the Coastal Plain and Foothills. Figure 2 and Figure 3 show the snow depth and SWE at each snow survey site.

Observations from year to year suggest that regional end-of-winter SWE and snow depth of the Foothills and Coastal Plain are generally higher than those of the Mountains. Similarly, the average Coastal Plain snow density is generally higher than the Foothills and Mountains snow density.

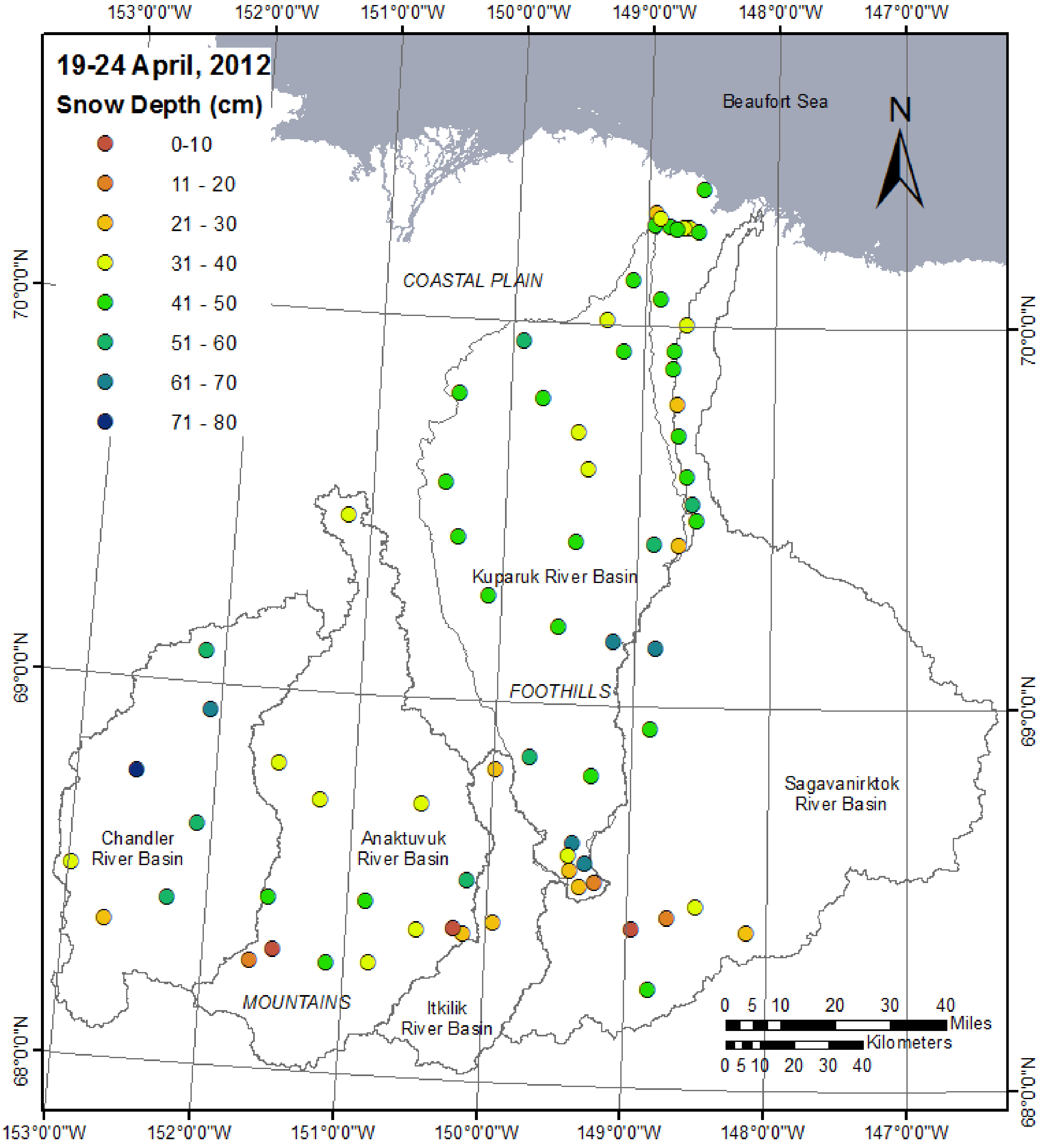

Figure 2. End-of-winter snow depth (cm) in the Central North Slope of Alaska in spring 2012. Each point represents average of 50 snow depths.

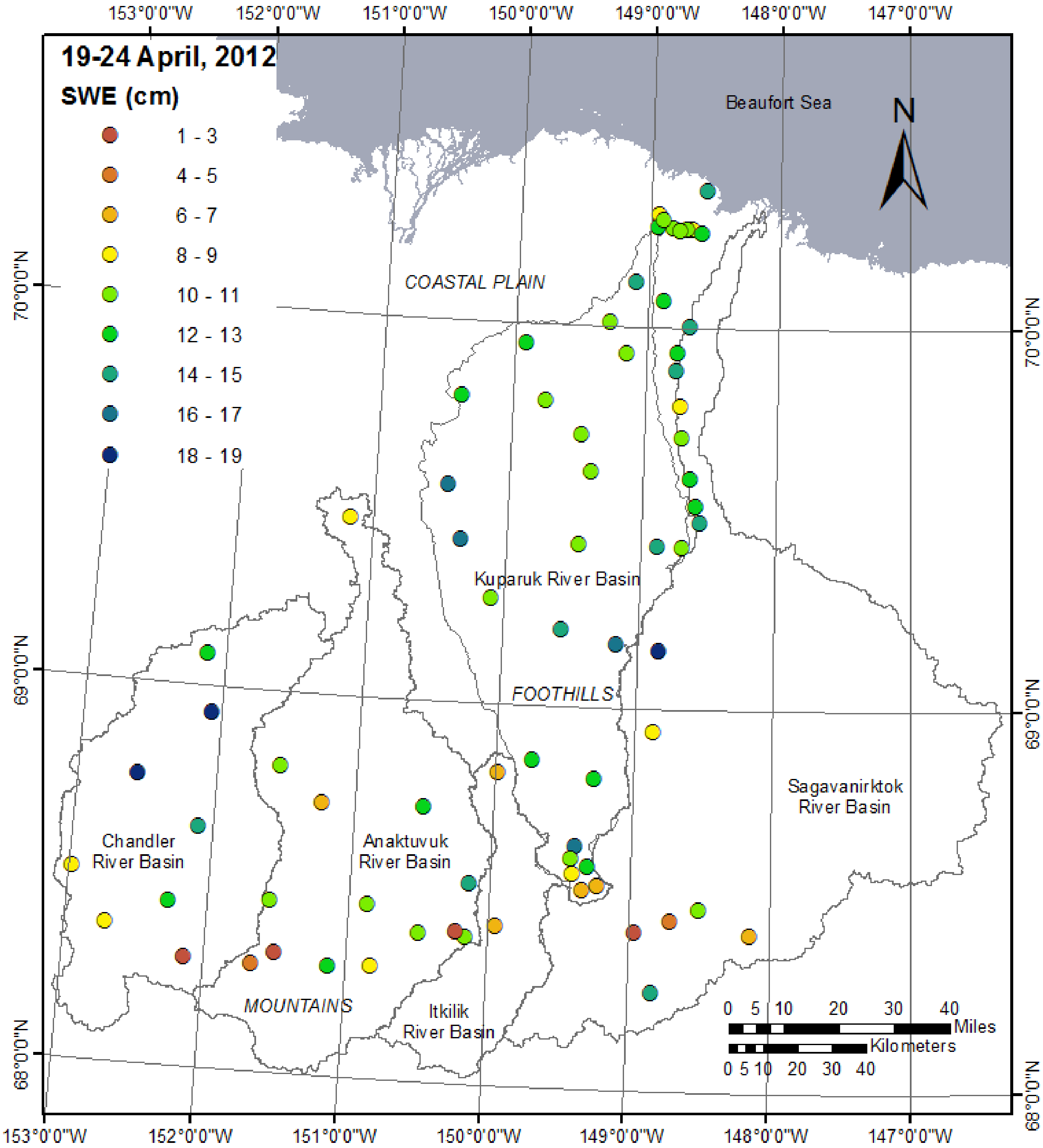

Figure 3. End-of-winter snow water equivalent (cm) in the Central North Slope of Alaska in spring 2012.

The number of visited snow survey sites at each basin varies from year to year because weather conditions do not always allow access to all the stations by helicopter; also research funding varies from year-to-year. The basin average snow depth and density, along with the SWE average, presented in Tables 3-5, should be interpreted with care as a slightly different number of stations is visited each year.

The Anaktuvuk and Chandler River basins have slightly higher end-of-winter SWE in 2012 when compared to 2011 (110% and 107% of the 2011 SWE). Both the Kuparuk and Sagavanirktok have less end-of-winter SWE in 2012 compared to the previous year (61% to 87% of the 2011 SWE).

Table 3. Basin average snow depth for 2012.

Basin	Number of sites	2012		Percent of last year
		Snow Depth (cm)	Std. Dev. (cm)	%
Chandler	8	46.7	22.9	108
Anaktuvuk	14	32.8	15.7	90
Kuparuk	25	41.8	14.4	66
Sagavanirktok	16	40.2	14.8	61

Table 4. Basin average snow density for 2012.

Basin	Number of sites	2012		Percent of last year
		Snow Density (kg/m^3)	Std. Dev. (kg/m^3)	%
Chandler	8	251	24.1	118
Anaktuvuk	14	249	58.8	108
Kuparuk	25	268	38.4	109
Sagavanirktok	16	263	33.3	95

Table 5. Basin average Snow Water Equivalent (SWE) for 2012.

Basin	Number of sites	2012		Percent of last year
		SWE (cm)	Std. Dev. (cm)	%
Chandler	8	11.2	5.7	107
Anaktuvuk	14	8.4	4.1	110
Kuparuk	25	11.0	3.9	87
Sagavanirktok	16	10.6	4.1	61

6.1 Long-term snow observations

The longest snow survey record on the AAS has been maintained by the U.S. Department of Agriculture (USDA) since the 1970s, based on few snow survey sites visited along the Dalton Highway. Our snow survey dataset covers shorter period of time (2000–2012), but it has more detailed spatial coverage: 42 snow survey sites that represent SWE at the different topographic and vegetation settings. Long-term snow survey sites cover the Kuparuk River watershed and different landscape units along the Dalton Highway, located in the Sagavanirktok and Putuligayuk River watersheds (see snow survey site highlighted in yellow on Figure 1). These sites are visited every year, if the weather allows. In addition, the short-term snow dataset (six or less years of data) are not included in basic statistics of Table 6 and the discussion below.

End-of-winter SWE (11.3 cm, 4.4 in) in 2012 accounts for 110% of the 13-year basin average SWE (10.3 cm, 4.1 in). The 2012 end-of-winter SWE for the Coastal Plain is slightly higher than average and represents 109% of the 13-year basin average SWE. End-of-winter SWE in the Foothills is accounts for 99% of the 13-year basin average SWE. The Foothills and Coastal Plain had the highest 13-year SWE average (15.4 and 13.4 cm, 6.1 and 5.3 in.) in 2009 (Table 6). SWE in 2011 is the second highest in the record – 13.6 cm (5.4 in) in the Foothills and 12.9 cm (5.1 in.) on the Coastal Plain. In 2010, the number of long-term observational sites in the Kuparuk River basin was decreased by 50%, eliminating most of the snow survey sites in the Mountains of the Kuparuk Basin. This is the reason why we no longer report SWE in the Mountains in Table 4. This database has become long enough that we can start to analyze variability from year to year (Table 6). The highest snow accumulations were observed in 2003, 2009 and 2011, whereas 2001, 2006, 2008 were relatively low snow years.

Table 6. Maximum, minimum, and average snow water equivalent in the Coastal Plain, Foothills, and Mountains of the Kuparuk, Sagavanirktok, and Putuligayuk regions from the long-term measurements (2000–2012, n=13). The statistics below do not include short term (less than six years of data) snow survey sites.

Region	2012 SWE		Maximum SWE		Minimum SWE		Average SWE	
	cm	in.	cm (year)	in.	cm (year)	in.	cm	in.
Mountains	-	-	14.7 (2003)	5.8	3.5 (2008)	1.4	8.1	3.1
Foothills	11.5	4.4	15.4 (2009)	6.1	8.9 (2006)	3.5	11.7	4.6
Coastal Plain	11.1	4.4	13.4 (2009)	5.3	8.4 (2001)	3.3	10.1	4.0
Domain average	11.3	4.4	13.2 (2011)	5.0	7.3 (2008)	2.9	10.3	4.0

7. SONIC SNOW DEPTH DATA

Sonic sensor snow depth data used in conjunction with snow survey data can enhance and expand the information gained from both sampling methods. Since the sonic sensor records just snow depth at a single point, the additional fifty snow depth measurements near each station represent local-scale variability relative to the measurement area under SR50A sensor (Tables 7 (2012) and Table 8 (2011) and Figures 4-18). The main advantage of the sonic snow depth sensor measurements is that it gives an indication of what happened at the site during the winter when the site was not visited. We use SR50 and SR50A interchangeable in this report; the SR50 is an older model, when we replace the older models we replace them with a SR50A.

During the 2011-2012 winter, SR50A measurements were recorded at fifteen meteorological stations. Only one station from the Bullen project (DBM1, Accomplishment Creek) remains in the Sagavanirktok River basin. Four stations (DFM1-4) remain in the Kuparuk basin as part of the Kuparuk Foothills study (ADOT&PF funded). As part of the Umiat Corridor Project (ADOT&PF funded), ten stations (DUM1-DUM8 and DUS2-DUS3) exist in the Anaktuvuk and Chandler basins. . The April snow survey determined average depth are the same each year (within 8 cm) at the South White Hills, North White Hills, Northwest Kuparuk, Upper May Creek, Nanushuk, Anaktuvuk, and White Lake, but higher in 2011 at five stations (Accomplishment Creek, Tuluga, Encampment, Siksikpuk, and White Hills) and higher in 2012 at the Itikmalakpak station. When we compare the observed snow depth at the SR50A sensor in late winter 2012 with the previous year, the snow depths are mostly equal to (within 8 cm) the snow depth at the sensor in late winter 2011. The exceptions are: Accomplishment Creek, Northwest Kuparuk, and Hatbox Mesa had higher SR50 snow depths at the end of winter 2011 and Nanushuk had slightly higher SR50 depths at the end of winter 2012.

There is considerable variability in terms of how well snow sensors represent local snow course depths from year-to-year, which in large part is dependent on the location of the snow depth sensor. For example, the SR50 sensor at North White Hills (DFM3) station (Figure 7) consistently records a lower SR50 snow depth than the fifty observed depths collected near the station during snow surveys. The SR50 sensor at Northwest Kuparuk (DFM4) station (Figure 8) records close to average snow depth (compared to the 50 observed depths measured near the station) each winter, with the exception of lower snow depth in winter 2006-2007 and higher depth in winter 2007-2008. This is an example of the challenges associated with siting the sensor and using SR50 snow depth data for quantitative analysis.

Table 7. Snow depth information from meteorological stations and co-located snow surveys for 2012.

Meteorological Station	Snow Survey Depth Range (cm)	Snow Survey Depth Average. (cm)	Observed Depth Under SR50 (cm)	SR50 Reported Depth at Time of Observed Depth (cm)	Difference Between Observed and SR50 Reported Depth (cm)
Accomplishment Creek (DBM1)	35-67	26.1	8.0	6.9	1.1
South White Hills (DFM1)	27-70	48.6	49.0	43.2	5.8
White Hills (DFM2)	0	0	0.0	NA	NA
North White Hills (DFM3)	28-56	33.3	23.0	21.0	15.3
Northwest Kuparuk (DFM4)	0-84	53.1	52.0	43.6	8.4
Itikmalakpak (DUM1)	23-57	46.0	38.0	39.2	-1.2
Upper May Creek (DUM2)	18-59	3.8	3.0	0.7	2.3
Nanushuk (DUM3)	0-79	38.0	26.0	23.6	2.4
Tuluga (DUM4)	3-72	39.5	48.0	49.6	-1.6
Encampment Creek (DUM5)	26-63	2.8	0.0	0.4	-0.4
White Lake (DUM6)	15-44	30.0	23.0	19.9	3.1
Hatbox Mesa (DUM7)	32-59	74.8	68.0	69.1	-1.1
Siksikpuk (DUM8)	0-94	50.8	72.0	67.0	5.0
Anaktuvuk (DUS2)	29-63	35.8	34.0	24.4	9.6
Chandler (DUS3)	NA	NA	NA	NA	NA

Table 8. Snow depth information from meteorological stations and co-located snow surveys for 2011.

Meteorological Station	Snow Survey Depth Range (cm)	Snow Survey Depth Average (cm)	Observed Snow Under SR50 (cm)	SR50 Reported Depth at Time of Observed Depth (cm)	Difference Between Observed and SR50 Reported Depth (cm)
Accomplishment Creek (DBM1)	28-141	102.4	79	82.3	-3.3
South White Hills (DFM1)	41-76	55.2	NA	50.1	NA
White Hills (DFM2)	0-21	12	16	16	0
North White Hills (DFM3)	15-52	30.6	22	26	-4
Northwest Kuparuk (DFM4)	28-79	51.5	61	61.4	-0.4
Itikmalakpak (DUM1)	16-51	26.5	18	16	2
Upper May Creek (DUM2)	1-15	6.4	5	4.3	0.7
Nanushuk (DUM3)	5-66	32.9	17	15.2	1.8
Tuluga (DUM4)	11-87	53.5	54	53.6	0.4
Encampment Creek (DUM5)	0-37	12.2	1	NA	NA
White Lake (DUM6)	10-45	23.1	27	24.9	2.1
Hatbox Mesa (DUM7)	38-64	53.4	85	84	1
Siksikpuk (DUM8)	31-87	60.6	77	76.7	0.3
Anaktuvuk (DUS2)	21-51	37.4	37	39.9	-2.9
Chandler (DUS3)	35-70	55.6	48	NA	NA

The results of the SR50 snow depth sensors are presented in Figures 4-18. Most stations reported good quality SR50 snow depth data during the winter of 2011-2012 with only a few station malfunctions. The SR50 at the White Hills (DFM2) station was inoperable through the entire winter period due to the station logger malfunctioning. No SR50 snow depth was recorded at Chandler (DUS3) between December 24, 2011 and May 18, 2012 due to a loss of power at the station. Additionally, the Chandler station could not be accessed during the spring snow survey field visits due to poor weather conditions.

The advantage of snow sensor information is its high temporal resolution which can capture the timing and magnitude of solid precipitation and wind blowing events. Records show that the snow accumulation began in late-September to mid-October of 2011, depending on station location (Figures 4-18). The Mountain region stations (Accomplishment Creek, Encampment Creek, Itikmalakpak, Upper May Creek, and White Lake) show the largest variation in snow depths throughout the winter season due to high snow accumulation rates during snow storms and snow losses from high wind events.

Following initial snow accumulation, the stations in the Foothills region (Anaktuvuk, Hatbox Mesa, Nanushuk, Siksikpuk, South White Hills, Tuluga and White Hills) and Coastal Plain region (North White Hills and Northwest Kuparuk) recorded gradual accumulation as the season progressed. The snow depths were variable, but overall average snow depth at the majority of the stations was less in the 2011-2012 winter as compared to the previous 2010-2011 winter.

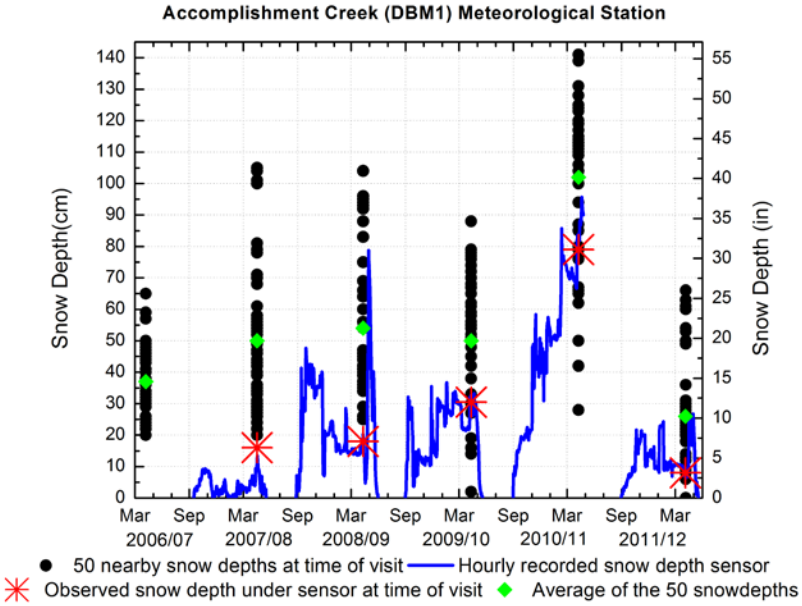

Figure 4. Accomplishment Creek meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2006-2012.

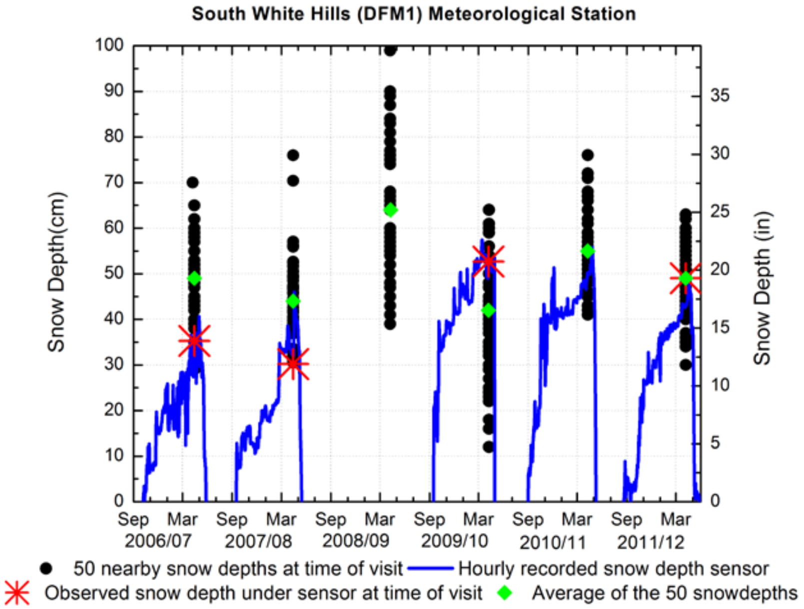

Figure 5. South White Hills meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2006-2012..

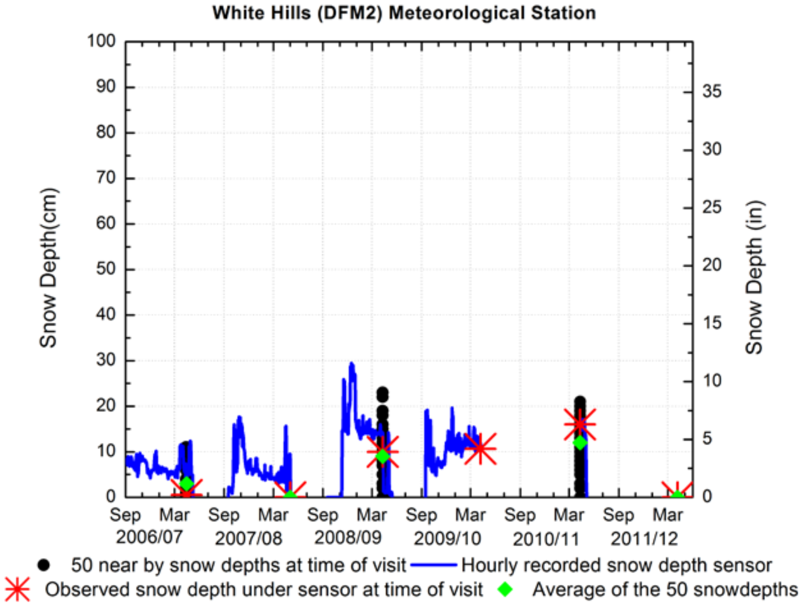

Figure 6. White Hills meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2006-2012.

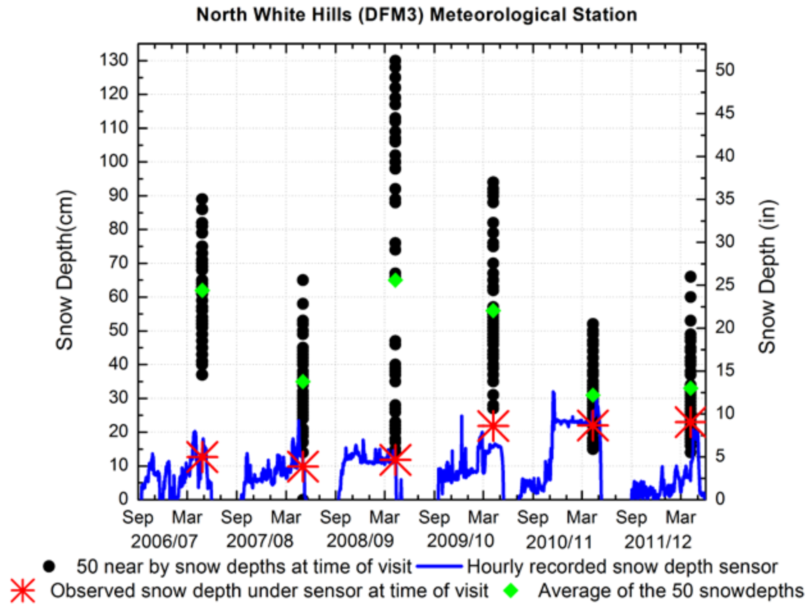

Figure 7. North White Hills meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2006-2012.

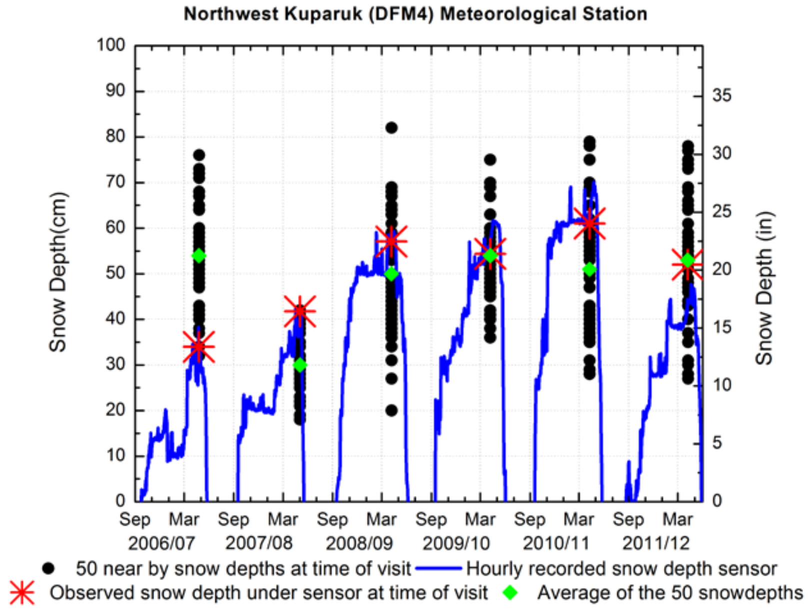

Figure 8. Northwest Kuparuk meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2006-2012.

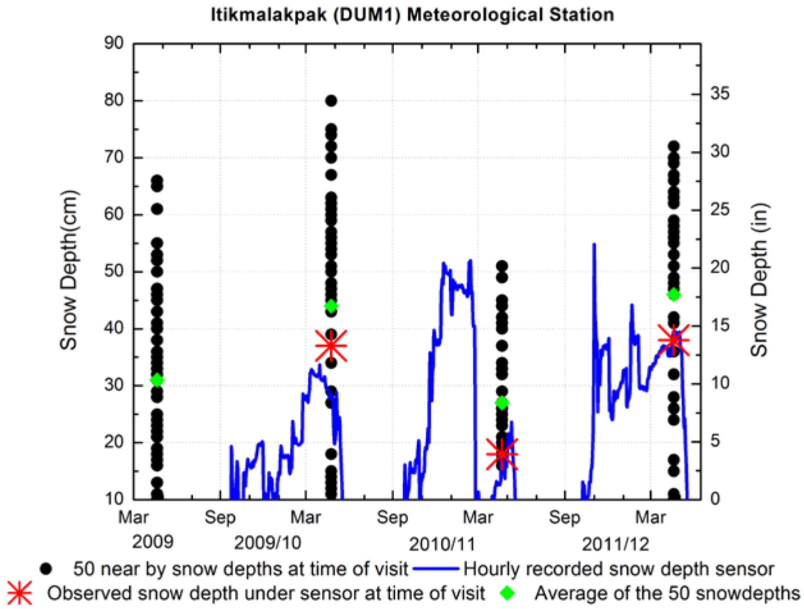

Figure 9. Itikmalakpak meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2009-2012.

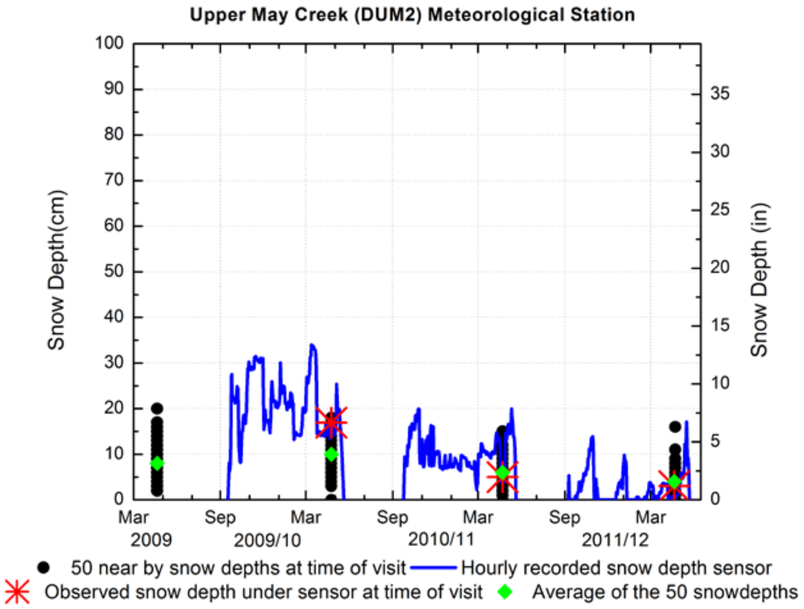

Figure 10. Upper May Creek meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2009-2012..

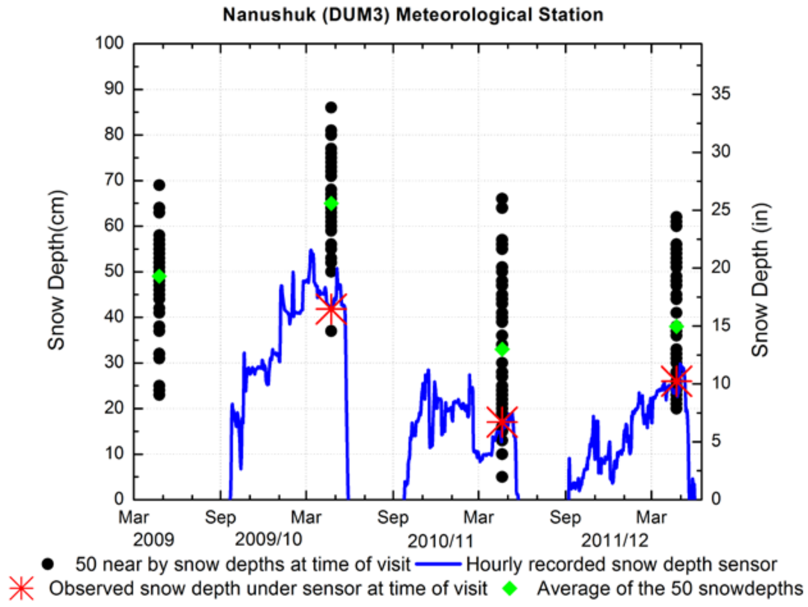

Figure 11. Nanushuk meteorological hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2009-2012.

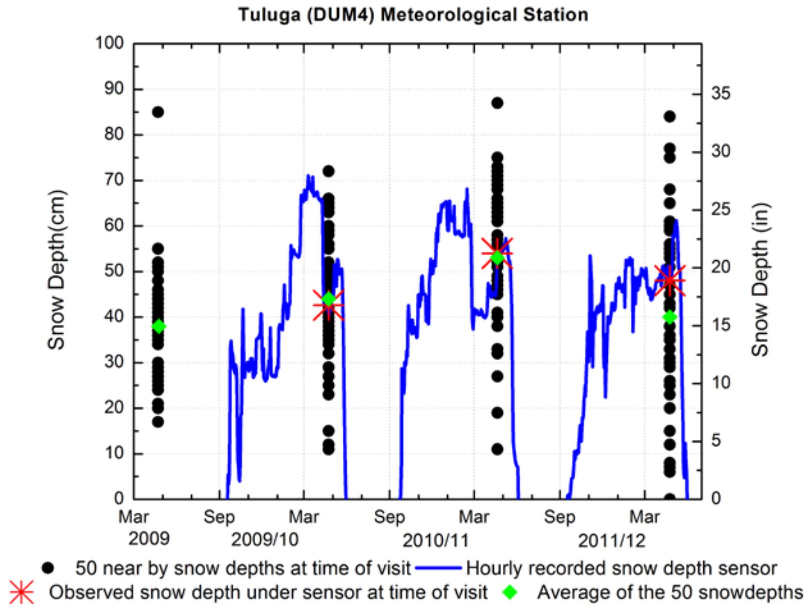

Figure 12. Tuluga meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2009-2012.

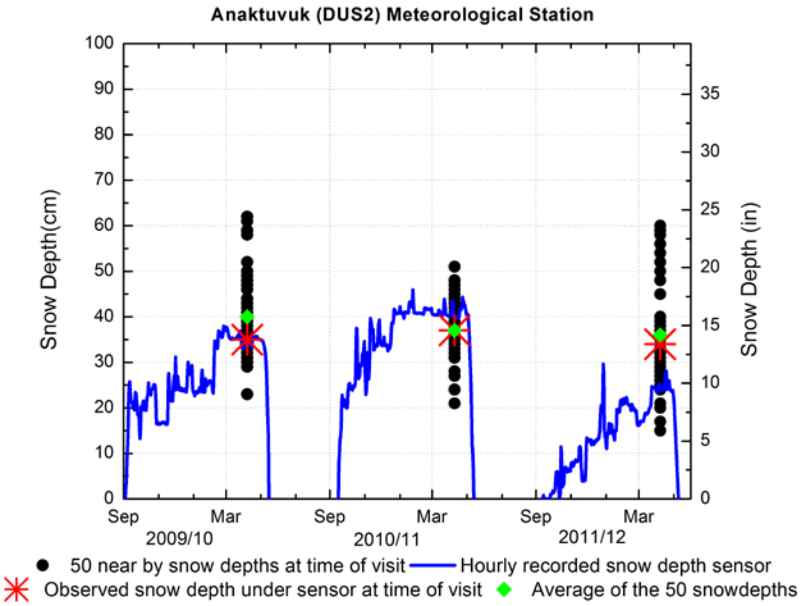

Figure 13. Anaktuvuk meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2009-2012.

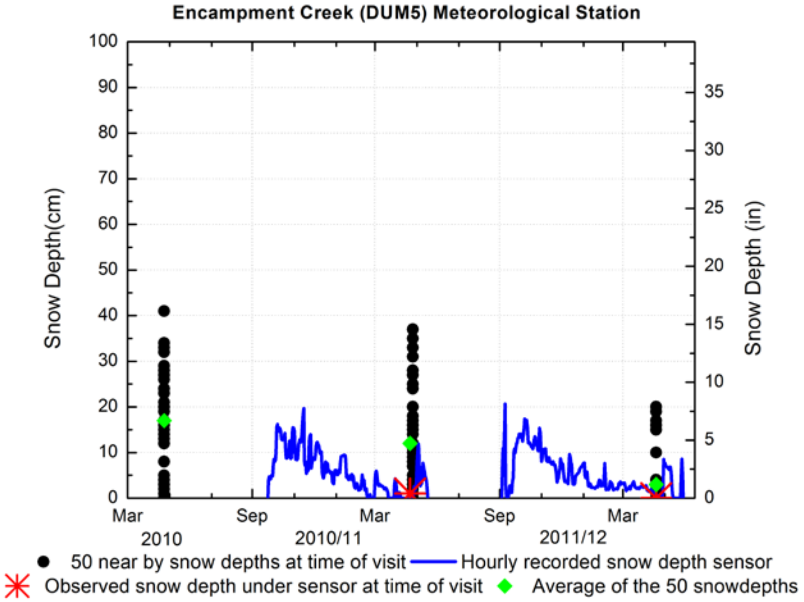

Figure 14. Encampment Creek meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2010-2012.

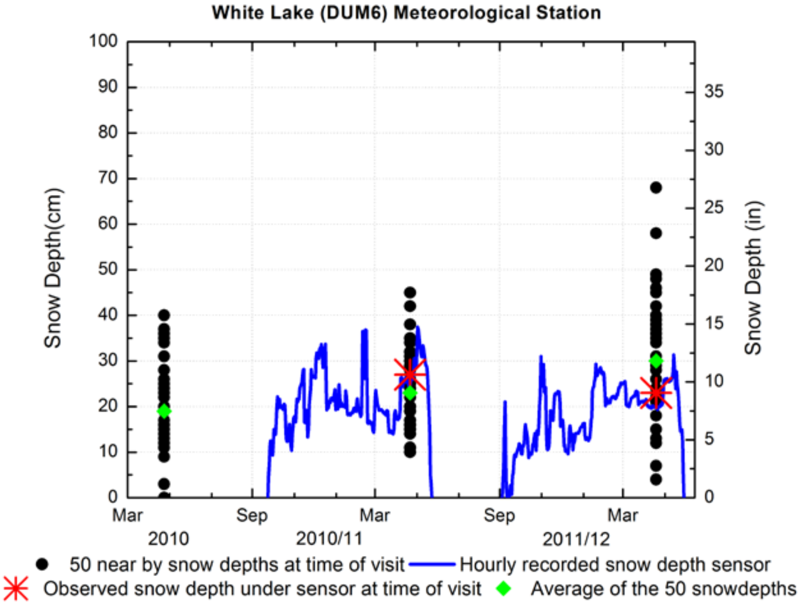

Figure 15. White Lake meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2010-2012.

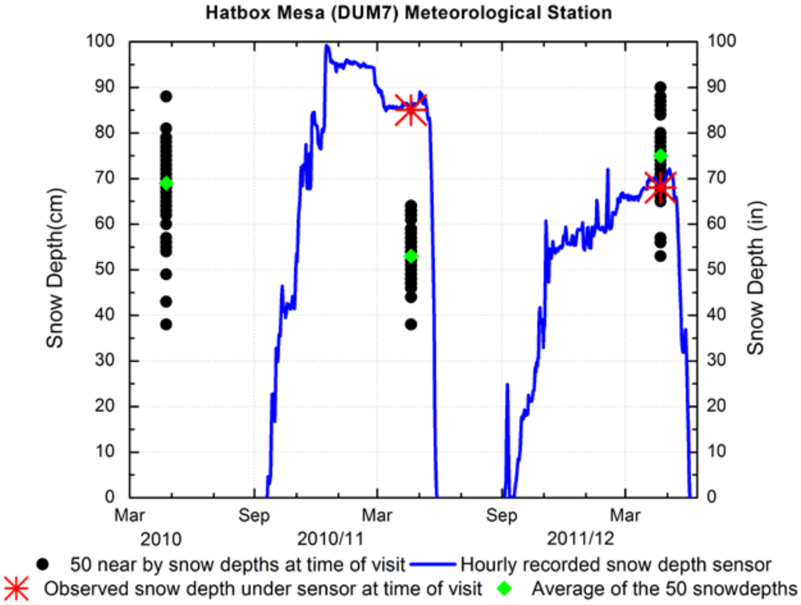

Figure 16. Hatbox Mesa meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2010-2012.

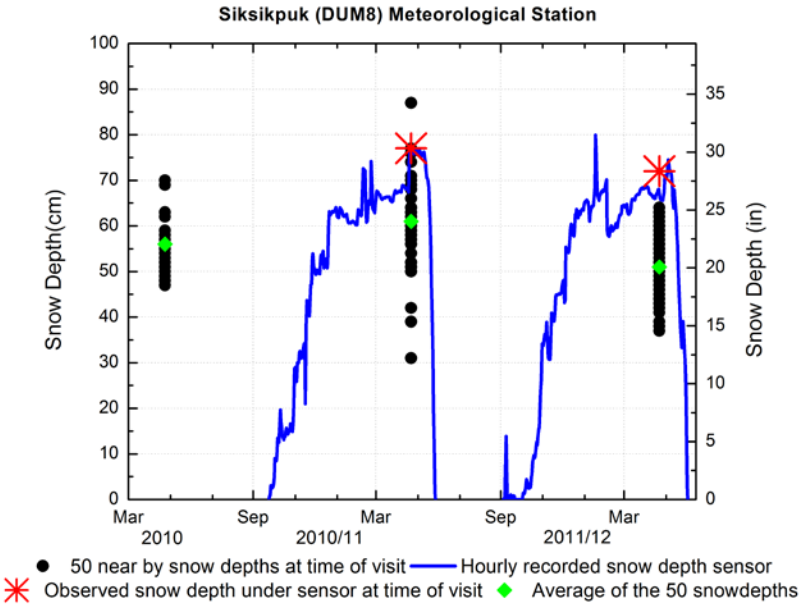

Figure 17. Siksikpuk meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2010-2012.

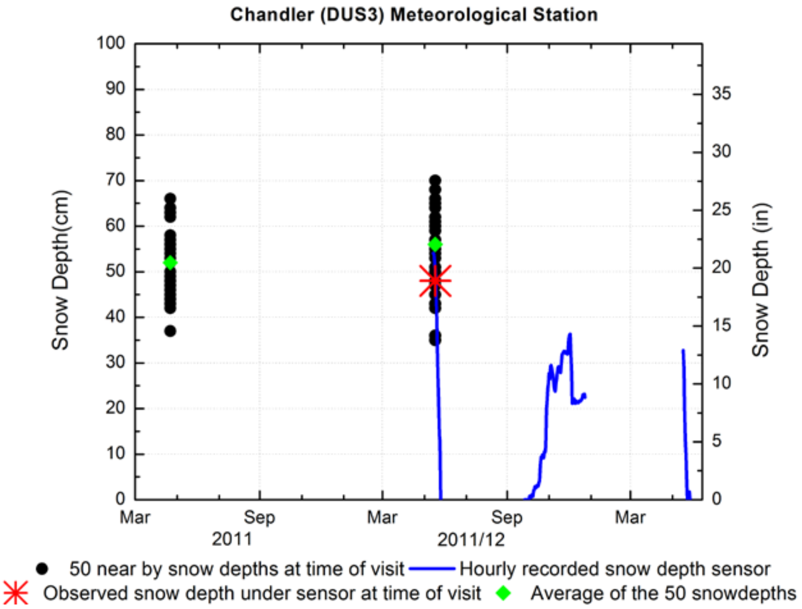

Figure 18. Chandler Bluff meteorological station hourly recorded SR50 sensor snow depths, observed snow depth under the sensor at time of visit, and 50 snow survey depths measured near sensor, 2010-2012.

Figures 19 and 20 show the hourly SR50 data at each station during the 2010-2011 (Figure 19) and 2011-2012 (Figure 20) winter periods. The figures are used to identify periods of snow deposition and erosion and aerial extent during large snow storms and wind events. For example, in Figure 19, a large storm event on February 23, 2011 is visible in the continuous SR50 snow depth record. Strong winds caused significant snow redistribution (accumulation or erosion) at most of the stations. After that, a long period of either snow accumulation or loss occurred at several of the northernmost stations during January through April 2011. In Figure 20, which shows the SR50 data for 2012 at each station, an event on February 3-4, 2012 caused snow accumulation at Hatbox Mesa, Northwest Kuparuk, Anaktuvuk, North White Hills, and Encampment Creek stations. This same storm caused a snow erosion event at Siksikpuk, Tuluga, Itikmalakpak, White Lake, and Accomplishment Creek stations. Nanushuk, South White Hills, and Upper May Creek had little or no change in snow depth during this period. Examination of meteorological data during this early February 2012 event show an increase in wind speeds and air temperature (for example, the wind speed at Anaktuvuk station increased from less than 1 m/s up to 8 m/s and the air temperature increased from-36 C to -8 C).

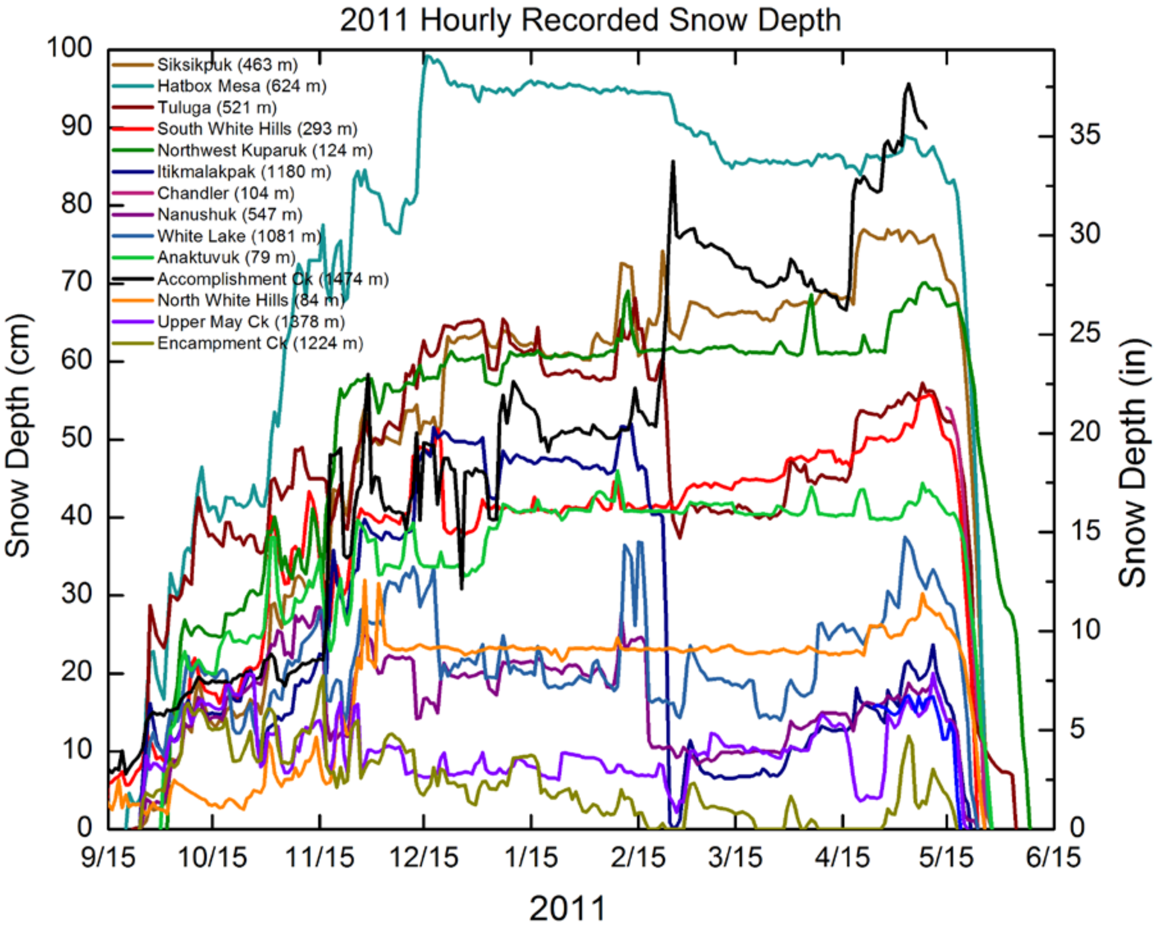

Figure 19. SR50 hourly snow depths at the fifteen meteorological stations during the 2010-2011 winter period. Station elevations (in meters) are listed in the legend.

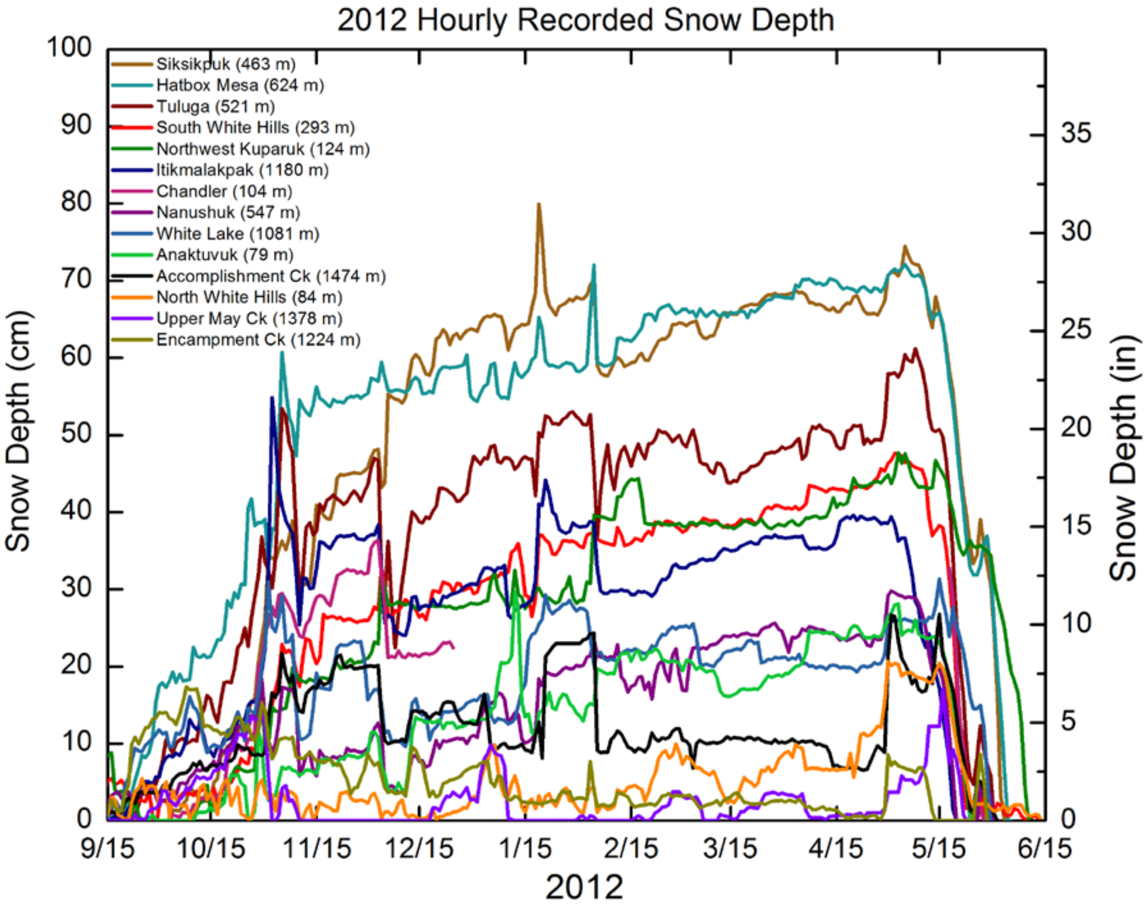

Figure 20. SR50 hourly snow depths at the fifteen meteorological stations during the 2011-2012 winter period. Station elevations (in meters) are listed in the legend.

The review of snow depth records for 2010-2011 and 2011-2012 winter periods indicates that large snow deposition and erosion events happen, a dozen times a winter at the most. We examined a few of the larger and spatially widespread winter storm events and found that most stations are subject to both snow accumulation and losses. A few stations are in snow erosional areas (such as the Mountain stations Upper May Creek and Encampment Creek, along with the high elevation White Hills station) as these stations often have strong winds and topography that favors snow to be blown away. The SR50 snow depth record of the more protected stations in the Mountain region (like Accomplishment Creek and Itikmalakpak Creek) indicate high amounts of snow accumulation, but still tend to have a snow loss during high wind events. The Hatbox Mesa and Siksikpuk stations located in the Foothills region of the Chandler basin accumulate a larger amount of snow by the end of winter with little loss to erosion. Stations located on the

Coastal Plain tend to have less overall variability in snow depth over the winter period and a gradual accumulation throughout the season.

8. ABLATION DATA

Historical ablation data (Figure 21) were collected at five sites (Upper Kuparuk, Happy Valley, Sagwon Hills, Franklin Bluffs and Betty Pingo) (see Section 3.2 for details). The data is summarized in Appendix B. In addition, we present snow depth graphs from all sonic sensors (SR50A) combined together for May through June of 2011 (Figure 22) and 2012 (Figure 23). Note that Figure 21 shows net decrease in SWE on a north-south transect, whereas Figures 22-23 show net decrease in snow depth over the whole study domain. All three figures provide a quantitative description of snow disappearance date across the domain.

We know that the ablation window varies greatly from year to year, depending on meteorological conditions such as radiation and air temperature along with snowpack depth. Most of the sites report onset of snowmelt around mid-May 2012. Depending on location and snow depth, the entire snowpack melted within a week at Itikmalakpak, Upper May Creek, Encampment Creek, Nanushuk, and Sagwon Hill; within 10-12 days at Accomplishment Creek, Upper Kuparuk, South White Hills, Anaktuvuk, Chandler, North White Hills, Happy Valley, Franklin Bluffs, and Betty Pingo; and it took almost 3 weeks for the snowpack to disappear at White Lake, Siksikpuk, Hatbox Mesa, Tuluga, and Northwest Kuparuk (Figures 21through 23). Most of the sites recorded late snowfall around May 26-27, 2012.

Southern sites, i.e. Upper May Creek, Itkillik, Nanushuk, Anaktuvuk, Chandler, Upper Kuparuk, reported complete snowmelt by May 20-25, 2012. Northern sites, i.e. Betty Pingo and Franklin Bluffs, Northwest Kuparuk, reported complete snowmelt ten days later by June 5, 2012. The snow at the Northwest Kuparuk site (located near the western boundary of the Kuparuk River watershed directly west of Franklin Bluffs) was the last area to melt in both 2011 and 2012.

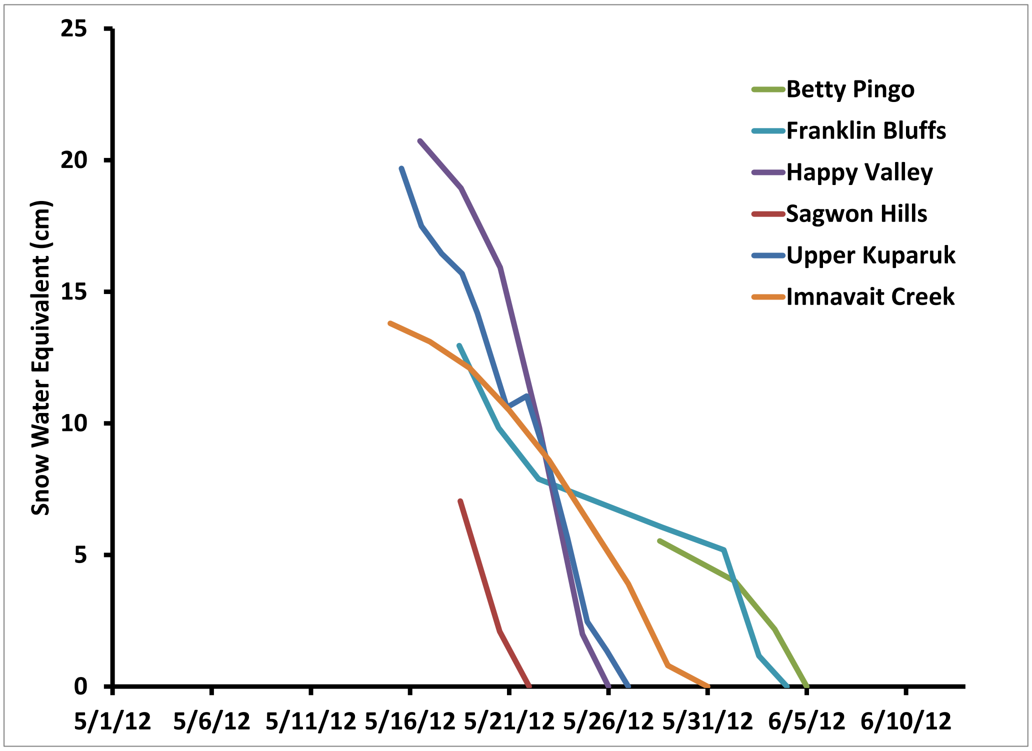

Figure 21. Ablation curves for selected sites in the Central Alaskan Arctic 2011-2012

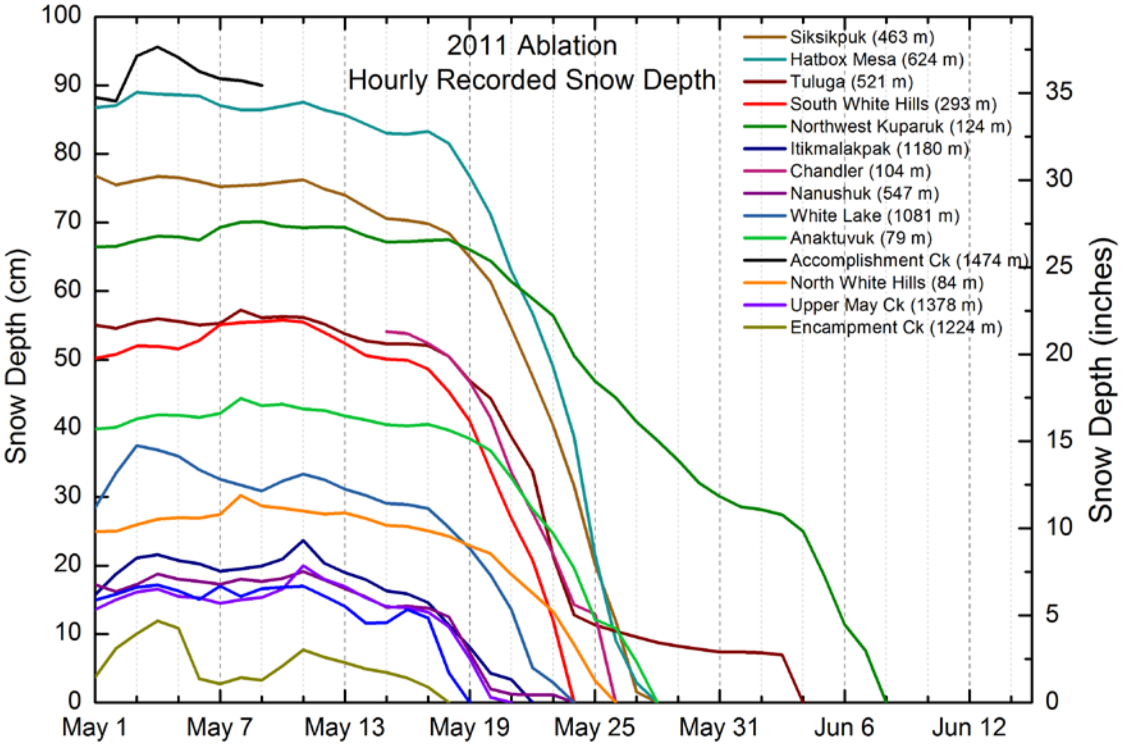

Figure 22. SR50 snow depth at meteorological stations in the Central Alaskan Arctic during the 2011 ablation period.

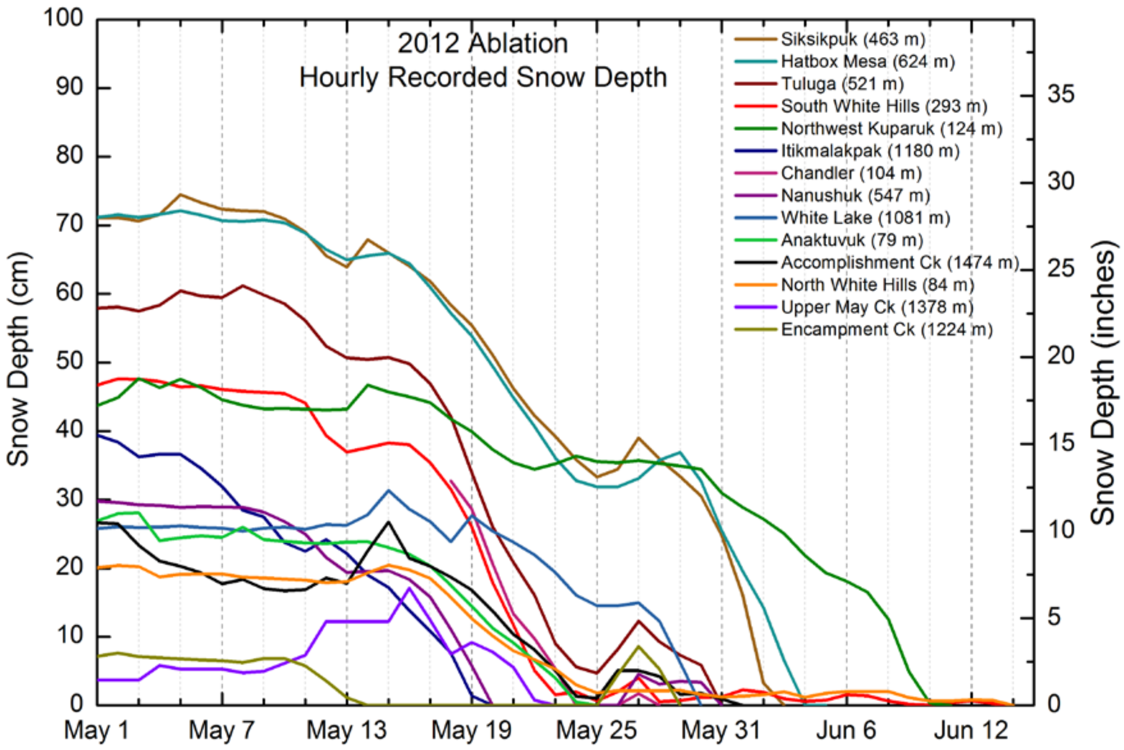

Figure 23. SR50 snow depth at meteorological stations in the Central Alaskan Arctic during the 2012 ablation period.

9. SUMMARY

This report describes snow depth, snow water equivalent, and snow density data collected in April–May 2012 in the Central Alaskan Arctic. Snow surveys were conducted in the watersheds of the Kuparuk, Anaktuvuk, Chandler, Itkillik and Sagavanirktok Rivers. As of 2012, the Kuparuk River watershed has 13 years of repeated end-of-winter snow survey data. The Sagavanirktok, Kadleroshilik, Shaviovik and Kavik River basins had 5 years of repeated snow surveys data, from 2006 to 2010. The Anaktuvuk and Itkillik River basins have 4 years of repeated snow survey data, 2009, 2010, 2011 and 2012. Snow survey observations in the Chandler River basin were initiated in 2010. Overall, 74 sites were visited in 2012. This number includes 14 sites located in the Mountains, 35 sites in the Foothills, and 25 sites on the Coastal Plain.

Such snow observations, and those presented here, are key components of many scientific and engineering applications. As mentioned in the introduction, the peak discharge of record for the large North Slope Rivers is due to snowmelt. Snow survey data provides useful input for hydrologic models to estimate snowmelt discharge in ungauged rivers. The end-of-winter SWE observed in 2012 accounts for 110% of the 13-year average SWE in the Kuparuk basin. Both Kuparuk and Sagavanirktok have less end-of-winter SWE in 2012 compared to the previous year. The previous year (2011) was recognized as the second highest SWE in the Kuparuk basin record. During the 13 year period of data collection, both the Foothills and Coastal Plain had the highest annual SWE (15.4 and 13.4 cm, 6.1 and 5.3 in, respectively) in 2009. Interestingly, snow data from the Anaktuvuk and Chandler River (west of Kuparuk) does not reflect these same tendencies of high/low snow accumulation averaged over the basin during the overlap period of records (2010-2012). Over the years, we clearly see that temporal variations in basin averaged SWE from year to year are much less than spatial variations in SWE within the basin for a given year (Stuefer et. al, 2013). For example, the standard deviation of SWE within the Kuparuk River domain was 26-47 mm (10-18.5 in), whereas the standard deviation for basin averaged SWE from year to year was only 16 mm from 2000 to 2011. The combination of a physically based model, with the assimilation of the snow observations, can provide a useful tool to address spatial scale questions and realistically reproduce natural snow variability (Stuefer et.al, 2013).

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Appendix A1. Snow survey data from Mountain region sites.

N	Survey Date	ID	ELEV	LAT	LON	SWE		Snow Depth		Snow Density		Basin
			m	dd	dd	cm	in	cm	in	kg/m^3	slug/ft^3	
1	04/19/12	ANA2	595	68.3158	-151.4967	2.3	0.9	8.6	3.4	356	0.690	Anaktuvuk
2	04/20/12	SAG1	678	68.4150	-148.9600	2.3	0.9	7.9	3.1	205	0.398	Sagavanirktok
3	04/20/12	SAG3	830	68.4462	-148.7042	3.7	1.5	18.0	7.1	236	0.457	Sagavanirktok
4	04/24/12	Galbraith	831	68.4780	-148.5030	9.9	3.9	40.4	15.9	305	0.591	Sagavanirktok
5	04/20/12	SAG2	868	68.2597	-148.8256	14.9	5.9	49.6	19.5	245	0.476	Sagavanirktok
6	04/19/12	MTN6	986	68.2814	-151.6606	3.1	1.2	11.9	4.7	326	0.632	Anaktuvuk
7	04/20/12	MTN3	1080	68.3917	-150.4843	9.4	3.7	34.6	13.6	152	0.295	Anaktuvuk
8	04/19/12	CHA2	1081	68.3629	-152.7067	8.1	3.2	30.0	11.8	239	0.464	Chandler
9	04/20/12	MTN1	1096	68.3852	-150.1521	8.7	3.4	25.4	10.0	212	0.410	Anaktuvuk
10	04/19/12	MTN5-Itikm	1168	68.2901	-151.1150	12.5	4.9	46.0	18.1	260	0.505	Anaktuvuk
11	04/19/12	MTN4	1179	68.2972	-150.8125	7.6	3.0	32.6	12.8	261	0.507	Anaktuvuk
12	04/19/12	CHA1	1224	68.2865	-152.1318	0.6	0.2	2.8	1.1	281	0.546	Chandler
13	04/22/11	MTN2-May	1378	68.3985	-150.2277	1.3	0.5	3.8	1.5	167	0.324	Anaktuvuk
14	04/20/12	DBM1	1474	68.4116	-148.1365	6.4	2.5	26.1	10.3	314	0.609	Sagavanirktok

Appendix A2. Snow survey data from Foothills region sites.

N	Survey Date	ID	ELEV m	LAT dd	LON dd	SWE		Snow Depth		Snow Density		Basin
						cm	in	cm	in	kg/m^3	slug/ft^3	
1	04/20/12	WKmet	159	69.4259	-150.3417	15.1	6.0	49.2	19.4	244	0.474	Kuparuk
2	04/20/12	MI7	175	69.4887	-148.5678	13.1	5.2	44.3	17.4	268	0.520	Sagavanirktok
3	04/20/12	MI6	179	69.5344	-148.5990	11.6	4.6	56.2	22.1	263	0.511	Sagavanirktok
4	04/21/12	WK04	203	69.4269	-149.4609	9.6	3.8	41.0	16.1	216	0.419	Putuligayuk
5	04/21/12	WK10	214	69.6173	-149.3839	8.6	3.4	35.0	13.8	328	0.636	Kuparuk
6	04/21/12	HV6	218	69.2748	-150.0869	10.5	4.1	46.9	18.5	233	0.452	Kuparuk
7	04/21/12	WK01	218	69.4265	-148.8722	14.5	5.7	51.8	20.4	233	0.451	Kuparuk
8	04/22/12	CHA8	271	68.9303	-152.0723	17.2	6.8	68.2	26.8	242	0.470	Chandler
9	04/21/12	Sagwon	275	69.4247	-148.6950	8.6	3.4	30.0	11.8	203	0.394	Kuparuk
10	04/21/12	DFM1	293	69.2034	-149.5611	14.6	5.8	48.6	19.1	280	0.544	Kuparuk
11	04/22/12	CHA5	300	69.0840	-152.1394	11.4	4.5	52.2	20.5	255	0.494	Chandler
12	04/21/12	HappyValley	314	69.1519	-148.8389	18.1	7.1	68.7	27.1	295	0.573	Sagavanirktok
13	04/21/12	DFM2	337	69.4865	-149.8214	0.0	0.0	0.0	0.0			Kuparuk
14	04/21/12	HV1	365	69.1682	-149.1548	16.2	6.4	60.6	23.9	207	0.402	Kuparuk
15	04/23/12	ITK1	436	68.8196	-149.9762	6.2	2.4	29.2	11.5	246	0.478	Itkillik
16	04/23/12	OilSpill	440	68.9424	-148.8660	7.6	3.0	45.6	17.9	219	0.425	Sagavanirktok
17	04/23/12	GUN3	447	68.7142	-151.2321	4.9	1.9	32.0	12.6	322	0.624	Anaktuvuk
18	04/22/12	CHA6-Sik	463	68.6301	-152.1022	13.3	5.2	50.8	20.0	284	0.551	Chandler
19	04/24/12	GUN4-Tul	497	68.8041	-151.5460	10.3	4.0	39.5	15.6	230	0.446	Anaktuvuk
20	04/23/12	GUN2-Nan	540	68.7207	-150.5030	12.4	4.9	38.0	15.0	240	0.466	Anaktuvuk
21	04/21/12	SM05	568	68.8565	-149.7332	11.4	4.5	52.0	20.5	264	0.512	Kuparuk
22	04/22/12	CHA4-Hat	624	68.7543	-152.5730	18.4	7.2	74.8	29.4	259	0.503	Chandler
23	04/20/12	ITK2	635	68.4170	-149.9472	5.9	2.3	21.2	8.3	223	0.433	Itkillik
24	04/21/12	SM03	651	68.8122	-149.2838	12.1	4.8	43.9	17.3	301	0.584	Kuparuk
25	04/19/12	CHA7	683	68.4301	-152.2715	12.6	5.0	56.7	22.3	211	0.409	Chandler
26	04/19/12	UKmet	778	68.6374	-149.4039	15.6	6.1	66.7	26.2	341	0.662	Kuparuk
27	04/20/12	TLK2	824	68.4587	-150.8559	10.7	4.2	46.1	18.1	201	0.390	Anaktuvuk
28	04/19/12	TLK4	835	68.4503	-151.5571	10.7	4.2	45.3	17.8	260	0.504	Anaktuvuk
29	04/19/12	CHA3	843	68.4990	-152.9805	7.8	3.1	38.2	15.0	238	0.462	Chandler
30	04/19/12	UK12-NH	904	68.6021	-149.4305	8.8	3.5	33.3	13.1	271	0.526	Kuparuk
31	04/19/12	UK04-GCL	908	68.5335	-149.2310	5.4	2.1	19.6	7.7	252	0.489	Kuparuk
32	04/19/12	UK01-EH	912	68.5849	-149.3063	12.2	4.8	60.6	23.9	260	0.504	Kuparuk
33	04/19/12	UK08-UH	968	68.5222	-149.3380	6.0	2.4	23.0	9.0	240	0.466	Kuparuk
34	04/20/12	TLK1	1000	68.5269	-150.1483	15.0	5.9	59.3	23.4	277	0.537	Anaktuvuk
35	04/19/12	UK14-WH	1027	68.5638	-149.4108	7.3	2.9	30.2	11.9	270	0.524	Kuparuk

Appendix A3. Snow survey data from Coastal Plain sites.

N	Survey Date	ID	ELEV	LAT	LON	SWE		Snow Depth		Snow Density		Basin
			m	dd	dd	cm	in	cm	in	kg/m^3	slug/ft^3	
1	04/22/12	WestDock	5	70.3602	-148.5697	14.7	5.8	41.2	16.2	273	0.529	Kuparuk
2	04/22/12	P01	12	70.2955	-148.9373	7.0	2.7	24.7	9.7	273	0.529	Putuligayuk
3	04/22/12	P04	12	70.2601	-148.8211	10.9	4.3	45.4	17.9	275	0.533	Putuligayuk
4	04/22/12	P06	12	70.2604	-148.6715	7.9	3.1	33.4	13.1	222	0.432	Putuligayuk
5	04/22/12	P07	12	70.2566	-148.7160	9.6	3.8	37.2	14.6	234	0.453	Putuligayuk
6	04/22/12	P08	12	70.2486	-148.6041	11.8	4.6	46.4	18.3	231	0.449	Putuligayuk
7	04/21/12	P02	15	70.2614	-148.9396	11.9	4.7	42.0	16.6	245	0.476	Putuligayuk
8	04/22/12	P05	15	70.2532	-148.7716	9.0	3.5	42.7	16.8	294	0.571	Putuligayuk
9	04/22/12	P03-Betty	30	70.2806	-148.8961	8.9	3.5	36.7	14.4	279	0.542	Putuligayuk
10	04/23/12	FB07	32	70.1160	-149.1010	14.8	5.8	47.3	18.6	230	0.447	Kuparuk
11	04/23/12	FB09	34	70.0710	-148.8780	11.9	4.7	42.5	16.7	269	0.523	Sagavanirktok
12	04/23/12	FB05	42	70.0113	-149.2829	10.7	4.2	37.5	14.8	295	0.572	Kuparuk
13	04/20/12	MI1	48	70.0032	-148.6792	13.2	5.2	37.9	14.9	280	0.543	Sagavanirktok
14	04/23/12	FB03	58	69.9316	-149.1563	8.8	3.5	40.6	16.0	271	0.525	Kuparuk
15	04/20/12	MI2	60	69.9336	-148.7677	12.0	4.7	44.2	17.4	252	0.490	Sagavanirktok
16	04/23/12	FranklinBluffs	71	69.8886	-148.7747	13.9	5.5	47.0	18.5	240	0.465	Sagavanirktok
17	04/22/12	DUS2-Anak	79	69.4645	-151.1690	8.2	3.2	35.8	14.1	217	0.420	Anaktuvuk
18	04/21/12	DFM3	84	69.7149	-149.4705	9.0	3.5	33.3	13.1	285	0.552	Kuparuk
19	04/22/12	H05	90	69.8000	-149.7500	10.2	4.0	42.3	16.7	234	0.454	Kuparuk
20	04/20/12	MI3	90	69.7950	-148.7361	7.7	3.0	25.2	9.9	287	0.557	Sagavanirktok
21	04/20/12	MI4	90	69.7130	-148.7165	11.0	4.3	45.9	18.1	301	0.583	Sagavanirktok
22	04/21/12	H01	113	69.5687	-150.4478	16.2	6.4	50.3	19.8	267	0.519	Kuparuk
23	04/22/12	DFM4	124	69.9475	-149.9169	12.2	4.8	53.1	20.9	348	0.676	Kuparuk
24	04/20/12	MI5	140	69.6050	-148.6487	11.6	4.6	43.3	17.1	219	0.424	Sagavanirktok
25	04/21/12	H02	172	69.8020	-150.3838	11.5	4.5	49.1	19.3	308	0.597	Kuparuk

APPENDIX B. HISTORICAL ABLATION DATA

Appendix B1. Snow water equivalent (cm) in the Imnavait Creek basin 1985-99 (basin average).

Month and Day	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
30-Apr											14				
1-May															
2-May										8					
3-May				7.5											
4-May							8.2								
5-May															
6-May										4.6	6.8				
7-May															
8-May	10.6									1.7	5.3				
9-May	10.3		10	6.9		9.9	1.1								
10-May	9.7		8.8	5.1			0.3			1.3	1.3				
11-May	7.9		8.6	4.8			0.2								
12-May			7.6	1.9		7.8	0.14								
13-May	8.1		7.4	0.4		6.9	0.12		10.1				12.5		6.9
14-May	7.5		7.5	0.0		6.5	0.06			0.1			10.5		5.7
15-May				0.0		4.9	0						11.0	9.5	5.1
16-May			7.7			3.6				0	0		7.3	8.7	3.9
17-May			7.5		13	1.8			5.8			10.1	5.8	6.5	3.6
18-May	8.0		6.9			1.1			0.7				5.3	6.2	3.2
19-May	7.3		5.2		12.3	0.4			0.1				4.5	4.2	2.2
20-May	6.9		3.9		12.0	0.02			0.0			10.2	3.7	1.5	1.1
21-May	6.2		2.6		12.0	0.0							2.8	1.5	0.6
22-May	6.2		1		11.4								2.2	0.1	0.4
23-May	5.7		0.2		10.7							10.2	1.9	0.0	
24-May	4.4		0.0		10.5			15.3				9.0	1.4		
25-May	1.8				9.3							6.6	0.7		
26-May	0.9				8.6			14.6				4.8	0.4		
27-May	0.6	11.4			7.6			13.9				2.6	2.5		
28-May	0.3	11.2			4.5			13.9					2.2		
29-May	0.1	10.2			2.0			14.1				1.6	2.2		
30-May	0.0	10.2			0.0			13.7				0.4	0.8		
31-May		8.9						13.0					0.6		
1-Jun		7.4						10.8				0.0	0.0		
2-Jun		5.1						9.7							
3-Jun		4.1						8.8							
4-Jun		2.3						7.5							
5-Jun		0.3						5.8							
6-Jun		0.0						5.1							
7-Jun								5.2							
8-Jun								4.0							
9-Jun								2.7							
10-Jun								1.0							
11-Jun								0.0							

Appendix B1. Snow water equivalent (cm) in the Imnavait Creek basin 2000-12 (basin average).

Month and Day	00	01	02	03	04	05	06	07	08	09	10	11	12
30-Apr											*	*	
1-May											*	*	
2-May											*	*	
3-May											*	*	
4-May											*	*	
5-May											*	*	
6-May											*	*	
7-May						12					*	*	
8-May											*	*	
9-May				15.7	12.0						*	*	
10-May				14.4							*	*	
11-May				14.9							*	*	
12-May				14.3				11.3	8.3		*	*	
13-May				14.4		5.7	9.6		8.4		*	*	
14-May				14.4	9.3	4.5			8.8		*	*	
15-May		13	12.4	15.1	8.2	3.3	6.8	12.4			*	*	13.8
16-May			12.2	15.1	7.8	1.4		11.0	7.7		*	*	
17-May			12.6	15.4	6.0	2.1	4.0	11.3	5.9		*	*	13.1
18-May		13	12.1	14.8	4.3		3.4	11.1	4.9	16.9	*	*	
19-May	11.2	14	11.2	15.2	2.0	1.8	2.9	10.4	4.3	17.4	*	*	12.1
20-May	10.7		11.1	15.4	2.1	2.1	1.3		2.9	16.1	*	*	
21-May	10.2	14	9.3	18.5	1.8	1.0	0.3	9.5	2.6	15.4	*	*	10.5
22-May	9.2		7.0	18.4	1.1	0.9	0.5	9.4	2.8	15.0	*	*	
23-May	9.5	14	5.4	16.4	0.2	0.8	0.1	6.7	0.2	12.9	*	*	8.6
24-May	9.3		0.5	15.3	0.0	0.4	0.0	5.0	0.1	12.8	*	*	
25-May	8.0	14	0.0	17.1		0.2		3.0	0.0	10.0	*	*	
26-May	7.5	13		17.3		0.1		1.8		11.1	*	*	
27-May	7.3	12		15.1		0.0		0.9		12.4	*	*	3.9
28-May	6.4	12		15.3				0.2		13.4	*	*	
29-May	3.9	12		14.5				0.0		12.6	*	*	0.8
30-May	0.2	9.6		12.8						12.4	*	*	
31-May	0.01	4.6		11.4						10.8	*	*	0.0
1-Jun	0.0	6.0		11.7						9.4	*	*	
2-Jun		5.9		7.2						6.6	*	*	
3-Jun		3.1		3.6						2.3	*	*	
4-Jun		2.2		0.4						0.0	*	*	
5-Jun		0.8		0.0							*	*	
6-Jun		0.2									*	*	
7-Jun		0.0									*	*	
8-Jun											*	*	
9-Jun											*	*	
10-Jun											*	*	
11-Jun											*	*	

* Data not collected

Appendix B2. Snow water equivalent (cm) at the Upper Kuparuk (UK) site

Month and Day	99	00	01	02	03	04	05	06	07	08	09	10	11	12
30-Apr		15		10	14	18	18		12				27.4	
1-May														
2-May														
3-May														
4-May														
5-May														
6-May														
7-May														
8-May														
9-May					17.4									
10-May					17.0									
11-May					15.3		13.0							
12-May					12.3		11.5			12.1				
13-May	4.7							12.4		10.6				
14-May	3.6			12.9		16.4	6.0			12.6			26.7	
15-May	1.7		17	12.5	18.3	17.0	13.2					14.5	27.5	19.7
16-May	1.2			15.3	17.4			8.0	14.2	10.1		14.8	26.2	17.5
17-May	1.0						9.1	7.8		11.8		12.6	25.3	16.5
18-May	0.0			15.2	18.1	11.5		6.4	13.0	9.6		12.7	23.6	15.7
19-May			14		18.7	9.8	7.2	4.5	13	7.2		11.0	21.4	14.2
20-May		20.5	16			7.7	8.1	1.8		7.5	23.8	12.1	19.9	10.6
21-May				12.6		9.2	5.5	0.0	11.8	5.6	20.3	13.9	16.6	11.0
22-May			17				0.3			4.0	16.7	10.0	12.5	8.6
23-May				5.8		5.9			8.0	0.9		9.4	4.5	5.6
24-May			17		17.6				5.4	0.0	12.4	7.0	1.1	2.5
25-May				0	17.9	1.1					9.2	3.2	0	1.4
26-May			18		17.3	0.5			3.1		10.4	0.5		
27-May			15						0.0					0
28-May			13		15.2						9.2			
29-May			15								6.2			
30-May			13.3		13.1									
31-May		17.2	10.1								7.8			
1-Jun			13.7		12.3									
2-Jun		17	9.7		10.6						7.2			
3-Jun					7.9									
4-Jun		17	0											
5-Jun		16												
6-Jun		9.8												
7-Jun		4.8												
8-Jun		1.3												
9-Jun		0												
10-Jun														
11-Jun														
12-Jun														

Appendix B3. Snow water equivalent (cm) at the Happy Valley (HV) site.

Month and Day	99	00	01	02	03	04	05	06	07	08	09	10	11	12
30-Apr			14	15	13	23	24		7.3		41		40	
1-May														
2-May														
3-May														
4-May														
5-May														
6-May														
7-May														
8-May														
9-May														
10-May					16.4									
11-May														
12-May														
13-May								22.0						
14-May				13.1										
15-May							28.3					14.4		
16-May				12.5										20.7
17-May									8.1				37.8	
18-May				9.6						20.0		14.9		18.9
19-May		15.3				17.4		22.0						
20-May	7.4		19	6.7			30.0					12.8	35.0	15.9
21-May					17.7	14.9					27.4			
22-May	10			0.8				14.1	7.8	16.2		14.9		9.8
23-May				0.0	11.1	14.7	28.6						30.7	
24-May								13		12.6	21.0	11.1		2.0
25-May					20.2	8.2			6.9					
26-May			14				26.7	8.2		6.2	15.6	6.6	12.1	0
27-May													5.8	
28-May					11.0		21	7	6.3	3.0		0.2		
29-May						0					17.5		0	
30-May		16.0					19	4.2	5.8	0				
31-May					24.3									
1-Jun			11.7				13	0	4.7		15.6			
2-Jun		13			4.4									
3-Jun			9.2				10		1.7					
4-Jun		12												
5-Jun			4.1				4.3		0					
6-Jun		11												
7-Jun			0											
8-Jun		2.3												
9-Jun														
10-Jun		0												
11-Jun														
12-Jun											0			

Appendix B4. Snow water equivalent (cm) at the Sagwon (SH) site.

Month and Day	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12
30-Apr		8.1	9.1	4.4	6.0		5.6			8.3	12			10	6.4	10	8.1	11	5.5		7.5		4.3		8.6	
1-May																										
2-May																										
3-May																										
4-May																										
5-May																										
6-May																										
7-May					1.7																					
8-May				2.0																						
9-May		5.4																								
10-May																										
11-May																										
12-May																										
13-May		3.9			1.7															6.0						
14-May																7.9										
15-May	5.2													7.9					3.6					5.1		
16-May																7.7										
17-May		3.9												7.7							7.3				7.9	
18-May		4.4														3.3						8.0		5.9		7.0
19-May										0.4				3.3				8.2		0.0						
20-May				1.1								1.7	5.8		8.1	0.0			4.3					5.8	4.7	2.1
21-May		3.9												0.0			8.4	4.8					0			
22-May													7.7								7.2	7.0		5.3		0
23-May																	10.2	4.9	3.4						2.1	
24-May		3.8									1.1		4.1									3.7		4.2	0	
25-May			5.9				2.3											2.8			7.1					
26-May		3.7													6.6				2.9			1.5		1.1		
27-May																										
28-May		3.7															9.2		2.2		7.1	0.0				
29-May																		2.8				8.0				
30-May		2.6																	0.3		6.3					
31-May																	2.0									
1-Jun		2.4													5.7			2.3	0		4.7					
2-Jun																										
3-Jun		1.8													1.8			1.3			0					
4-Jun																										
5-Jun		1.7													0.5			0.5								
6-Jun															0.0											
7-Jun																		0								
8-Jun																										
9-Jun																										
10-Jun																										
11-Jun																										
12-Jun																										

Appendix B5. Snow water equivalent (cm) at the Franklin Bluffs (FR) site

Month and Day	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12
30-Apr		9.3		4.7	11.3		12.7					6.5		10		8.5	12		12	10	6.6				12.1	
1-May																										
2-May																										
3-May																										
4-May								6.1																		
5-May																										
6-May									7.0																	
7-May																										
8-May				5.6																						
9-May		2.7																								
10-May																	10.2									
11-May																										
12-May																										
13-May																										
14-May					10.7											8.3										
15-May	8.5																		12.0							
16-May						8.0										6.5										
17-May																	15.6				8.7				13.6	
18-May																4.7	17.6									13.0
19-May										6.9							19.5			8.1						
20-May												7.1		14.5	13	3.3	19.1	9.1	11.5						13.9	9.8
21-May					10.9	6.7											12.5					9.2	9.1			
22-May		5.4										9.1				1.0	12.3		12.8	5.5	8.4					7.9
23-May																0.0										
24-May					8.6							8.2					10.0			1.8		8.9	4.8		10.2	
25-May			22.3				14					9.6					9.2	2.9			7.8					
26-May		4.9										9.1							12.3	0		7.0	0.0		8.2	
27-May					8.6							8					11.4								4.2	
28-May		4.0										8.6					9.4		11		6.5	0.5				6.1
29-May											22.9	7.8						2.9							2.2	
30-May		3.4										6.9					7.3		8		6.3	0		9.2		
31-May					2.8							6.7		14.7			14.6							5.8		5.2
1-Jun		1.6										4.7			13.4			2.3	6		5.8			5.5		
2-Jun												2.9					2.6							4.1		2.0
3-Jun		0.8										1.9			9.6			1.3	2.7		1.9			3.9		
4-Jun												1.4		14			0.5							2.1		0
5-Jun		0.7										0.7			7.7			0.4	0.4		0			0		
6-Jun			7.7									0			5.5		0	0.4								
7-Jun		0												9.2	4.5			0	0							
8-Jun														8.2	3.5											
9-Jun														3.5	2											
10-Jun														2	0											
11-Jun														1.2												
12-Jun														0.3												

Appendix B6. Snow water equivalent (cm) at the Betty Pingo (BP) site

Month and Day	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12
30-Apr														12			8.0		10.6	
1-May																				
2-May																				
3-May																				
4-May																				
5-May																				
6-May			6.6																	
7-May																				
8-May																				
9-May			7.6																	
10-May			7.1																	
11-May			6.3																	
12-May			6.0																	
13-May			6.0							9					9.3					
14-May			5.9																	
15-May			5.8				9.9													
16-May										8.9										
17-May		7.3			12.8					8.3	10.9									
18-May					12.7					6.3	10.0		7.0							
19-May				4.7	12.9					5.4	11.5	8.1								
20-May		7.2		4.4	13.3					4.5	12.7		9.5						10.7	
21-May		6.8		4.6	13.2		9.3	12.8	8.3	4.5	12.6					9.1	4.2			
22-May				4.3	12.6		8.5			2.7	12.7									
23-May		4.2		2.8	11.8					0.6	11.3									
24-May	10	3		1.9	11.3		9.2			0.0	9.5	2.7		6.3	8.2	6.9	1.4		5.6	
25-May	10	1.8	5.8	1.4	13.0		7.5									5.0				
26-May	12	0.9	5.1	1.8	12.3		8.1				11.1		10.8	2.6	8.8	3	0		1.9	
27-May	12	0.6	4.1	0.7	13.3		8.5				11.8					3.2				
28-May	11	0.8	3.7	0.4			7				11.8			0	9.2	1.0			0	5.5
29-May	5.5	0.4	3				7.2				11.5	2.6				0.5				
30-May	3.8	0.1	2.1				7				9.8		5.5		7	0.3				
31-May		0	1.3				6.8				10.1	2.6	4.4			0				
1-Jun	0		0				5.7	14.9	8.8		8.9		4.2							4.0
2-Jun			0				5.7				7.1	1.9			6.4					
3-Jun							4.5		4.1		6.5	1.3	3							2.2
4-Jun							3.4				1.9	1.1	2.4		3.1					
5-Jun					9.7		2.9		3.4		0.0	0.6	1.1							0
6-Jun					6.6		2.6	8.4	2			0	0.2		0					
7-Jun					4.2			6.7	1.2											
8-Jun					3.4			6.2	0.9											
9-Jun					1.4			3.8	0.7											
10-Jun					0.9			1.7	0											
11-Jun								0.3												
12-Jun								0.0												

Appendix B7. Snow water equivalent (cm) at the West Dock (WD) site

Month and Day	99	00	01	02	03	04	05	06	07	08	09
30-Apr		**6.5**	**5.7**	**7.3**	**18**	**7**	**6.3**		**5.8**		**10.0**
1-May											
2-May											
3-May											
4-May											
5-May											
6-May											
7-May											
8-May											
9-May											
10-May											
11-May											
12-May											
13-May				**7.7**					**6.5**		
14-May											
15-May							**3.7**	**8.8**			
16-May				**7.6**							
17-May				**7.7**	**7.3**						
18-May				**6.5**	**9.4**			**7.3**			
19-May				**4.8**							
20-May				**4.3**	**14.6**	**8.2**	**4.9**				
21-May	**10.6**		**6.3**	**4.3**	**11.2**						**9.7**
22-May	**8.9**			**3.1**	**9.3**					**8.2**	
23-May				**1.0**							
24-May	**12**			**0.0**	**11.2**					**11.0**	**8.7**
25-May	**9.6**					**2**					
26-May	**11**				**9.2**		**3.8**		**6.2**	**4.5**	**4.5**
27-May	**11**				**7.3**			**4**			
28-May	**11**				**8.9**				**6.0**	**0.0**	
29-May	**9.1**				**6.6**			**0**			**3.9**
30-May	**11**				**10.3**	**2.4**	**3.3**		**8.3**		
31-May	**8.9**	**6.2**					**2**				**0.0**
1-Jun	**8**		**6.3**		**14.1**	**2.4**	**1**				
2-Jun	**6.8**				**5.7**				**7.1**		
3-Jun	**7.6**		**4.2**		**4.9**	**1**	**0.6**				
4-Jun	**5.6**				**4.0**	**1**	**0.2**		**4.3**		
5-Jun	**4.7**	**7.2**	**2.8**			**0.8**					
6-Jun	**4.7**	**6.8**	**1.7**		**0.4**	**0.4**			**0**		
7-Jun	**3.4**	**5.4**	**0.9**								
8-Jun	**2.8**	**3.4**	**0.4**								
9-Jun	**3.3**	**1.6**	**0.4**								
10-Jun	**1.6**	**0.7**	**0.2**								
11-Jun	**0.5**	**0.6**	**0**								
12-Jun	**0**	**0**									

Appendix B8. 2010 Snow water equivalent (cm) at the Atigun, Galbraith Lake and Oilspill hill sites.

Day-Month 2010	Atigan Pass	Galbraith Lake	Oil Spill Hill
30-Apr			
1-May			
2-May			
3-May			
4-May			
5-May			
6-May			
7-May			
8-May			
9-May			
10-May			
11-May			
12-May			
13-May			
14-May			
15-May	19.2	2.2	2.2
16-May	20.2	0.8	0.8
17-May		0.1	0.1
18-May	18.6		
19-May	19.1		
20-May			
21-May	16.3		
22-May			
23-May	11.4		
24-May			
25-May	8.9		
26-May			
27-May	7.7		
28-May	5.8		
29-May			
30-May			
31-May			
1-Jun			
2-Jun			
3-Jun			
4-Jun			
5-Jun			
6-Jun			
7-Jun			
8-Jun			

Appendix B9. 2011 Snow water equivalent (cm) at the Anaktuvuk River, Chandler River, Itkilik River met sites.

Day-Month 2011	Anaktuvuk River	Chandler River	Itkilik River
30-Apr	8.3	11.3	
1-May			
2-May			
3-May			
4-May			
5-May			
6-May			
7-May			
8-May			
9-May			
10-May			
11-May			
12-May			
13-May			
14-May		11.9	
15-May			11.9
16-May		13.8	
17-May		10.3	13.8
18-May		13.2	10.3
19-May	8.3	7.6	13.2
20-May	7.8	5.9	7.6
21-May	8.2	4.1	5.9
22-May	5.2	.9	4.1
23-May	6.4	0	.9
24-May	5.4		0
25-May			
26-May	.1		
27-May			
28-May			
29-May			
30-May			
31-May			
1-Jun			
2-Jun			
3-Jun			
4-Jun			
5-Jun			
6-Jun			
7-Jun			
8-Jun			