Table 3. Regional snow water equivalent in 2010.

Region	Number of sites	SWE		Percent of last year	Percent of average 2000–2010
		Cm	in	%	%
Mountains					
Kuparuk River	1	5.5	2.2	*	*
Sagavanirktok, Kadleroshilik, Shaviovik and Kavik Rivers	18	8.1	3.2	75	*
Chandler, Anaktuvuk and Itkillik Rivers	15	7.1	3.2	73	*
Foothills					
Kuparuk River	20	11.2	4.4	73	97
Sagavanirktok, Kadleroshilik, Shaviovik and Kavik Rivers	10	11.4	4.5	91	*
Chandler, Anaktuvuk and Itkillik Rivers	10	12.5	4.9	*	*
Coastal Plain					
Kuparuk River	22	10.1	4.0	76	107
Sagavanirktok, Kadleroshilik, Shaviovik and Kavik Rivers	12	10.4	4.1	107	*
Chandler, Anaktuvuk and Itkillik Rivers	0	**	**	*	*
Total					
Kuparuk River	43	10.2	4.0	83	106
Sagavanirktok, Kadleroshilik, Shaviovik and Kavik Rivers	40	9.6	3.8	87	*
Chandler, Anaktuvuk and Itkillik Rivers	25	9.2	3.6	81	*

* no data or not enough data available for comparison

** these basins do not extend to the Coastal Plain

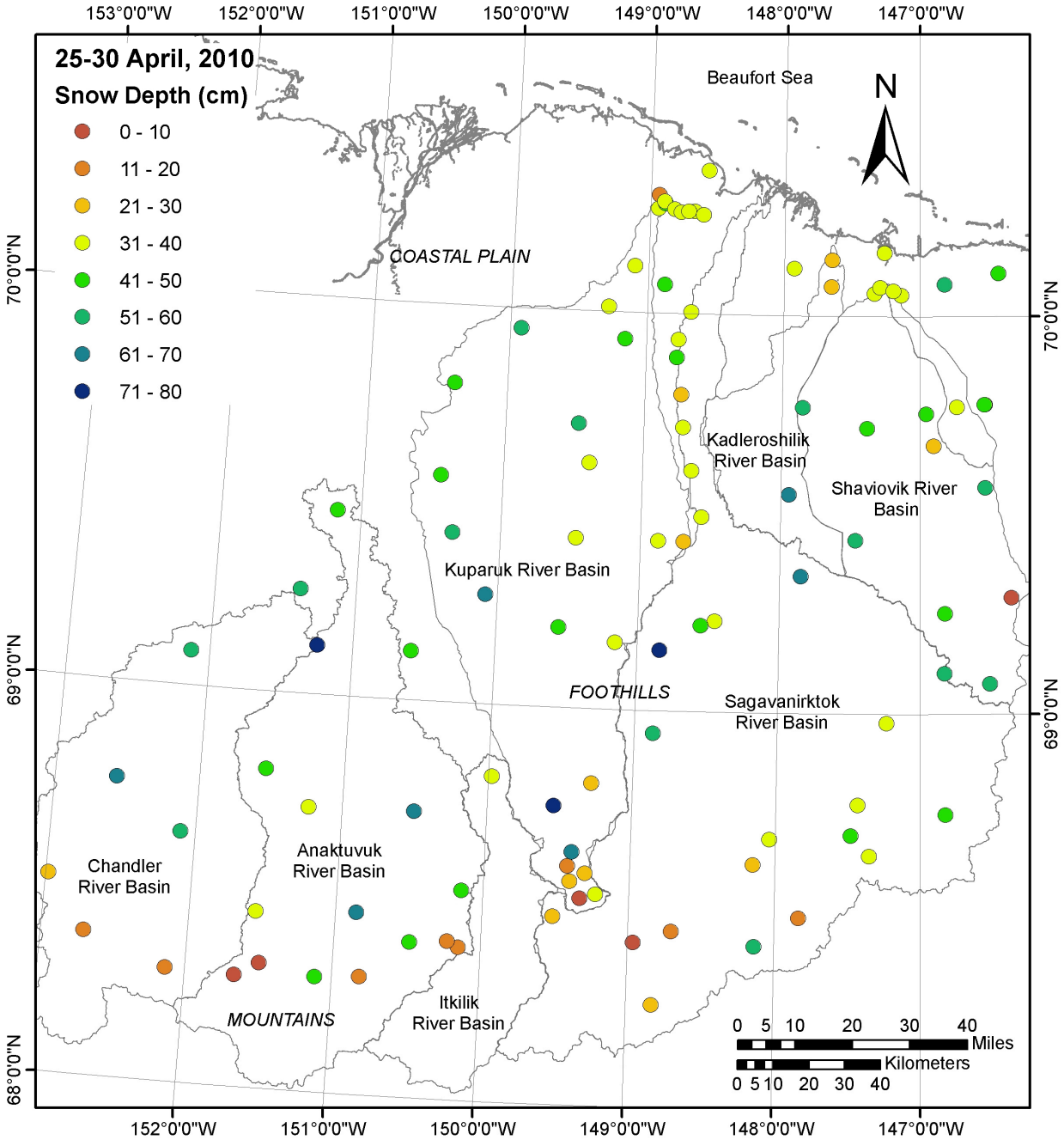

Figure 2. End-of-winter snow depth (cm) on the North Slope of Alaska in spring 2010. Each point represents average from 50 snow depths.

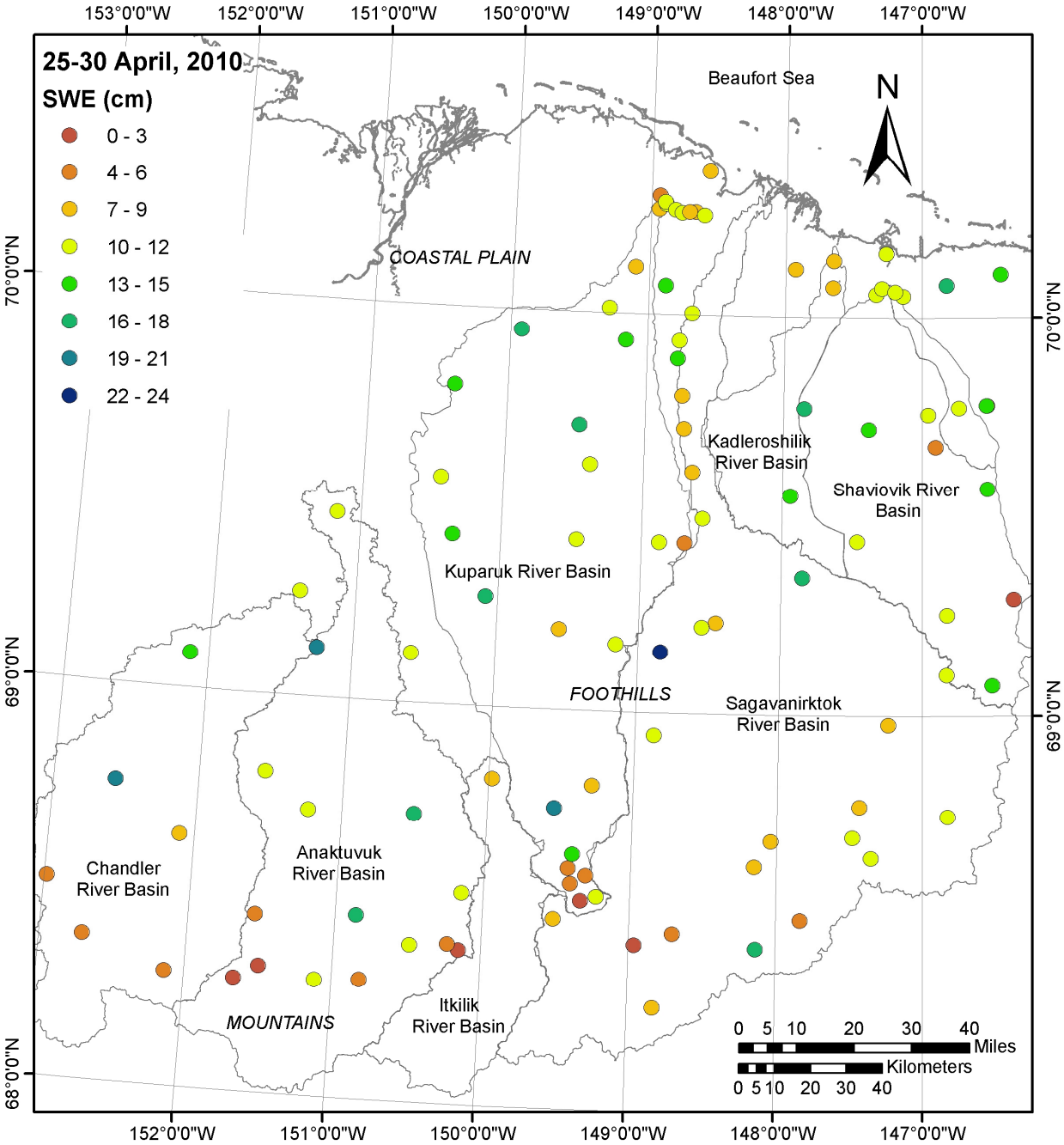

Figure 3. End-of-winter snow water equivalent (cm) on the North Slope of Alaska in spring 2010.

Long-term observations in the Kuparuk River

Long-term snow surveys on the AAS have been maintained by the U.S. Department of Agriculture (USDA) since the 1970s. Our snow survey dataset collected from the Kuparuk River basin covers a relatively short period of time (2000–2010) when compared with the NRCS period of record, yet it has more detailed spatial coverage: 43 snow courses in the Kuparuk River basin. End-of-winter SWE over the Kuparuk River watershed in 2010 accounts for 106% of the 10-year basin average SWE (Table 3). The 2010 end-of-winter SWEs for the Foothills and Coastal Plain are close to average and represent 97% and 107%, respectively, of the 11-year basin average SWE (Table 3). The Foothills and Coastal Plain had the highest 11-year SWE average (15.4 and 13.4 cm, 6.1 and 5.3 in.) in 2009. In 2010, the number of sites in the Kuparuk River basin was decreased by 50% and only 1 snow survey site was visited in the Mountains. This database has become long enough that we can start to analyze variability from year to year (Table 4). The highest snow accumulations were observed in 2003 and 2009, whereas 2001, 2006, 2008 were relatively low snow years.

Table 4. Maximum, minimum, and average snow water equivalent in the Coastal Plain, Foothills, and Mountains regions of the Kuparuk River basin (2000–2010, *n*=11), including the basin average.

Region	Maximum		Minimum		Average	
	cm (year)	in.	cm (year)	in.	Cm	in.
Mountains	14.7 (2003)	5.8	3.5 (2008)	1.4	8.1	3.1
Foothills	15.4 (2009)	6.1	8.9 (2006)	3.5	11.5	4.5
Coastal Plain	13.4 (2009)	5.3	8.4 (2001)	3.3	9.4	3.7
Kuparuk River basin	12.7 (2003)	5.0	7.3 (2008)	2.9	9.6	3.8

7. SONIC SNOW DEPTH DATA

While end-of-winter snow surveys provide areal snow depth which accounts for spatial snowpack heterogeneity, the SR50 measures the snow depth directly under the sensor throughout the entire winter. Most stations reported good quality data during the 2009-2010 winter (Figures 4-20) with only one site (Kavik station) not collecting data during the majority of winter and late season problems occurring at four of the other sites (Bullen, White Hills, North White Hills and South White Hills).

The SR50 at Kavik station was non-functional until it was repaired on April 24th, after which time the station collected data. The White Hills station SR50 began malfunctioning and was not recording data after April 24. The Bullen station ceased reporting due to a malfunctioning data logger on April 16. At the time of this report, South White Hills (DFM1) and North White Hills (DFM3) stations had not reported telemetrically since May 14. The Lower Kadleroshilik SR50 was relocated approximately 3m from the original location before the 2009-2010 winter season thus limiting interannual comparisons of the data.

The 2009-2010 winter is the first complete winter season snow depth was measured to the west at stations installed as part of the Umiat Corridor Project (Figure 1). These stations are located west of Toolik in the Foothill and Mountain region with one station (Anaktuvuk) located to the north approximately at the same latitude as Umiat.

The advantage of snow sensor information is its high temporal resolution which can capture the timing and magnitude of snow events. Records show that the snow accumulation began in latter part of October, 2009 (Figures 4 to 20). Following initial accumulation, the Coastal Plain and Foothill stations recorded gradual accumulation as the season progressed. There were no early season storms that some stations had reported in previous seasons. Project staff documented a warm period of near freezing temperatures with drizzle on December 10th near Toolik and along the Dalton Highway. The Mountain stations (Accomplishment Creek, Ribdon, Juniper) show an increase in snow depth, indicating the higher elevations saw this precipitation event as snowfall while the Coastal Plain and Foothill stations reported no or slight accumulation during this timeframe. Western stations in the Anaktuvuk Basin (Tuluga, Itikmalakpak, Upper May Creek, Nunushuk) show a consolidation of the snowpack close to December 1st (Figures 16-19). A high wind event occurred on approximately February 3 resulting in little accumulation and even snow erosion at Upper May Creek, but few stations recorded any changes in snow depth. Stations also recorded a similar event the first week of January. Little accumulation occurred from the end of December until the February 3rd storm, and continued to be sparse until accumulation occurred on February 24. Snow depth records at Mountain stations Accomplishment Creek and Juniper show more erosion and accumulation episodes throughout season; whereas the Mountain station

Ribdon had two times the snow depth as that recorded at Accomplishment and Juniper (50 cm vs. 25 cm) Creeks, but much less snow depth variability. The Coastal Plain and Foothill stations reported maximum snow accumulation around April 1st except for Northwest Kuparuk which was closer to May 1st. The Anaktuvuk Basin stations showed a maximum accumulation slightly earlier, around mid-March. Determining maximum accumulation for the White Hills, and North White Hills stations was not possible since these two sites are located on slight rises where the wind scours the area under the sensor.

Mid to late April snow course participants observed mostly clear conditions and mild weather on the Coastal Plain while the Foothills and Mountain regions were considerably more overcast. Starting approximately May 12, the Coastal Plain and Foothills regions were overcast with blustery conditions which prevailed until late May, resulting in late season ablation. Conditions in the Mountain region were considerably warmer with clearer conditions during this time resulting in earlier ablation compared to Foothills and Coastal Plain. Sensor data mirror these field observations.

On-site checks to ensure proper operation and accuracy of the snow sensor included measurement of four snow depths at a 22° angle around the sensor and one directly underneath. At the time of the station visit, sensors were reporting typically within 0.8 to 1.2 in (2-3 cm) of the actual snow depth (Table 5). The greatest discrepancy is seen at Upper Kadleroshilik, Lower Kadleroshilik, North White Hills, and Itikmalakpak stations where sensor values show a -4.3 in (-11.0 cm), 2.05 in (5.2 cm), 2.4 in (6.1 cm), and -2.1 in (-5.4 cm) difference between observed and reported value, respectively. Considering all stations, the average difference between sensor and observed snow depth is 0.4 in (1.0cm).

Snow sensor data used in conjunction with snow survey data can enhance and expand the information gained from both sampling methods. Since a snow depth sensor records snow depth at a point, the additional fifty snow depth measurements near each station represent local-scale variability relative to the measurement area under SR50 sensor (Figures 4-20). Accomplishment Creek, Juniper Creek, Upper Kadleroshilik, Lower Kadleroshilik, North White Hills, and Nanushuk sensor readings reflect the lower range of depths measured from snow surveys

(Figures 4, 6, 8, 10, 14, and 18 respectively). Sag-Ivishak, Northwest Kuparuk, Itikmalakpak, and Tuluga are near the middle range of snow survey depths (Figures 7, 15, 16, and 19 respectively). Ribdon, Kavik, Bullen, South White Hills, Upper May Creek, and Anaktuvuk reflect the upper range of snow course depth values (Figure 5, 9, 11, 12 and 20 respectively). There is considerable variability in terms of how snow sensors represent local snow course depths from year-to-year, which in large part is dependent on the location the snow depth sensor.. However, some stations remain consistent year-to-year in their representation of the local environment, such as North White Hills, Sag-Ivishak, and Accomplishment Creek.

The majority of station data for 2009-2010 winter season indicate higher snow accumulation compared to the 2006-2007 and 2007-2008 seasons and similar accumulation compared to the 2008-2009 record (Figures 4-20). Coastal Plain stations (Bullen, Lower Kadleroshilik and Northwest Kuparuk) reported an average of 0.8 in (2 cm) greater snow depth than in 2008-2009, in terms of average snow course depth. Foothills stations Sag-Ivishak, Upper Kadleroshilik, Kavik, South White Hills and White Hills reported an average of 3.5 in (8.8 cm) less snow as previous season. Although sensor data for the Mountain stations between the 2008-2009 and 2009-2010 seasons are similar in terms of cumulative snow depth, at the end of 2009-2010 the average snow course depth values were 4.3 in (11.0 cm) less than in 2008-2009.

Table 5. Snow depth information from meteorological station and co-located snow survey. Range and average snow depth from snow survey. Observed snow depth under SR50 snow sensor, reported SR50 snow depth at time of observed measurement, and difference between observed and reported snow depth.

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)	2.0-88.0	50.3	30.5	31.9	-1.5
Ribdon Creek (DBM2)	10.0-59.0	34.3	NA	52.0	NA
Juniper Creek (DBM3)	32.0-88.0	54.1	27.3	24.06	3.2
Sag-Ivishak (DBM4)	36.0-66.0	46.3	44.2	46.9	-2.7
Upper Kadleroshilik (DBM5)	45.0-87.0	64.8	59.5	70.5	-11.0
Kavik (DBM6)	14.0-48.0	23.12	33	34.6	-1.6
Lower Kadleroshilik (DBM7)	12.0-59.0	26.9	6	0.8	5.2
Bullen (DBM8)	40.0-70.0	52.1	72.2	NA	NA
South White Hills (DFM1)	12.0-64.0	39.9	NA	52.7	NA
White Hills (DFM2)	NA	NA	NA	10.67	NA
North White Hills (DFM3)	27.0-94.0	55.9	21.8	15.7	6.1
Northwest Kuparuk (DFM4)	36.0-75.0	53.5	54.4	55.4	-1.0
Itikmalakpak (DUM1)	4.0-80.0	44.38	37.0	42.4	-5.4
Upper May Creek (DUM2)	0-18.0	10.0	16.0	16.9	-1.0
Nanushuk (DUM3)	37.0-86.0	65.4	40.0	41.8	-1.8
Tuluga (DUM4)	11.0-72.0	44.3	42	42.6	-0.6
Anaktuvuk (DUS2)	19.0-38.0	28.48	36.6	35.0	1.6

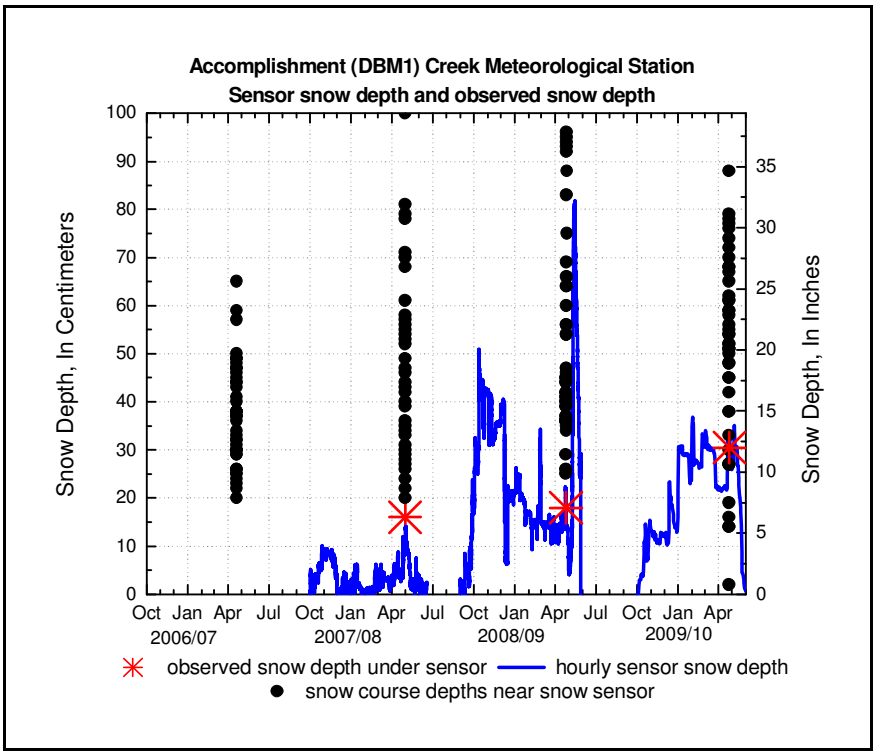

Figure 4. Accomplishment Creek meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

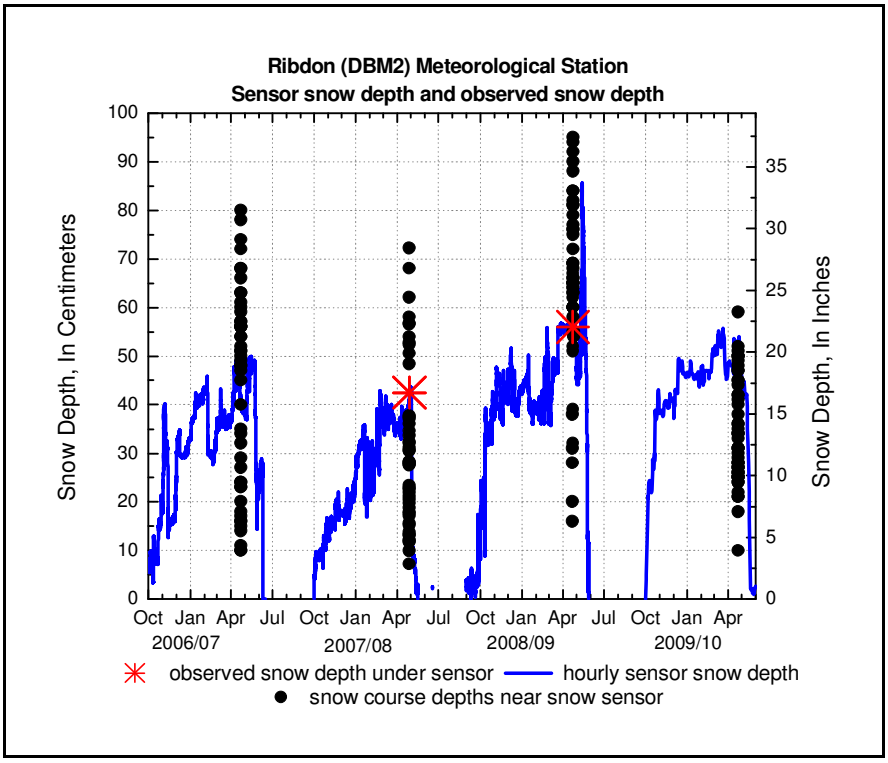

Figure 5. Ribdon meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

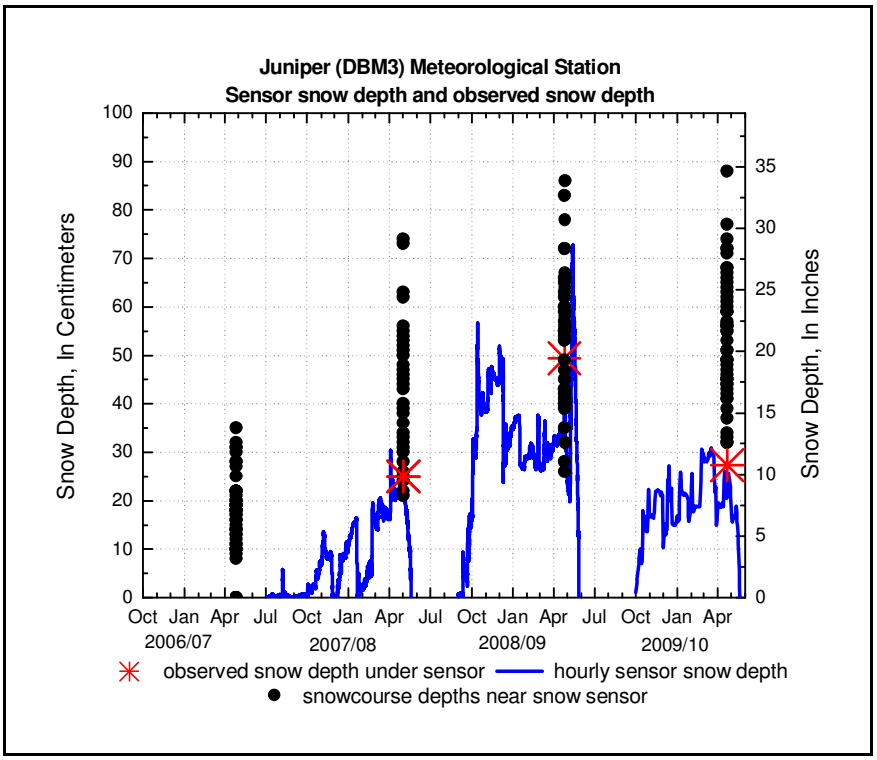

Figure 6. Juniper meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

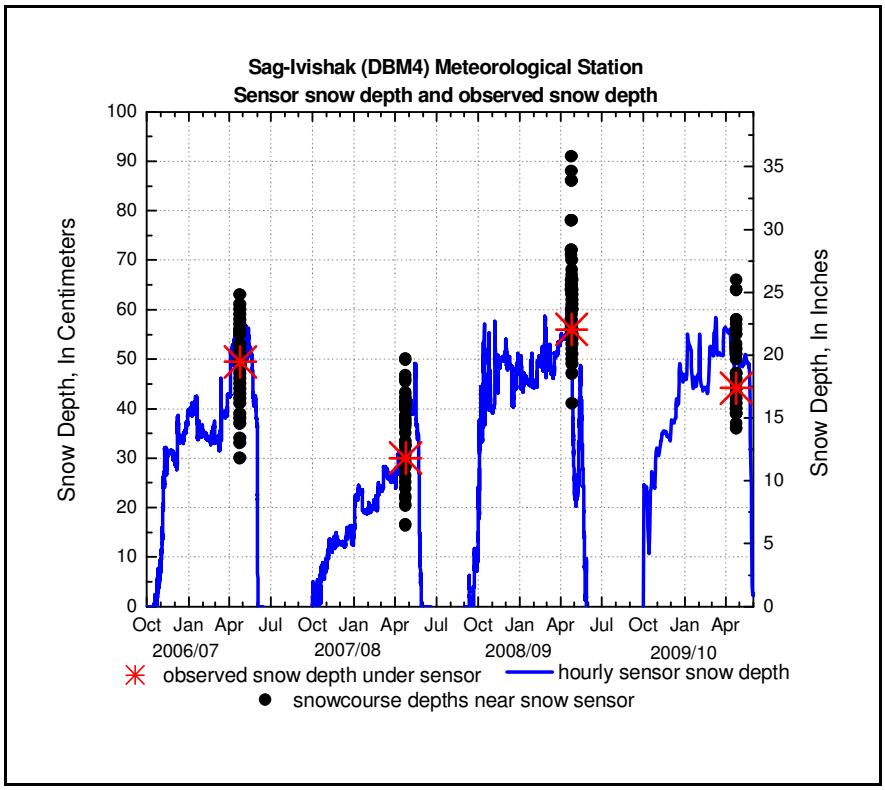

Figure 7. Sag-Ivishak meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

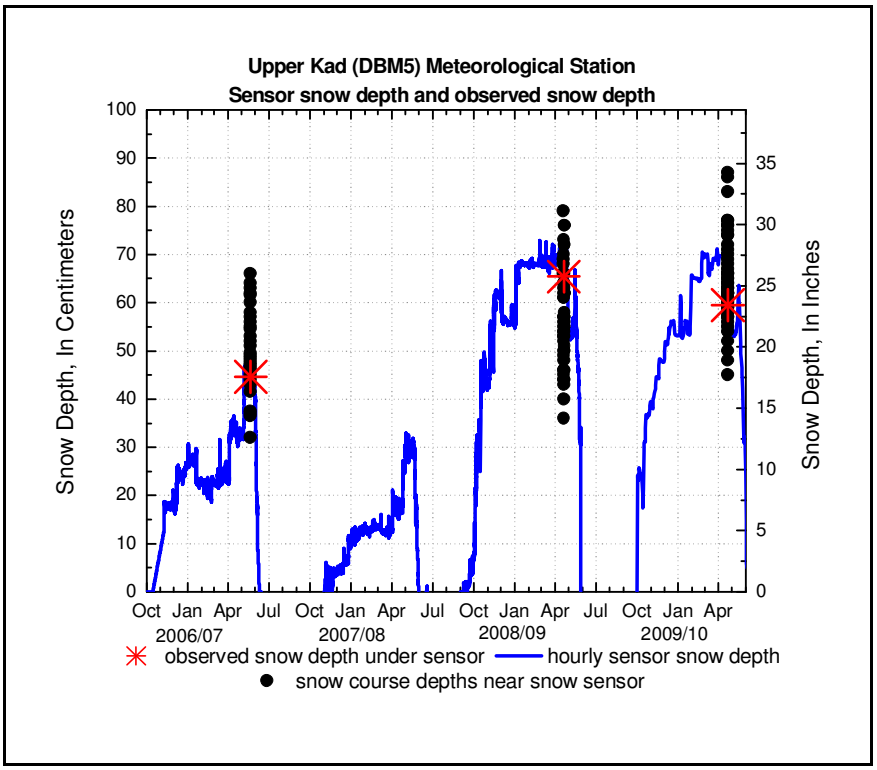

Figure 8. Upper Kadleroshilik meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

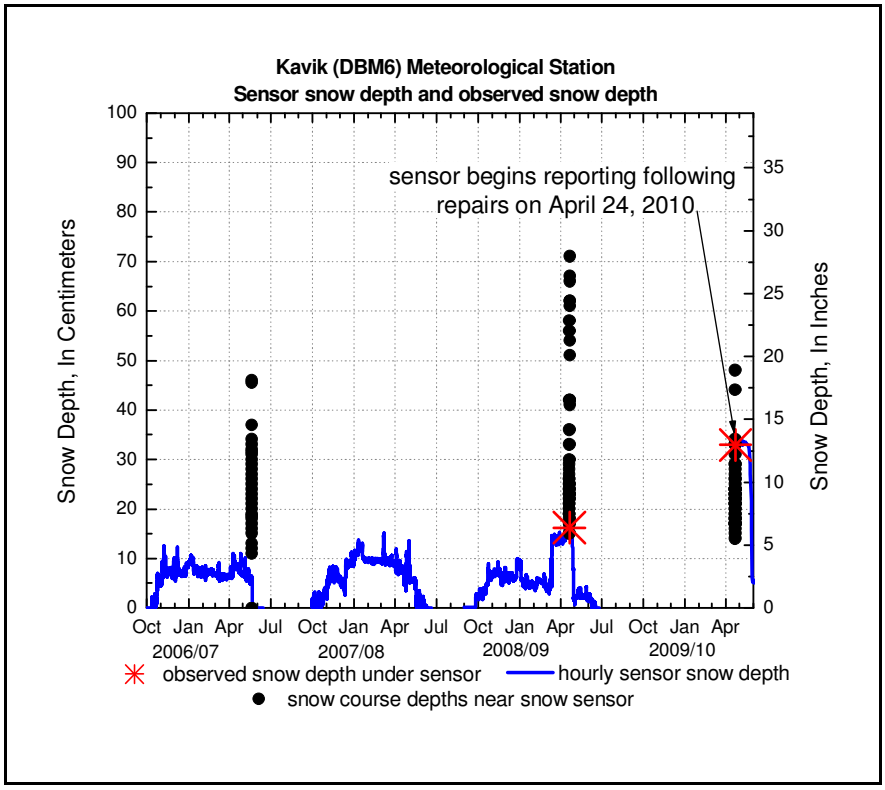

Figure 9. Kavik meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

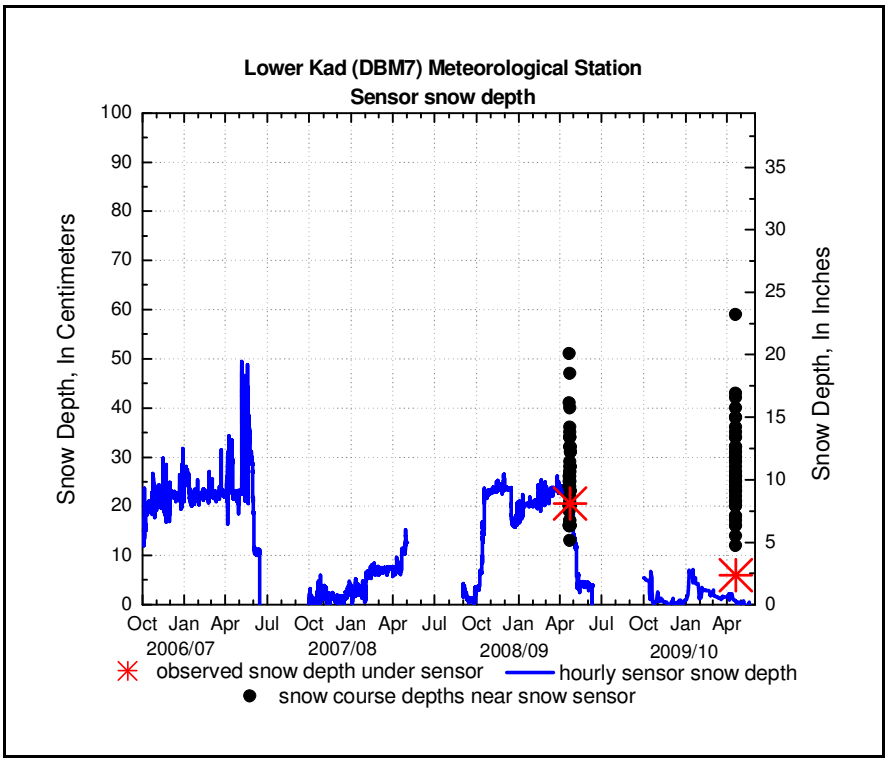

Figure 10. Lower Kadleroshilik meteorological station hourly SR50 sensor snow depths measured over the winter, observed snow depth under the sensor, and snow survey depths measured near sensor.

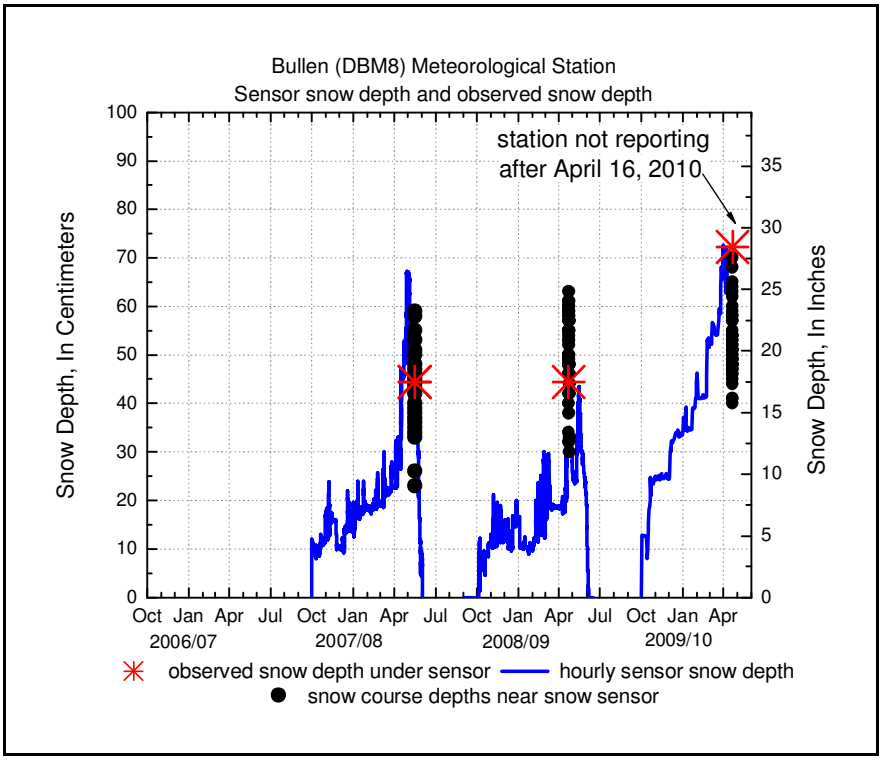

Figure 11. Bullen meteorological station hourly SR50 sensor snow depths measured, observed snow depth under the sensor, and snow survey depths measured near sensor.

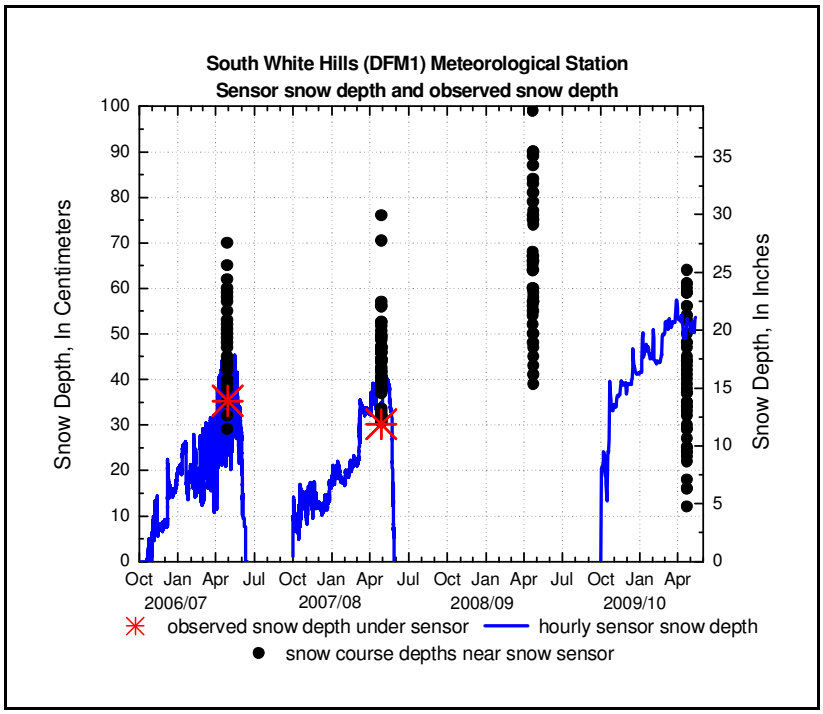

Figure 12. South White Hills meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

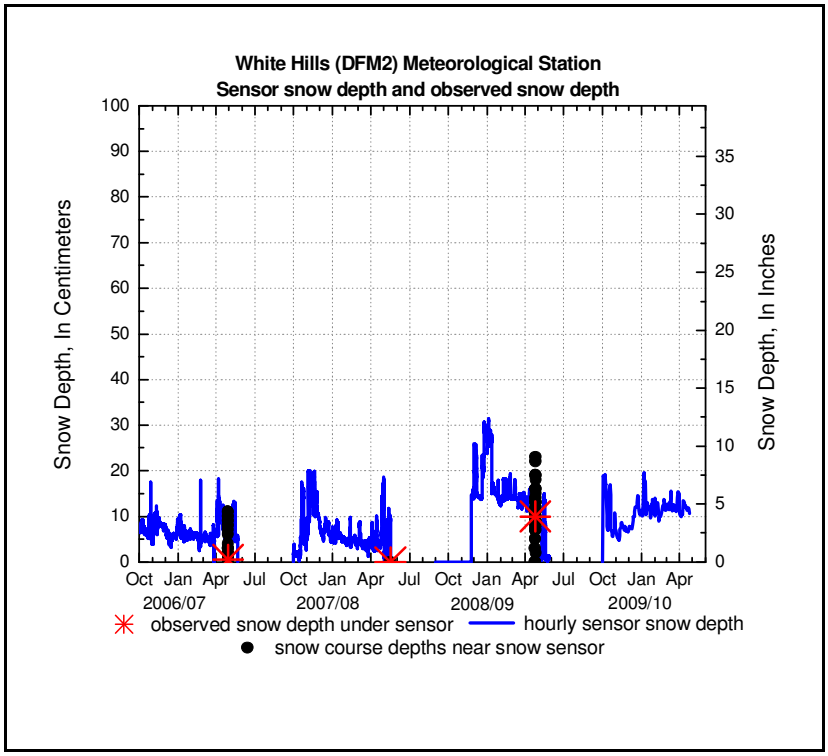

Figure 13. White Hills meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

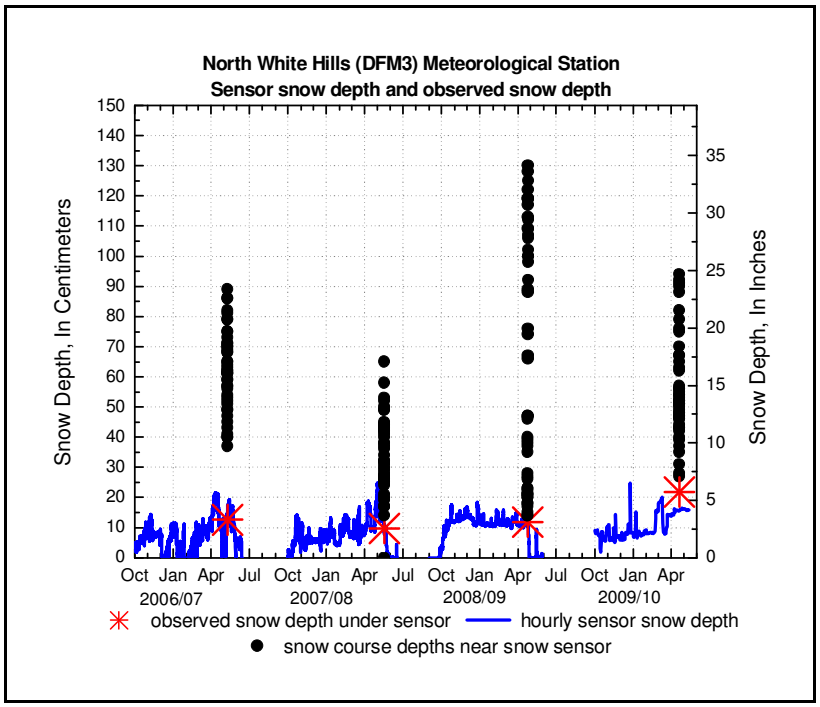

Figure 14. North White Hills meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

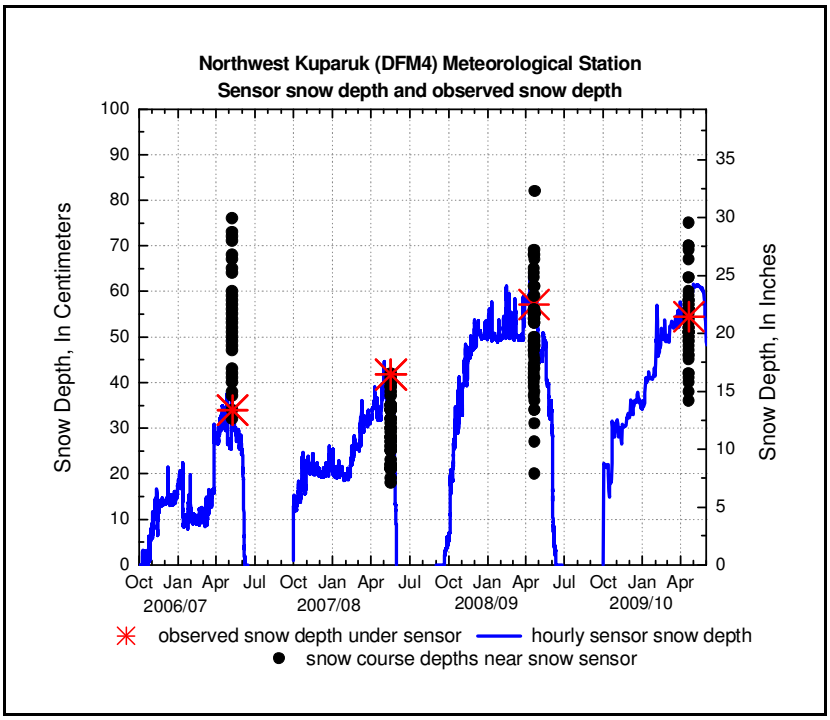

Figure 15. Northwest Kuparuk meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

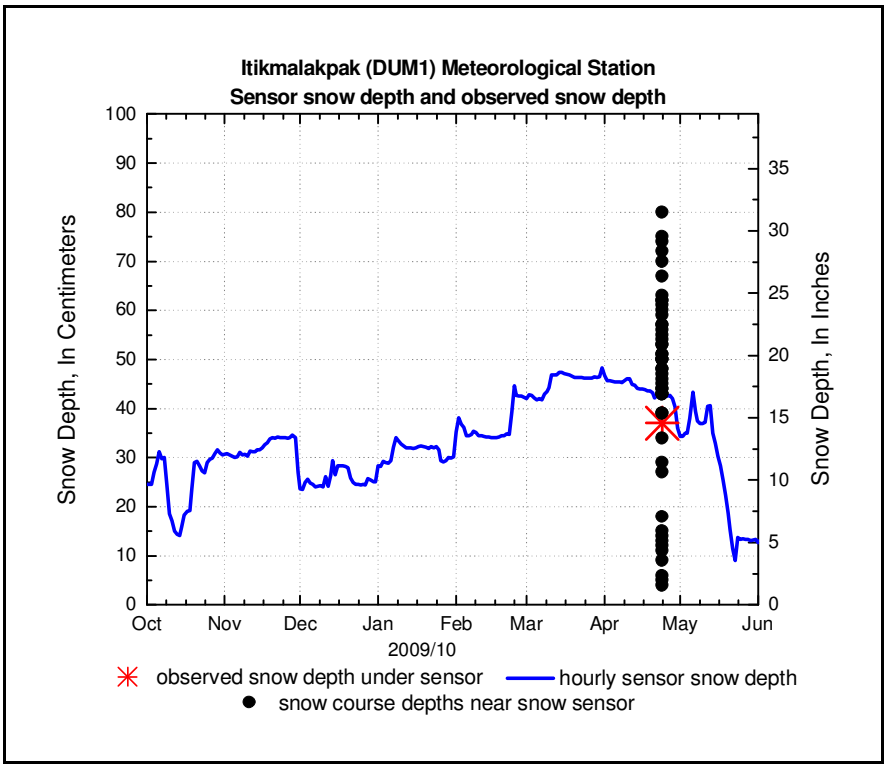

Figure 16. Itikmalakpak meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

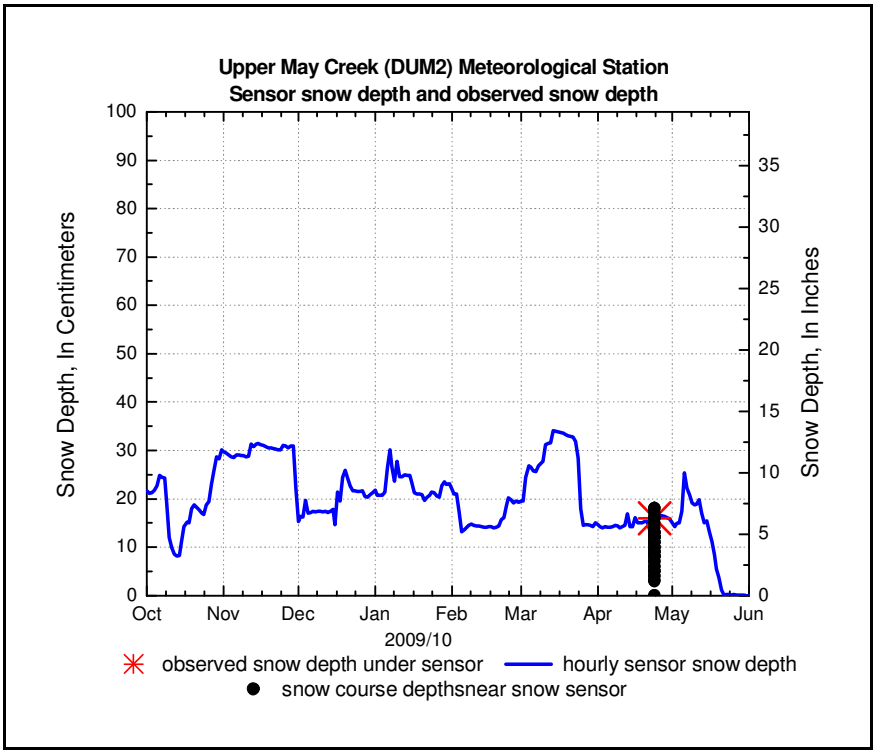

Figure 17. Upper May Creek meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

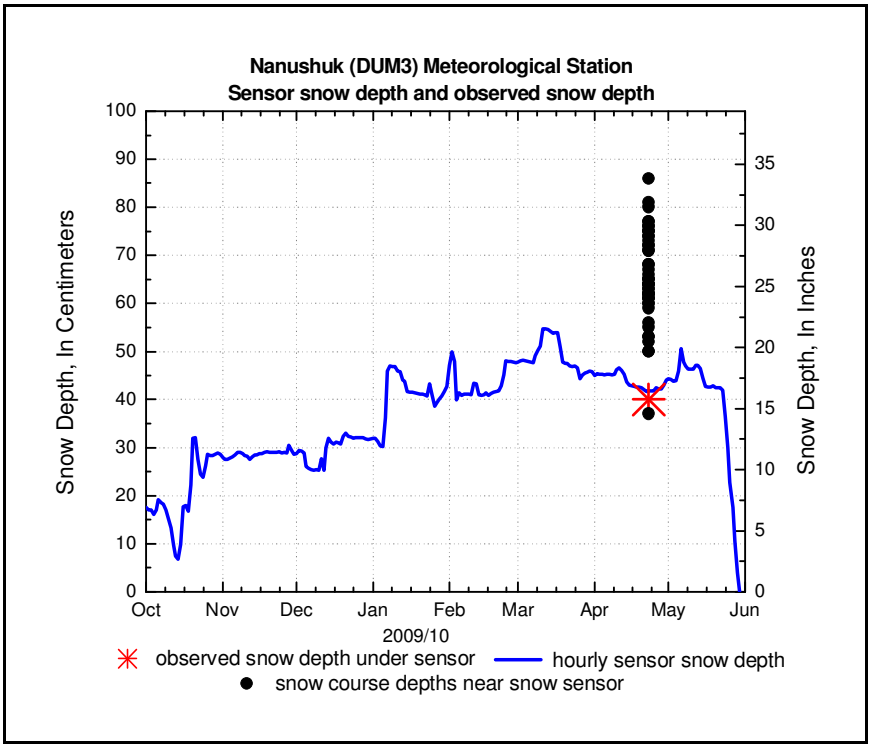

Figure 18. Nanushuk meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

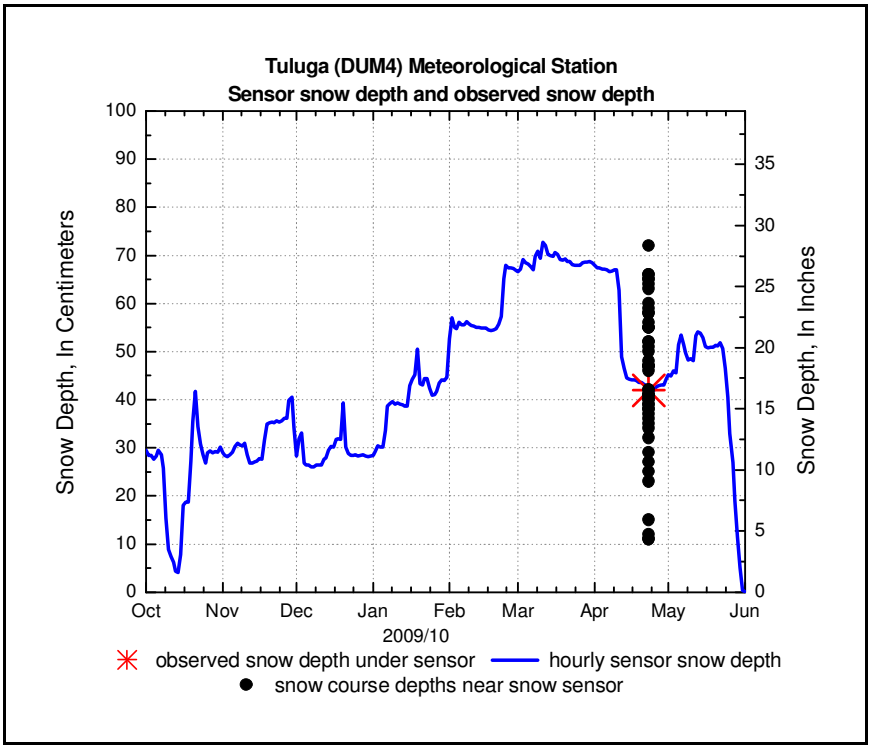

Figure 19. Tuluga meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

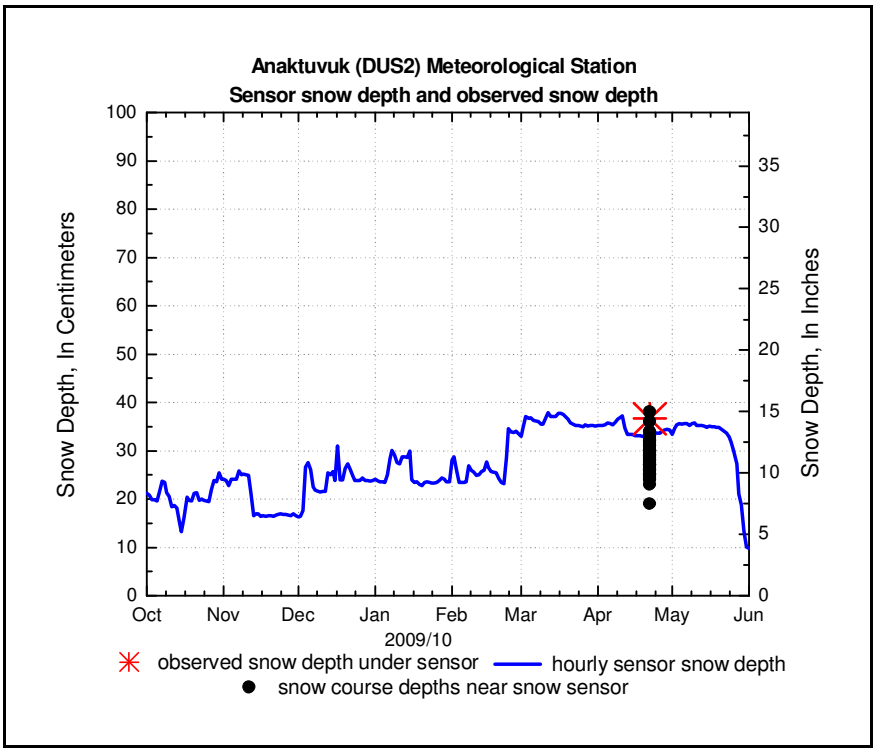

Figure 20. Anaktuvuk meteorological station hourly SR50 sensor snow depths, observed snow depth under the sensor, and snow survey depths measured near sensor.

8. ABLATION DATA

Historical ablation data were collected at four sites (Upper Kuparuk, Happy Valley, Sagwon and Franklin Bluffs) (see Section 3.2 for details). In addition to historical sites, three new sites were monitored in the Mountains and Foothills (Atigun Pass, Galbraith and Oil Spill Hill). The data is summarized in Appendix B. The ablation window varies greatly, depending on meteorological conditions such as radiation and air temperature along with snowpack depth (Figure 21). The 2010 snowpack completely melted by May 28 in southern sites, i.e. Upper Kuparuk, Happy Valley and Sagwon (Figure 16). It took another week for the snowpack to melt on the Coastal Plain, i.e. Franklin Bluffs (Figure 16). The timing of snowmelt is easily seen in photographs that were taken at most of the sites during the snow surveys. Photos were taken in the north, east, south, and west directions. Figure 22 provides south facing photos for a few of the sites. Based on our measured and photographed ablation observations, snowpack across the entire Kuparuk River basin completely melted by June 4, 2010 with the melt starting in the headwaters and progressing northward. Field team, measuring discharge in the lower Kadleroshilik and

Shaviovik River watersheds, indicated that snow remained on the ground until June 9 and 10, 2010 with less then 10% of area covered by snow. No ablation measurements were collected at these areas, other than observer notes and photographs.

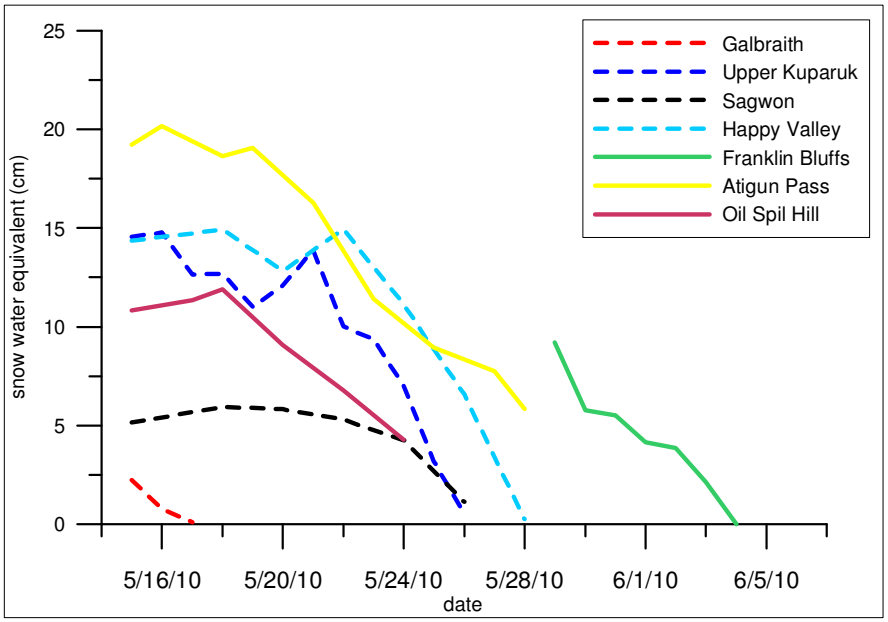

Figure 21. Net volumetric decrease in SWE. Snow ablation curves at the Foothills are shown as dashed lines and, on the Coastal Plain, as solid lines.

9. SUMMARY

This report describes snow depth, snow water equivalent, and snow density data collected in April–May 2010 in the Central Alaskan Arctic. Snow surveys were conducted in the watersheds of the Kuparuk, Anaktuvuk, Chandler, Itkillik, Sagavanirktok, Shaviovik, Kadleroshilik, and Kavik Rivers. As of 2010, the Kuparuk River watershed has 11 years of repeated end-of-winter snow survey data. There are snow survey data in the Kuparuk River basin prior 2000. This data is available in Kane et al. (2009). The Sagavanirktok, Kadleroshilik, Shaviovik and Kavik River basins have 5 years of repeated snow surveys data, from 2006 to 2010. The Anaktuvuk and Itkillik River basins have 2 years of repeated snow survey data, 2009 and 2010. Snow survey observations in the Chandler River basin were initiated in 2010. Overall, 108 sites were visited in 2010. This number includes 34 sites located in the Mountains, 40 sites in the Foothills, and 34 sites on the Coastal Plain.

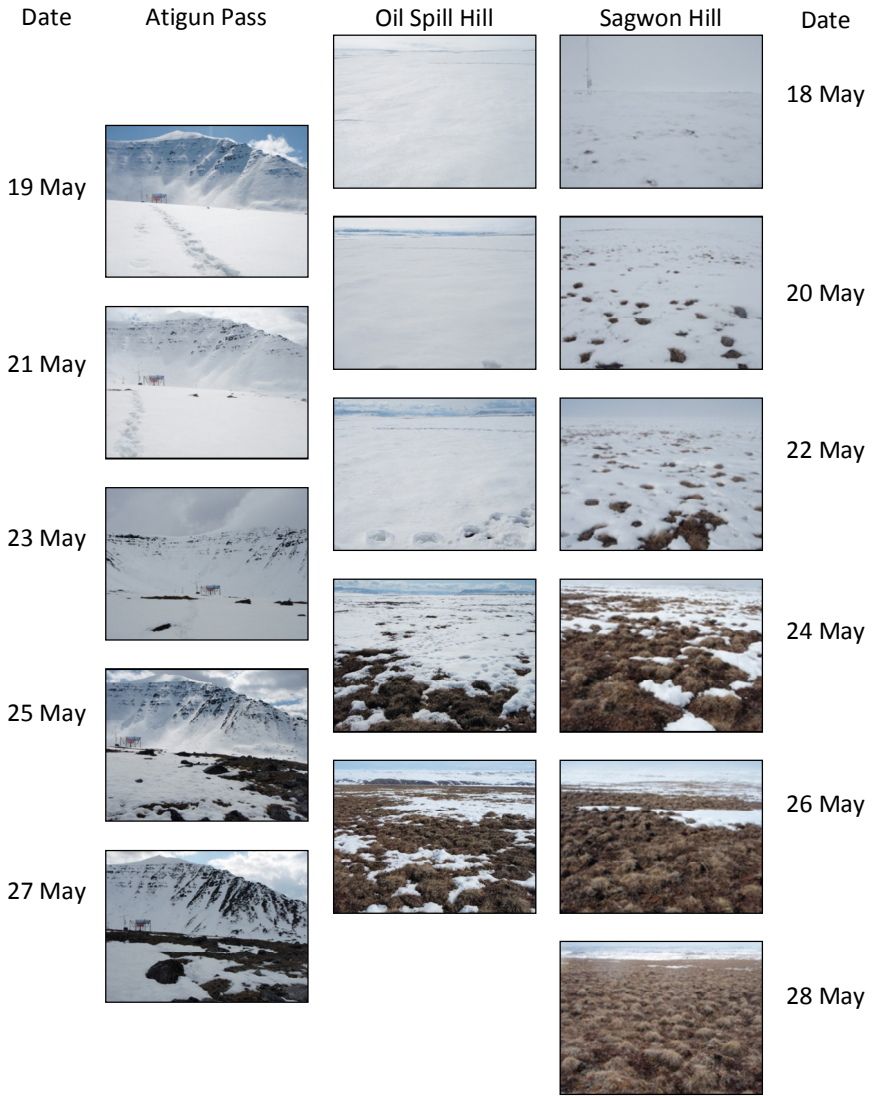

Figure 22. Progress of snowmelt as captured by photographs taken at Atigun Pass, Oil Spill Hill and Sagwon Hill. All photographs are taken facing south.

The Kuparuk River watershed end-of-winter SWE observed in 2010 accounts for 106% of the 11-year average SWE. The Foothills and Coastal Plain end-of-winter SWE observed in 2010 represent 97% and 107%, respectively, of the 11-year average SWE. The Foothills and Coastal Plain had the highest 11-year SWE average (15.4 and 13.4 cm, 6.1 and 5.3 in.) in 2009. Only one snow survey site was visited in the mountains in the Kuparuk River basin. Based on adjacent watersheds, the Mountains have 73 to 75% of the previous year SWE. The snowpack across the entire Kuparuk River basin melted by June 4, 2009.

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Appendix B10. Snow water equivalent (cm) at the Oil Spill Hill site.

Month and Day	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10
30-Apr																										
1-May																										
2-May																										
3-May																										
4-May																										
5-May																										
6-May																										
7-May																										
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9-May																										
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11-May																										
12-May																										
13-May																										
14-May																										
15-May																										10.8
16-May																										
17-May																										11.3
18-May																										11.9
19-May																										
20-May																										9.1
21-May																										
22-May																										6.8
23-May																										
24-May																										4.3
25-May																										
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27-May																										
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