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Evaluating snow depth measurements from ground-penetrating radar and airborne lidar in boreal forest and tundra environments during the NASA SnowEx 2023 campaign

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Supplemental Tables

Table S1: Daily snow depth accumulation measurements during the March 2023 SnowEx campaign. Measurements from Farmers Loop/Creamer's Field (FLCF) were obtained from the Creamer's Field SNOTEL station (Site ID: 1302). Measurements obtained from the Caribou/Poker Creek Research Watershed (CPCRW) and Upper Kuparuk-Toolik (UKT) field sites were collected on storm interval boards. No measurements were available from the Bonanza Creek Experimental Forest (BCEF). Arctic Coastal Plain (ACP) snow depth accumulation was estimated from precipitation measurements (estimated snow density = 75 kg m^{-3}) obtained from the NOAA AK Deadhorse 3 S weather station. Trace indicates accumulated snow depth of <0.01 m.

Date	FLCF	CPCRW	UKT	ACP
8 March	0 m	Trace	0.18 m	0.02 m
9 March	0.03 m	0.08 m	0 m	0 m
10 March	0.03 m	0.02 m	0 m	Trace
11 March	0 m	No Observation	0.02 m	Trace
12 March	0 m	Trace	No Observation	0.02 m
13 March	0.05 m	No Observation	0.03 m	0 m
14 March	0 m	No Observation	0 m	0 m
15 March	0 m	No Observation	0 m	0 m

Table S2: Boreal forest 2023 snow depth means and standard deviations (std) from GPR, excavated depth, and lidar transect profiles. Snow densities used to calculate radar velocity for the GPR snow depths are also given. Airborne lidar surveys were conducted at all three sites on 11 March 2023.

Site	Date	Transect ID	GPR System	Bulk Snow Density (kg m^{-3})	GPR Mean (m)	GPR std (m)	Excavated Mean (m)	Excavated std (m)	Lidar mean (m)	Lidar std (m)
FLCF	7 March	DN013	1.0 GHz 1 pol	207	0.56	0.06	0.48	0.05	0.40	0.10
		CN069	1.0 GHz 1 pol	253	0.58	0.05	0.56	0.05	0.36	0.05
	8 March	WN104	1.6 GHz 1 pol	197	0.85	0.04	0.51	0.11	0.52	0.07
		DN040	1.6 GHz 1 pol	218	0.74	0.02	0.42	0.13	0.49	0.14
	9 March	WB032	1.6 GHz 1 pol	163	0.64	0.02	0.60	0.09	0.03	0.08
	10 March	EB100	1.6 GHz 1 pol	187	0.54	0.08	0.59	0.09	0.36	0.09
	11 March	DN091	1.0 GHz 1 pol	193	0.60	0.05	0.73	0.03	0.51	0.07
	13 March	DB106	1.0 GHz 1 pol	208	0.48	0.08	0.60	0.06	0.31	0.01
BCEF	10 March	WB497	1.0 GHz 1 pol	204	0.76	0.07	0.69	0.08	0.45	0.06
	13 March	DB337	1.6 GHz 1 pol	208	0.63	0.07	0.55	0.10	0.49	0.06
	14 March	SA326	1.6 GHz 1 pol	225	0.81	0.08	0.76	0.09	0.65	0.06
	15 March	WA437	1.6 GHz 1 pol	198	0.96	0.06	0.74	0.15	0.73	0.03
CPCRW	8 March	DB247	1.0 GHz 1 pol	214	0.84	0.05	0.71	0.10	0.61	0.06
	9 March	DB254	1.0 GHz 1 pol	207	0.80	0.04	0.80	0.04	0.41	0.12
	11 March	WN281	1.6 GHz 1 pol	193	0.95	0.07	0.91	0.13	0.72	0.03
		WA282	1.6 GHz 1 pol	208	0.77	0.03	0.79	0.05	0.70	0.03
	14 March	EA229	1.0 GHz 1 pol	250	0.73	0.05	0.72	0.11	0.74	0.06

Table S3: Arctic Coastal Plain 2023 snow depth means and standard deviations (std) from GPR, excavated depth, and lidar transect profiles. Snow densities used to calculate radar velocity for the GPR snow depths are also given. Airborne lidar survey was conducted on 10 March 2023.

Date	Transect ID	GPR System	Bulk Snow Density (kg m^{-3})	GPR Mean (m)	GPR std (m)	Excavated Mean (m)	Excavated std (m)	Lidar Mean (m)	Lidar std (m)
11 March	A557	1.0 GHz 1 pol	317	0.31	0.05	0.25	0.07	0.44	0.02
	N556	1.0 GHz 1 pol	234	0.31	0.06	0.30	0.05	0.58	0.01
12 March	A500	1.0 GHz 1 pol	256	0.45	0.10	0.41	0.09	0.55	0.07
	N501	1.0 GHz 1 pol	243	0.30	0.03	0.28	0.02	0.39	0.04
	N502	1.0 GHz 1 pol	256	0.18	0.05	0.17	0.05	0.37	0.02
13 March	A522	1.0 GHz 1 pol	255	0.42	0.02	0.43	0.03	0.62	0.02
	A523	1.0 GHz 1 pol	295	0.41	0.07	0.30	0.05	0.45	0.03
	I529	1.0 GHz 1 pol	283	0.26	0.05	0.24	0.06	0.41	0.03
	N524	1.0 GHz 1 pol	311	0.26	0.05	0.28	0.06	0.56	0.02
14 March	N547	1.0 GHz 1 pol	276	0.30	0.02	0.20	0.04	0.42	0.01
	A548	1.0 GHz 1 pol	255	0.32	0.06	0.34	0.05	0.52	0.03
	I549	1.0 GHz 1 pol	359	0.40	0.04	0.39	0.04	0.50	0.05
	N546	1.0 GHz 1 pol	247	0.37	0.10	0.32	0.09	0.56	0.03

Table S4: Upper Kuparuk-Toolik 2023 snow depth means and standard deviations (std) from GPR, excavated depth, and lidar transect profiles. Snow densities used to calculate radar velocity for the GPR snow depths are also given. Airborne lidar survey was conducted on 13 March 2023.

Date	Transect ID	GPR System	Bulk Snow Density (kg m^{-3})	GPR Mean (m)	GPR std (m)	Excavated Mean (m)	Excavated std (m)	Lidar Mean (m)	Lidar std (m)
8 March	N659	1.0 GHz 1 pol	291	0.46	0.02	0.49	0.06	0.61	0.01
9 March	A784	1.0 GHz 2 pol	225	0.45	0.05	0.38	0.05	0.47	0.03
	N787	1.0 GHz 2 pol	238	0.70	0.27	0.80	0.17	0.76	0.11
	N789	1.0 GHz 2 pol	274	0.53	0.10	0.57	0.14	0.57	0.06
	N786	1.0 GHz 1 pol	231	0.72	0.06	0.56	0.10	0.69	0.08
	N788	1.0 GHz 1 pol	250	0.92	0.06	0.64	0.04	0.81	0.05
	N790	1.0 GHz 1 pol	291	0.38	0.07	0.42	0.07	0.42	0.03
10 March	A766	1.0 GHz 2 pol	220	0.46	0.08	0.49	0.07	0.30	0.07
	N762	1.0 GHz 2 pol	225	0.39	0.05	0.41	0.04	0.31	0.06
	N760	1.0 GHz 2 pol	226	0.54	0.09	0.54	0.06	0.39	0.03
	A759	1.0 GHz 1 pol	229	0.42	0.10	0.44	0.09	0.39	0.04
11 March	N730	1.0 GHz 2 pol	214	0.39	0.04	0.47	0.03	0.29	0.08
	A739	1.0 GHz 2 pol	233	0.40	0.03	0.40	0.04	0.26	0.03
15 March	D698	1.0 GHz 2 pol	229	0.39	0.04	0.42	0.08	0.48	0.08

Data Availability

GPR, lidar, and snow pit data are archived with the NSIDC DAAC (Bonnell et al., 2025; Larsen, 2024; Mason et al., 2024; Meehan and Rowland, 2024; Webb, 2024). Creamer's Field SNOTEL data are available at https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=1302. NOAA AK Deadhorse 3 S weather station data are available at https://www.ncei.noaa.gov/access/crn/sensors.htm?stationId=1793.

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