Summertime Particulate Fluxes in the Sagavanirktok River on the North Slope of Alaska

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Background and Objectives

Significant fluvial export of particulate matter from the Arctic rivers has been traditionally associated with wintertime ice breakup at the start of the seasonal spring thaw. Previous research has established that particulate organic carbon (POC) export from Arctic rivers to the coastal ocean reaches its peak in May to early June during the spring freshet (*McClelland et al., 2016*). However, rapid changes in Arctic climate due to climate change may alter these establish patterns of material flux (*Doxaran et al., 2015*). Surface waters were collected from tundra streams and the Sagavanirktok River on the North Slope of Alaska in summers of 2019 & 2022. Samples were analyzed for total suspended solids (TSS), particulate carbon (PC) concentrations, the stable carbon isotopic composition of PC (δ^{13}C-PC). A two end-member mixing model applied to δ^{13}C-PC values was used to estimate POC concentrations. Measured TSS concentrations and estimated POC concentrations were compared with particle size values collected using a laser *in situ* particle size analyzer. Lastly, daily TSS and POC fluxes were estimated based on river and stream discharge. Results show significant variability in TSS and POC concentrations and fluxes related to landscape interactions, precipitation, and discharge during the summertime open water thaw season with some fluxes on the order of those observed during the spring freshet. As the Arctic climate changes TSS and POC fluxes through the Sagavanirktok River and other Arctic Rivers during the summertime open water thaw season may become more variable, especially during periods of extreme precipitation and high river discharge.

Study Area and Methods

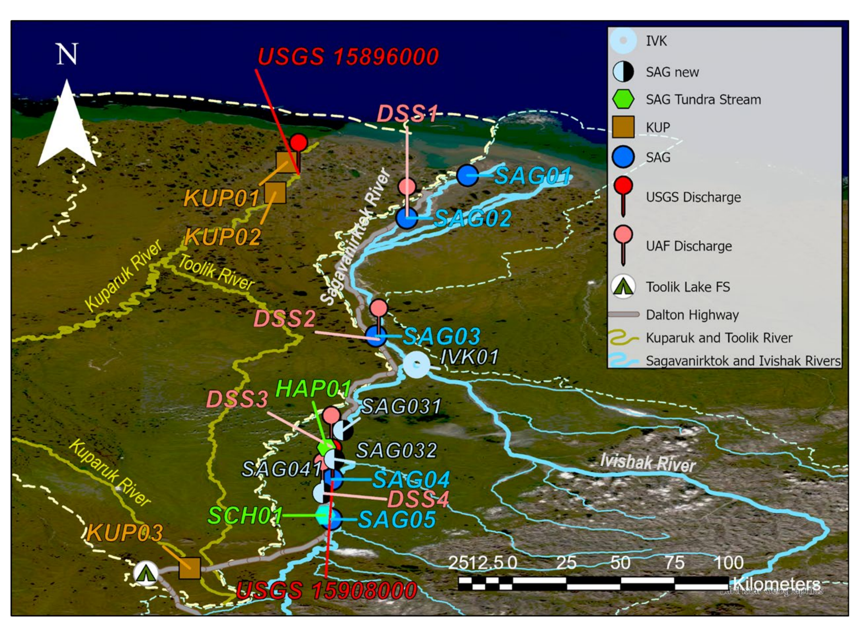

Figure 1. Study area on the North Slope of Alaska showing sites on the Sagavanirktok River and transitional tundra streams that feed the Sagavanirktok River. The location of the Sagavanirktok River USGS discharge gaging station (15908000) and University of Alaska-Alaska Department of Transportation discharge gaging stations (DSS1-4; Toniolo et al. (2019) are shown. This study focuses on the area between site SAG05 and SAG03. Kuparuk River (KUP01-03) sites are not discussed.

Table 1. River and stream discharge measurements and methods used for sampling and analysis of surface waters. Surface waters were bulk-sampled in the field in 500-1000 ml glass or HDPE bottles and filtered in the laboratory with 12 hours of collection (*Smith et al., 2023 (in prep.)*).

Parameter	Method(s)
River/Stream Discharge	RiverRay/RiverPro Acoustic Doppler Current Profiler (ADCP), Sontek Flow Tracker 2 AD Velocimeter (ADV), Flow Meter, gaging stations
Total Suspended Solids (TSS)	Gravimetric measurement; 250-500 ml bulk surface water; vacuum filtration; 0.45 µm nucleopore filter
Particle Spectra (1-500 µm), Particle Concentration, Mean Particle Size	Sequoia Laser In-Situ Scanning Transmissometer (LISST) 200X
Particulate Carbon (PC), Stable Isotope Analysis (δ^{13}C-PC)	CHN Analyzer in-line with Thermo Delta V IRMS; 250-500 ml bulk surface water; matter retained on a 0.7 µm GF/F filter after vacuum filtration

Discharge data and surface water samples were collected from sites on the Sagavanirktok River and transitional tundra streams during the open water season in June – October, 2019 and 2022 (**Fig. 1 & 2**) using methods shown and described in **Table 1**. Particulate organic carbon concentrations were estimated from measured δ^{13}C-PC values using a two-end member mix assuming a δ^{13}C-POC value of -29.5 ‰ representing tundra-sourced organic matter (terrestrial C3 plants) and a δ^{13}C-PIC value of -5 ‰ representing the particulate inorganic carbon (PIC) signature of metamorphic rocks dominating the Brooks Range that separates the North Slope from central Alaska:

$$\delta^{13}\text{C-PC} = (X)\ \delta^{13}\text{C-POC} + (1-X)(\ \delta^{13}\text{C-PIC})$$

Measured PC concentration was multiplied by X to yield an estimated POC concentration in mg/L.

Figure 2. Midshipman 1/C Sarah Blank and the AKMFS Team collecting data on the North Slope of Alaska.

Results

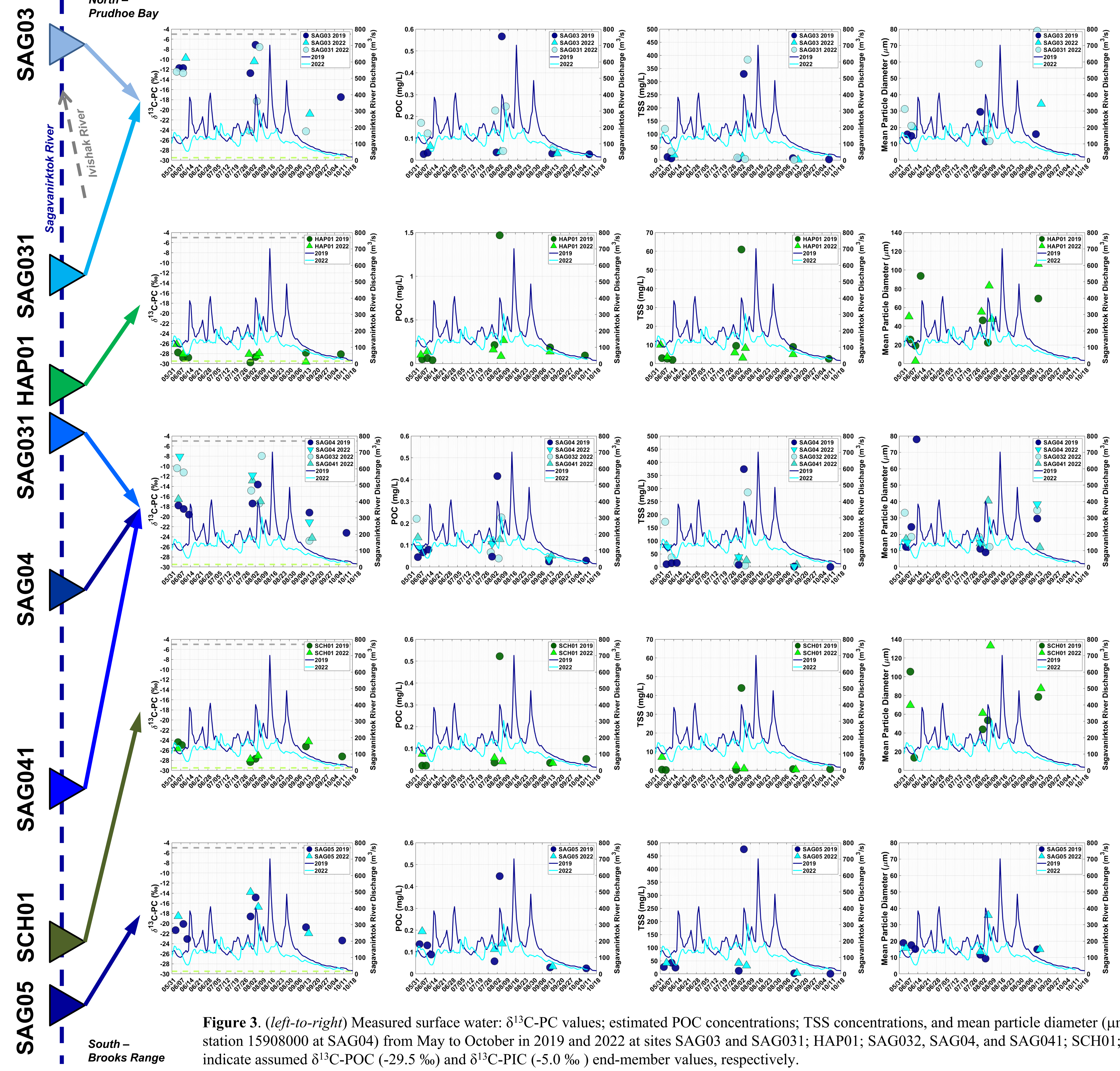

Figure 3. (*left-to-right*) Measured surface water: δ^{13}C-PC values; estimated POC concentrations; TSS concentrations, and mean particle diameter (µm) plotted against Sagavanirktok River discharge (USGS gaging station 15908000 at SAG04) from May to October in 2019 and 2022 at sites SAG03 and SAG031; HAP01; SAG032, SAG04, and SAG041; SCH01; and SAG05. The green and gray dashed lines on the δ^{13}C-PC indicate assumed δ^{13}C-POC (-29.5 ‰) and δ^{13}C-PIC (-5.0 ‰) end-member values, respectively.

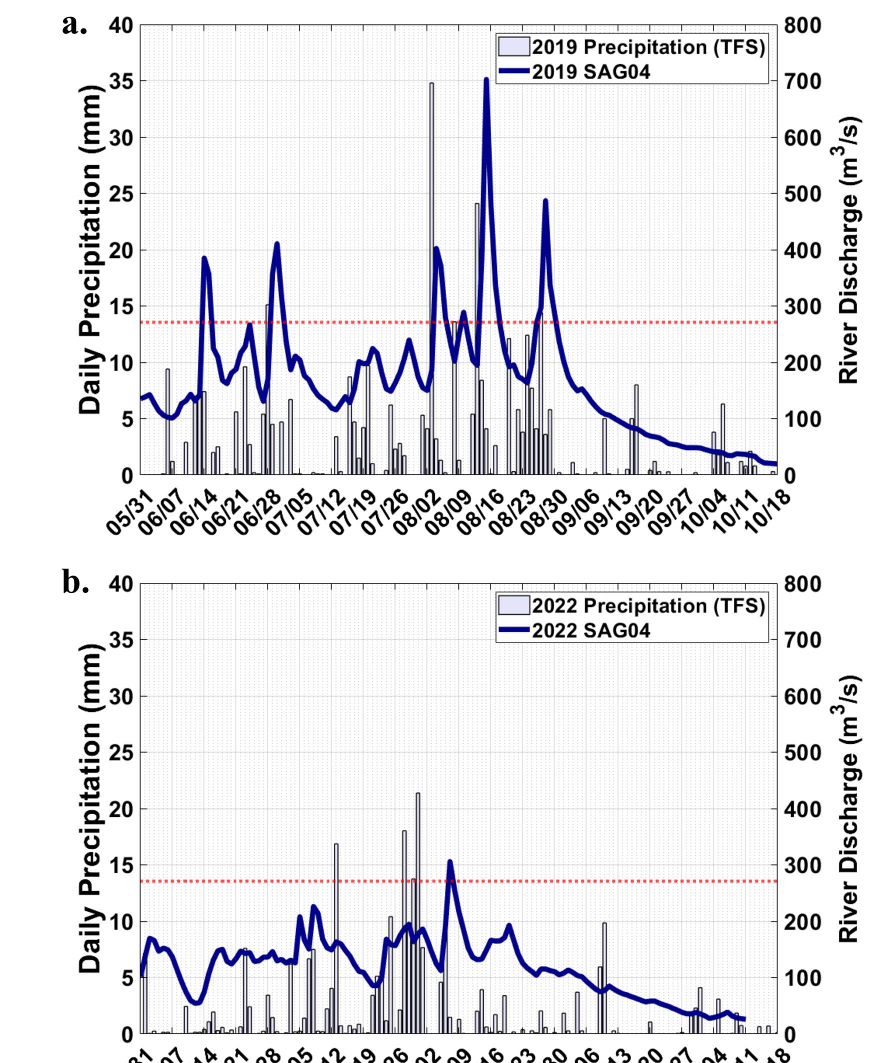

Figure 4. Daily precipitation measured at Toolik Field Station (*EDC, 2023*) and daily-averaged Sagavanirktok River measured at USGS gaging station 15908000 (https://waterdata.usgs.gov/nwis/uv?15908000) from (**a**) June – October 2019 and (**b**) June – October 2022. The horizontal dashed line shows a threshold for an extreme precipitation event. Compiled multi-year daily weather data collected at the Arctic Tundra LTER site at Toolik Lake (*Shafer et al., 2019*) were used to calculate the mean and standard deviation of daily precipitation during the open water season (June – October) over the period from 2008-2018. Extreme precipitation events in the 2019 and 2022 open water thaw seasons was defined as the exceeding the 2008-2018 mean daily precipitation plus 3 standard deviations.

Table 2. Sagavanirktok river discharge in m³/s, POC flux in tons per day, and TSS flux in tons per day at site SAG03 from June through September in 2019 and 2022.

SAG03	Flow (m³/s)	POC (t/day)	TSS (t/day)
06 JUN 2019	236.4	2.08	259.44
09 JUN 2019	292.8	3.19	172.51
31 JUL 2019	402.8	4.00	233.87
04 AUG 2019	930.1	525.85	26434.01
11 SEP 2019	245.0	2.75	174.40
09 OCT 2019	87.1	0.41	25.229
11 JUN 2022	136.9	3.91	243.76
03 AUG 2022	334.0	5.05	395.67
15 SEP 2022	159.2	0.66	25.72

Discussion

Estimates of POC and TSS concentrations in the Sagavanirktok River vary with river discharge during the open water season (**Fig. 3**). The Sagavanirktok is a high-TSS, low-POC river but δ^{13}C-PC values suggest pulsed inputs of POC into the main-stem river, especially during extreme precipitation events followed by high river discharge like in early August 2019 (**Fig. 4**). There is known to be a correlation between river discharge and POC and TSS concentrations in North Slope rivers (*Rember and Trefry, 2004; McClelland et al., 2016*). The suspended load of the Sagavanirktok River is mostly inorganic and is isotopically heavier than that of the tundra streams like HAP01 and SCH01. A wide range of δ^{13}C-PC values, however, can be seen in the Sagavanirktok River by location and by time in the season. This supports the idea that the main-stem Sagavanirktok River receives pulsed inputs of POC during the open water season either through high hydrologic connectivity with tundra streams like HAP01 and SCH01 or through erosion of the tundra along it banks during high discharge events that occur when the seasonal thaw layer is deepest and organic-rich tundra materials are more mobile. Particle diameter was larger at the SCH01 and HAP01 sites as opposed to the SAG sites, but particle diameter was more varied at all SAG sites suggesting multiple inputs of materials. **Table 2** lists calculated POC and TSS fluxes at site SAG03. While SAG03 is not located at the mouth of the Sagavanirktok River, it is located down river of the Ivishak River, the last major tributary that joins the river. Peak POC and TSS flux recorded in early August during the open water season in 2019 and 2022 are on same order as fluxes at or near the freshet (*Rember and Trefry, 2004; McClelland et al., 2016*).

Conclusions

- ***POC and TSS fluxes through the Sagavanirktok River during extreme precipitation and discharge events in the open water season can be significant and rival those that occur during the spring freshet***
- ***If the frequency of mid- to late-summer high-discharge events increases, surveying POC and TSS concentrations throughout the open water season will be necessary to understand material flux into the Arctic Ocean. Changes in regional climate, such as increased precipitation and tundra thawing, are likely to continue to alter seasonal POC and TSS flux to the Arctic Ocean***

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References: Rember and Trefey (2004), *Geochim. et Cosmochim, Acta* 68(3): 477–489; Lamoureux, S. F. and Lafrenière, M. J. (2014), *Environ. Res. Lett.* 9: 045002; McClelland, J. W. et al. (2014), McClelland et al., (2016), *Water Resour. Res.* 50: 1823–1839; Doxaran. D. et al. (2015), *Biogeosciences* 12: 3551–3565; Environmental Data Center (EDC) Team (2023), Toolik Field Station (https://toolik.alaska.edu/edc/monitoring/ abiotic/met-data-query.php); Lafrenière, M. J. and Lamoureux, S. F. (2019), *Earth-Science Reviews* 191: 212-223; Shaver, G. (2019), Environmental Data Initiative; Toniolo, H. (2019), University of Alaska Fairbanks, Water and Environmental Research Center (http://ine.uaf.edu/werc/research Fairbanks).

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