

Background

Regional changes in climate are impacting North Slope Alaska watershed landscapes through enhanced permafrost thaw and degradation and alteration of hydrologic processes. Results of the biogeochemical analyses of river and stream samples collected from June – October 2019 and mixing estimates show that during high discharge conditions in the open water season, integrated material inputs from tundra streams can significantly alter surface water biogeochemistry in and constituent fluxes through rivers that discharge into the Arctic Ocean. Variability can be used as an indicator of material contributions from changing tundra landscapes.

Study Area and Methods

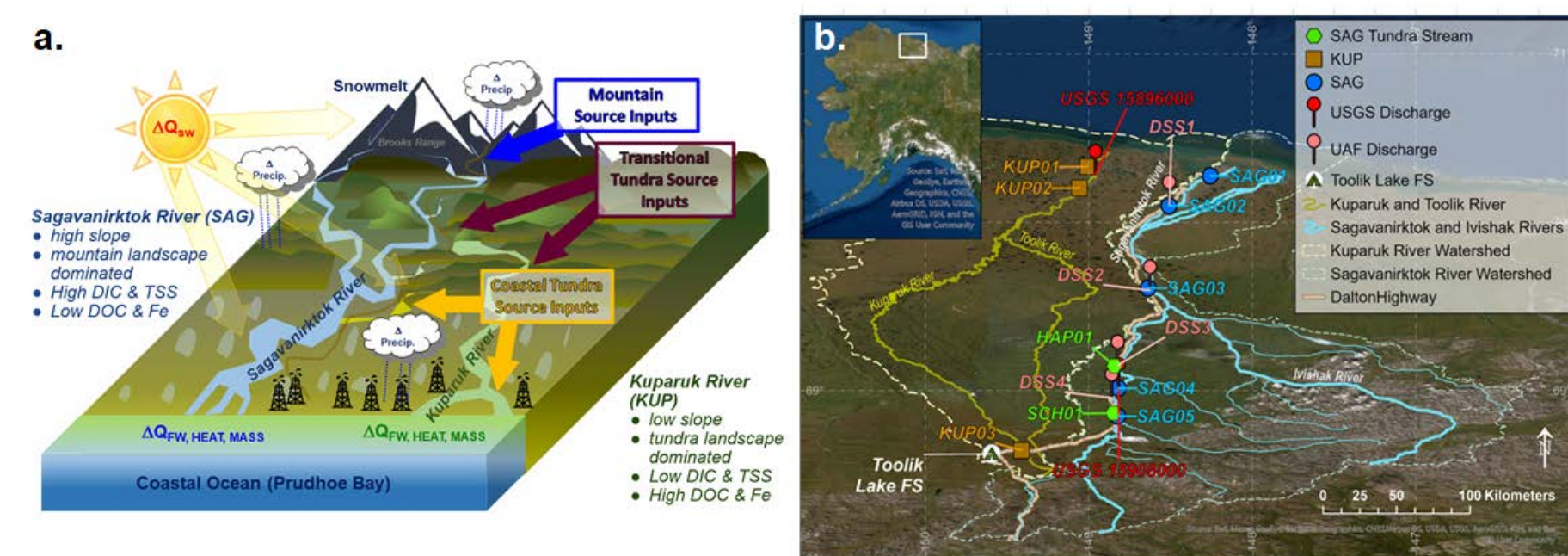


Figure 1. (a) The AKMFS concept and (b) Study area on the North Slope of Alaska with sampling sites on the Sagavanirktok (SAG01-05) and Kuparuk Rivers (KUP01-03) and transitional tundra streams that feed the Sagavanirktok River: Schuyler Creek (SCH01) and Happy Valley Creek (HAP01). Also: the Dalton Highway (AK pipeline “haul” road); Toolik Lake Field Station (FS), and USGS discharge gaging stations (15896000: Kuparuk River and 15908000: Sagavanirktok River) and University of Alaska (UAF)-Alaska Department of Transportation (ADOT) discharge gaging stations (DSS1-4; *Toniolo et al. (2019)*).

The Alaska North Slope Material Flux Study (AKMFS) is a 3-year field research study to investigate how seasonal-to-interannual variability in landscape-specific source contributions change surface water chemistry in the Sagavanirktok and Kuparuk Rivers on the North Slope of Alaska and how material and heat fluxes through these rivers change as they flow from the Brooks Range to the Beaufort Sea (**Fig. 1a**). River and stream discharge data and surface water samples were collected from 3 sites on the Kuparuk River (KUP01-03), 5 sites on the Sagavanirktok River (SAG01-05), and 2 transitional tundra streams (Schuyler Creek (SCH01) and Happy Valley Creek (HAP01)) during four open water season periods: 03-13 June, 31 July – 07 August, 10-12 September, and 08-11 October 2019 (**Fig. 1b**).

Surface Water Parameter(s)	Analytical Method(s)
River/Stream Discharge	RiverRay Acoustic Doppler Current Profiler (ADCP), Sontek Flow Tracker 2 Acoustic Doppler Velocimeter (ADV), Flow Meter, USGS & UAF gaging stations
Total Suspended Solids (TSS)	Gravimetric measurement
Major Ions and Nutrients	Dionex ICS-3000 Ion Chromatography System (ICS)
Minor and Trace Elements	Thermo-Fisher Element XR Double-focusing Inductively Coupled Plasma Mass Spectrometer (ICPMS)
Dissolved Inorganic & Organic Carbon (DIC & DOC) and Stable Carbon Isotope Analysis ($\delta^{13}C$)	OI Analytical 1030D Total Organic Carbon Analyzer in-line with Thermo Delta V Isotope Ratio Mass Spectrometer (IRMS)
Particulate Organic Carbon (POC) and Stable Carbon Isotope Analysis ($\delta^{13}C$, $\delta^{15}N$)	CHN Analyzer in-line with Thermo Delta V IRMS

Figure 2. Surface water sample and discharge data collection and analytical methods used for surface water sample analysis.

Samples were collected from rivers and streams by filtering surface water from the upper 10 cm of main channel flow into pre-cleaned collection bottles. Sample processing was performed at Toolik Field Station and samples were stored cold prior to laboratory analysis (**Fig. 2**). For SCH01 & KUP01, stream discharge data was collected using a RDI Teledyne RiverRay Acoustic Doppler Current Profiler (ADCP) or a Sontek FlowTracker2 Acoustic Doppler Velocimeter (ADV).

References: McClelland, J. W. et al. (2014), *Water Resour. Res.*, 50, 1823–1839; Rember, R. D. and R. H. Trefry (2004), *Geochim. Cosmochim. Acta*, 68(3), 477–489; Shogren, A. J. et al., (2019), *Sci Rep* 9, 12894; Toniolo, H. (2019), University of Alaska Fairbanks, Water and Environmental Research Center (<http://ine.uaf.edu/werc/research/Fairbanks>).

River Fluxes and Tundra Stream Biogeochemistry

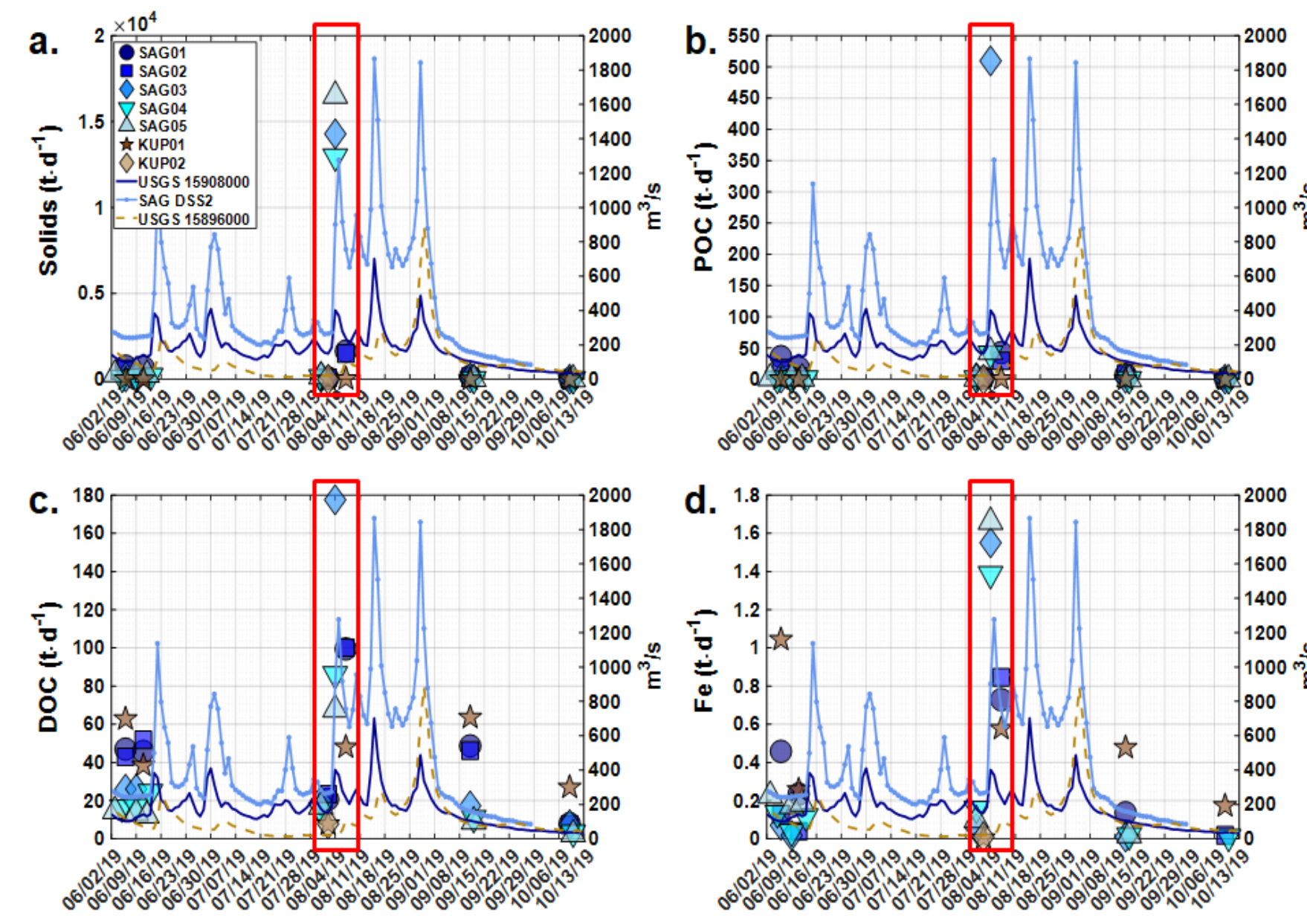


Figure 3. (a) Total Solids flux ($t \cdot d^{-1}$); (b) POC flux ($t \cdot d^{-1}$); (c) DOC flux ($t \cdot d^{-1}$); and (d) Dissolved Fe flux ($t \cdot d^{-1}$) in the main-stem Sagavanirktok River (SAG01-05) and Kuparuk River (KUP01-03) from June – October 2019. The secondary y-axis shows daily averaged river discharge measured at USGS gaging station 15908000 and UAF station DSS2 for the Sagavanirktok River (*Toniolo et al., 2019*) and USGS gaging station 15896000 for the Kuparuk River. The red rectangle brackets a Sagavanirktok River high discharge event on 04 August 2019.

Under normal discharge conditions in the open water season from the early summer to fall, the high slope, mountain landscape-dominated Sagavanirktok River has higher TSS (**Fig. 3a**) and POC (**Fig. 3b**) fluxes and lower DOC (**Fig. 3c**) and dissolved iron (**Fig. 3d**) fluxes than the lower slope, tundra landscape-dominated Kuparuk River (*Rember and Trefry, 2004; McClelland et al., 2014*). During a high discharge event on 04 August 2019 DOC and dissolved Fe fluxes in the Sagavanirktok River increased sharply and were much greater than those in the Kuparuk. The increased DOC and dissolved Fe fluxes through the main-stem Sagavanirktok River on 04 August 2019 were coincident with a higher discharge of surface waters with TSS (**Fig. 4a**) and POC (**Fig. 4b**) concentrations similar to those in the main-stem Sagavanirktok River (SAG03-05) and significantly higher DOC (**Fig. 4c**) & dissolved Fe (**Fig. 4d**) concentrations into the river from Schuyler Creek (SCH01) and Happy Valley Creek (HAP01).

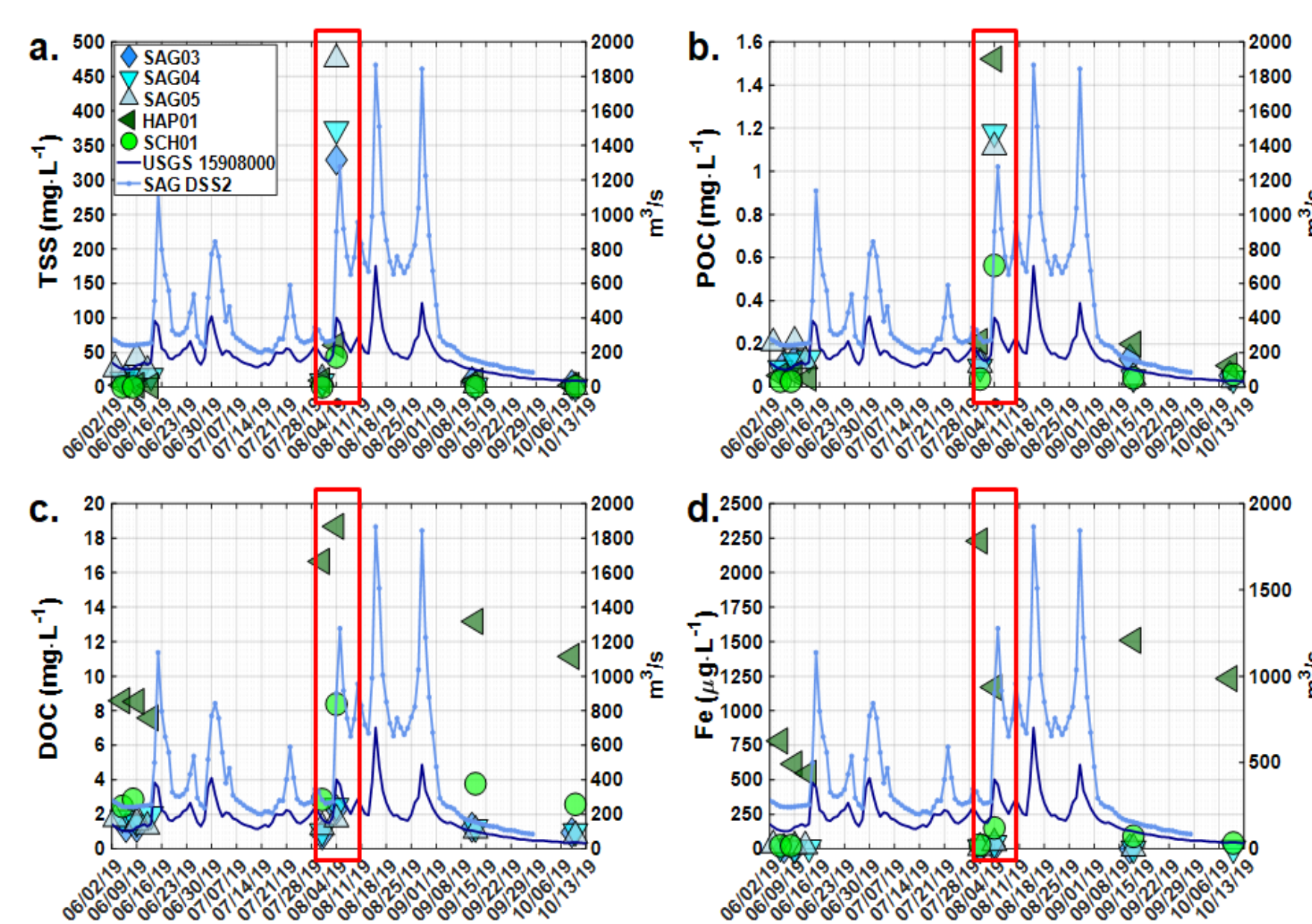


Figure 4. (a) TSS concentrations ($mg \cdot L^{-1}$); (b) POC concentrations ($\mu g \cdot L^{-1}$); (c) DOC concentrations ($mg \cdot L^{-1}$); and (d) Dissolved Fe concentrations ($\mu g \cdot L^{-1}$) at Schuyler Creek (SCH01) and Happy Valley Creek (HAP01) and in the Sagavanirktok River (SAG03-05) from June – October 2019. The secondary y-axis shows daily averaged river discharge measured at USGS gaging station 15908000 and UAF station DSS2 for the Sagavanirktok River (*Toniolo et al., 2019*). The red rectangle brackets the high discharge event on 04 August 2019.

Sagavanirktok River and Transitional Tundra Stream Mixing

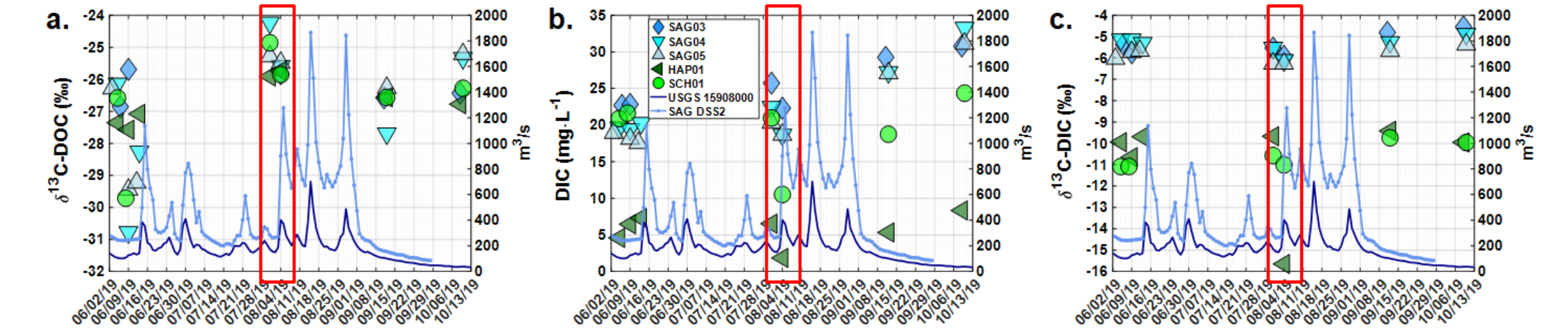


Figure 5. Measured (a) $\delta^{13}C$ -DOC (‰) values; (b) DIC concentrations ($mg \cdot L^{-1}$), and; (c) $\delta^{13}C$ -DIC (‰) values at Schuyler Creek (SCH01) and Happy Valley Creek and main-stem Sagavanirktok River sites (SAG03-05) from June – October 2019. The secondary y-axis shows daily averaged Sagavanirktok River discharge measured at USGS gaging station 15908000 and UAF station DSS2 (*Toniolo et al., 2019*). The red rectangle brackets a Sagavanirktok River high discharge event on 04 August 2019.

Schuyler Creek and Happy Valley Creek both drain significant sub-watershed areas dominated by transitional tundra landscape which can integrate dissolved and colloidal Fe and leached soil organic matter (OM) from the surrounding active tundra soil matrix. Shifts in $\delta^{13}C$ -DOC values, DIC concentrations, and $\delta^{13}C$ -DIC values at SAG03-05 on 04 August 2019 are consistent with an addition of surface waters with $\delta^{13}C$ -DOC values, DIC concentrations, and $\delta^{13}C$ -DIC values similar to those measured at SCH01 and HAP01 (**Fig. 5**).

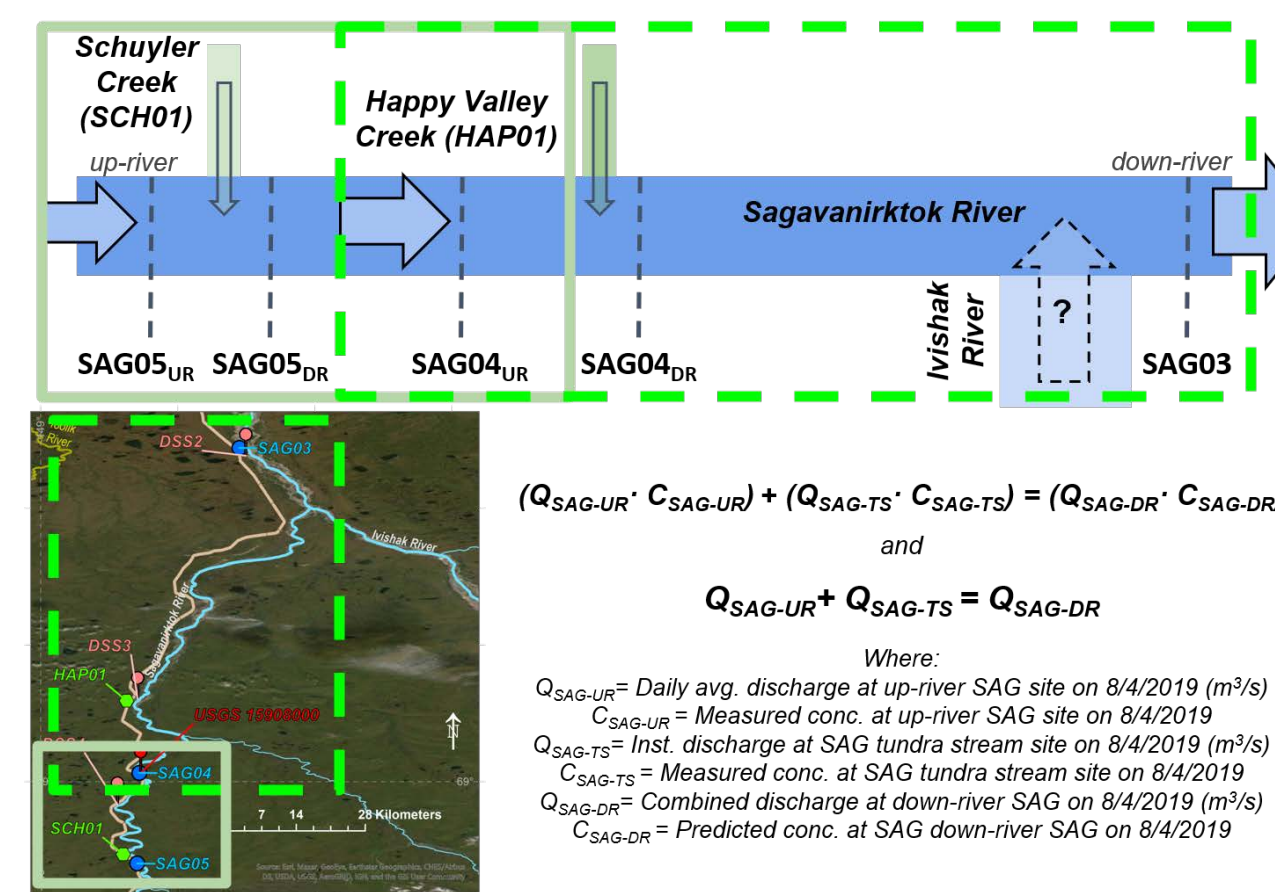


Figure 6. Mixing model for main-stem Sagavanirktok River (SAG03-05) assuming 2-component, steady-state, instantaneous, conservative mixing with transitional tundra streams SCH01 and HAP01.

A simple mixing model (**Fig. 6**) was used to estimate whether integrated DOC and dissolved Fe inputs from streams like Schuyler Creek and Happy Valley Creek can significantly alter surface water biogeochemistry in and constituent fluxes through the main-stem Sagavanirktok River during high discharge events in the open water season. This model approach provides only a general, first-order estimate since DOC and dissolved Fe do not behave conservatively, there are multiple, additional potential sources for DOC and dissolved Fe inputs and the system, as modeled, may not be in steady-state. Modeled results (**Table 1**) of an instantaneous mix of surface waters with concentrations measured at site SAG05 with those measured at SCH01 on 04 August 2019 when compared to measured values at SAG04 suggest a potential input of tundra-sourced DOC from diffuse or discrete sources like SCH01 coincident with higher discharge and hydraulic connectivity (*Shogren et al., 2019*). Modeled results (**Table 2**) of an instantaneous mix of surface waters with concentrations measured at site SAG04 with those measured at HAP01 on 04 August 2019 are less conclusive when compared to measured down-river values at SAG03 but still consistent with a significant input of tundra-sourced DOC. The Ivishak River, a major mountain-sourced tributary of the Sagavanirktok River, joins the main-stem Sagavanirktok just up-river from site SAG03 and can nearly double the discharge. Predicted constituent concentrations at SAG04 and measured values at SAG03 can be used to estimate surface water constituent concentrations in the Ivishak River on 04 August 2019. Results are consistent with what could be expected for a high slope, mountain-dominated tributary of the Sagavanirktok River.

Conclusions

During high discharge conditions in the open water season, integrated material inputs from smaller tundra streams like Happy Valley and Schuyler Creek can significantly alter surface water biogeochemistry in and constituent fluxes through the Sagavanirktok River. Such variability can be used as an indicator of material contributions from changing tundra landscapes.

Future Work (2021-2022)

- Target sampling before, during, and after high river discharge and better bracket areas where tundra streams join river main-stems
- Collect samples and data from the Ivishak River
- Use additional tracers to identify tundra streams
- Investigate interaction of precipitation, soil saturation, hydraulic residence time, and biogeochemical processes within the soil active layer in determining dissolved carbon and inorganic constituent inputs from sub-watersheds to larger Arctic rivers

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