Introduction

This supplementary information provides the procedures for sample collection and analysis for rivers east of the Sagavanirktok along the North Slope of Alaska (Text S1), details on watershed delineation and watershed slope and soil organic carbon content estimation (Text S2), regression coefficients for relationships between watershed slope and concentrations of DOC, DON, and NO$_3^-$ (Table S1), and the following sample data used to generate Figures 1-3 in the main text as an excel file: sampling location, season, catchment/watershed name, latitude, longitude, date or timeframe of sample collection, watershed area, watershed slope, DOC, DON, DOC:DON, NO$_3^-$, and SOCC concentrations.
Procedures for sample collection and analysis for the eastern North Slope rivers are fully described here. Water samples from the Kavik, Canning, Hulahula, Okilplak, Jago, Aichilik, Kongakut, and Turner rivers were collected from a wide range of catchments, including sampling sites in the headwaters of the Brooks Mountain Range, along river main stems, in low-lying tundra tributaries, and at downstream locations near river deltas. Sampling was largely performed by citizen scientists and researchers from the Arctic National Wildlife Refuge (a branch of the U.S. Fish and Wildlife Service), the United States Geological Survey, and the University of Alaska, Fairbanks. This necessitated development of a lightweight, portable, easily operable sampling procedure. In the field, surface water samples for dissolved constituents were collected using acid washed pre-leached 140 mL polypropylene syringes. Samples were then immediately filtered using 33 mm diameter 0.45 µm polyethersulfone membrane syringe tip filters into acid washed pre-leached polycarbonate bottles. Following filtration, samples were acidified for preservation (final pH < 2) using ultra-pure hydrochloric acid. Samples were analyzed for DOC and total dissolved nitrogen (TDN) at the University of Texas Marine Science Institute (UTMSI) on a Shimadzu TOC/TN analyzer. NO$_3^-$ was also measured from collected samples at UTMSI using a cadmium reduction method modified for a BioTek µQuant microplate spectrophotometer (Jones, 1984). Ammonium (NH$_4^+$) data were not measured for most collection sites; therefore, DON was calculated from TDN minus NO$_3^-$ alone. Although missing NH$_4^+$ values add some uncertainty to estimates of DON concentrations, rivers draining Alaska’s North Slope typically have low NH$_4^+$ concentrations and uncertainties introduced by not accounting for the contribution of NH$_4^+$ are minor (Khosh et al., 2017; Townsend-Small et al 2011).

Watershed areas upstream of sampling locations on the six largest rivers (Ob’, Yenisey, Lena, Kolyma, Yukon, and Mackenzie) were delineated with ESRI ArcGIS version 10.2 software (North Pole Lambert Equal Area Projection) using a 1 km digital elevation model (Hydro 1K DEM). Exact coordinates of sampling locations were used for the Yukon, Mackenzie, Ob’, Yenisey, and Kolyma delineations. The Lena was delineated from a point 40 km upstream of the sampling location due to ambiguities in DEM resolution for this site. Watershed areas upstream of the Pechora at Ust-Tsilma, Mezen at Malonisogorskoye, Severnaya Dvina at Ust-Pinega, Olenek 7.5 km downstream from Buur’s offing, and Yana at Ubileynaya were delineated using the same approach. Watershed areas for Alaska’s North Slope rivers were delineated using the same software, but with a 40 m DEM (USGS National Elevation Dataset). Watershed slope (%) was estimated from each delineated area using Google Earth Engine for the larger pan-Arctic rivers and ArcGIS for the smaller North Slope rivers. Although these software packages are different, their areal extrapolation methods to calculate watershed slope are similar. Refer to Burrough & McDonell (1998) for more details on how watershed slope is calculated. Watershed area and slope calculations for the Ob’ excluded a large endorheic basin (an internal drainage area with no connection to the rest of the river network) of ~245,277 km$^2$ that lies within the southern region of the watershed. Likewise, a smaller endorheic zone (7,693 km$^2$) was excluded from the southern region of the Yenisey watershed. Average soil organic carbon content was calculated within GIS-delineated catchment boundaries for each sampling location using the soil organic matter dataset (100 cm) from the Northern Circumpolar Soil Carbon Database (NCSCD) (Hugelius et al., 2013). The highest spatial resolution dataset (0.012°) was used for all watersheds, except for the Yenisey where a 0.05° resolution dataset covered a greater areal extent of the watershed. The Ob’ watershed is not included because a large portion of the watershed was missing in the NCSCD soil organic carbon dataset.
Table S1. Regression coefficients for relationships between watershed slope values (%) and fluvial constituent concentrations (mg L\(^{-1}\)). Results are provided for analyses using all available data as well as balanced datasets (i.e., equal spring and summer representation of data). 95% confidence intervals (CI) are reported below coefficient values. Values and CIs in bold indicate a significant difference (\(\alpha\) set at 0.05) between spring and summer coefficients from an analysis of covariance (ANCOVA) test. For DOC and DON, the regression models take the form of \(y = \ln(x) + b\). The NO\(_3^{-}\) models take the form of \(y = mx + b\).

|                | DOC                      |           |           | DON                      |           |           | NO\(_3^{-}\) |           |
|----------------|--------------------------|-----------|-----------|--------------------------|-----------|-----------|-------------|-----------|
|                | Intercept                | Slope     | R\(^2\)   | n                        | Intercept | Slope     | R\(^2\)     | n          |
| Unbalanced     |                          |           |           |                          |           |           |             |           |
| Spring Value   | 15.1                     | -3.64     | 0.75      | 35                       | 0.421     | -0.091    | 0.70        | 33         |
| CI             | 13.9 to 16.3             | -4.01 to -3.27 |           | 0.387 to 0.455    | -0.101 to -0.080 |     | 0.033 to 0.066 | -0.0004 to 0.0006 |   | 0.0001 | 0.002 | 33 |
| Summer Value   | 12.3                     | -2.94     | 0.62      | 52                       | 0.503     | -0.120    | 0.65        | 44         |
| CI             | 11.3 to 13.4             | -3.27 to -2.61 |           | 0.460 to 0.545    | -0.134 to -0.106 |     | -0.017 to 0.035 | 0.0014 to 0.0029 |   | 0.0022 | 0.16 | 44 |
| Balanced       |                          |           |           |                          |           |           |             |           |
| Spring Value   | 14.7                     | -3.39     | 0.67      | 22                       | 0.395     | -0.081    | 0.67        | 20         |
| CI             | 13.1 to 16.2             | -3.92 to -2.86 |           | 0.358 to 0.433    | -0.095 to -0.068 |     | 0.032 to 0.070 | -0.0003 to 0.0010 |   | 0.0004 | 0.017 | 20 |
| Summer Value   | 10.8                     | -2.54     | 0.70      | 22                       | 0.365     | -0.082    | 0.73        | 20         |
| CI             | 9.7 to 11.8              | -3.63 to -1.45 |           | 0.331 to 0.398    | -0.093 to -0.070 |     | -0.034 to 0.038 | 0.0031 to 0.0056 |   | 0.0044 | 0.41 | 20 |

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