Uncertainties in estimating export fluxes of carbon species from high latitude rivers

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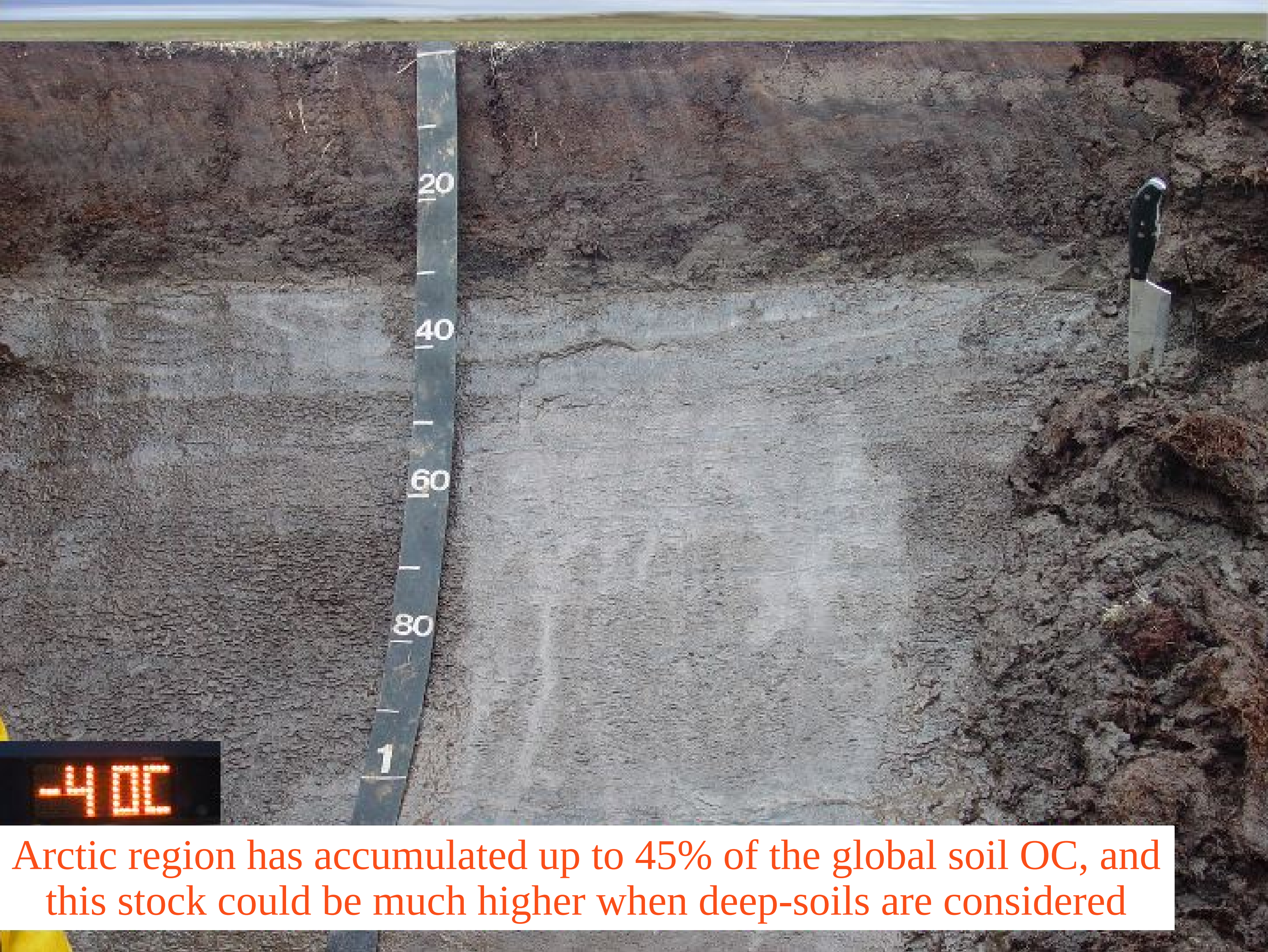
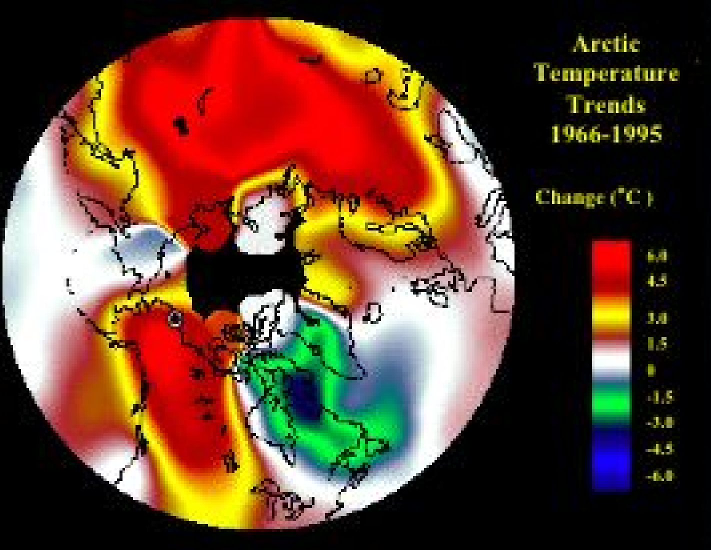


Arctic region has accumulated up to 45% of the global soil OC, and this stock could be much higher when deep-soils are considered



Amplified warming in Arctic: evidence from modeling and sea ice retreat

Impact and biogeochemical consequence of global warming in the arctic region

Mass transfer of organic carbon across the land/ocean interface

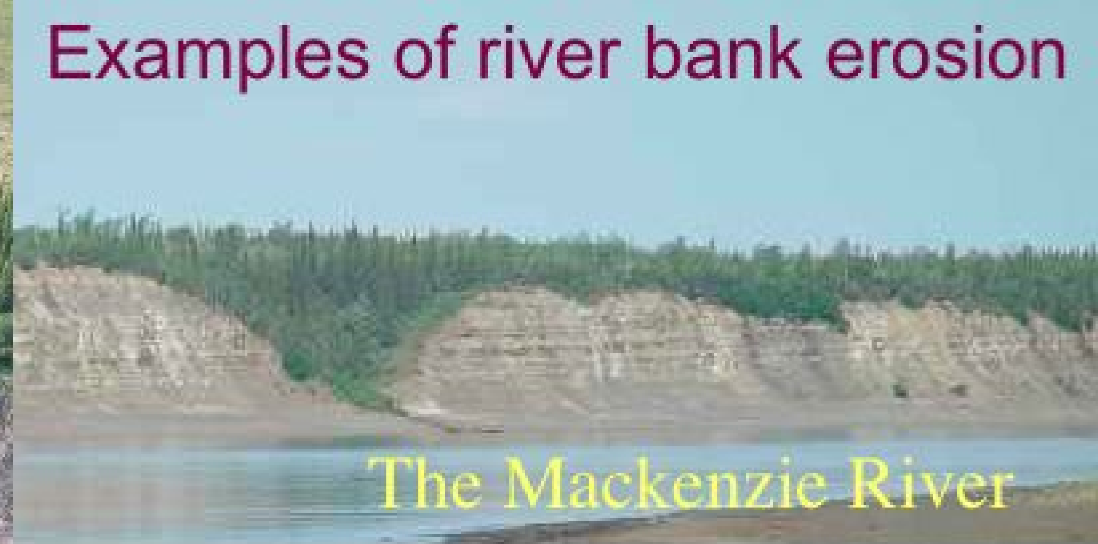
Biogeochemical consequence of global warming in the north

Interactions of soil organic carbon with aquatic environments




Degradation of permafrost and peatlands in the arctic region

Examples of river bank erosion



Riverine export of organic carbon to the Arctic Ocean

Seemingly contradictory observations

- Amplified warming in the north (ACIA, 2005);
- Thawing of permafrost in the arctic region (Jorgenson et al., 2006);
- Old organic C (up to 15,000 yr BP) in permafrost and arctic estuarine sediments (Ping et al., 1997; Guo et al., 2004; Goni et al., 2005; Drenzek et al. 2007);
- Increasing arctic river discharge (Peterson et al. 2002; Wu et al., 2005); Increasing DOC release from peatlands and permafrost (Frey & Smith, 2005; Evans et al 2006);
- Contemporary DOC in Arctic rivers (Benner et al. 2004; Guo & Macdonald, 2006; Neff et al. 2006; Raymond et al., 2007);
- What is the connection between DOC and climate change?

How will warming alter riverine DOC export?

Flux increase:

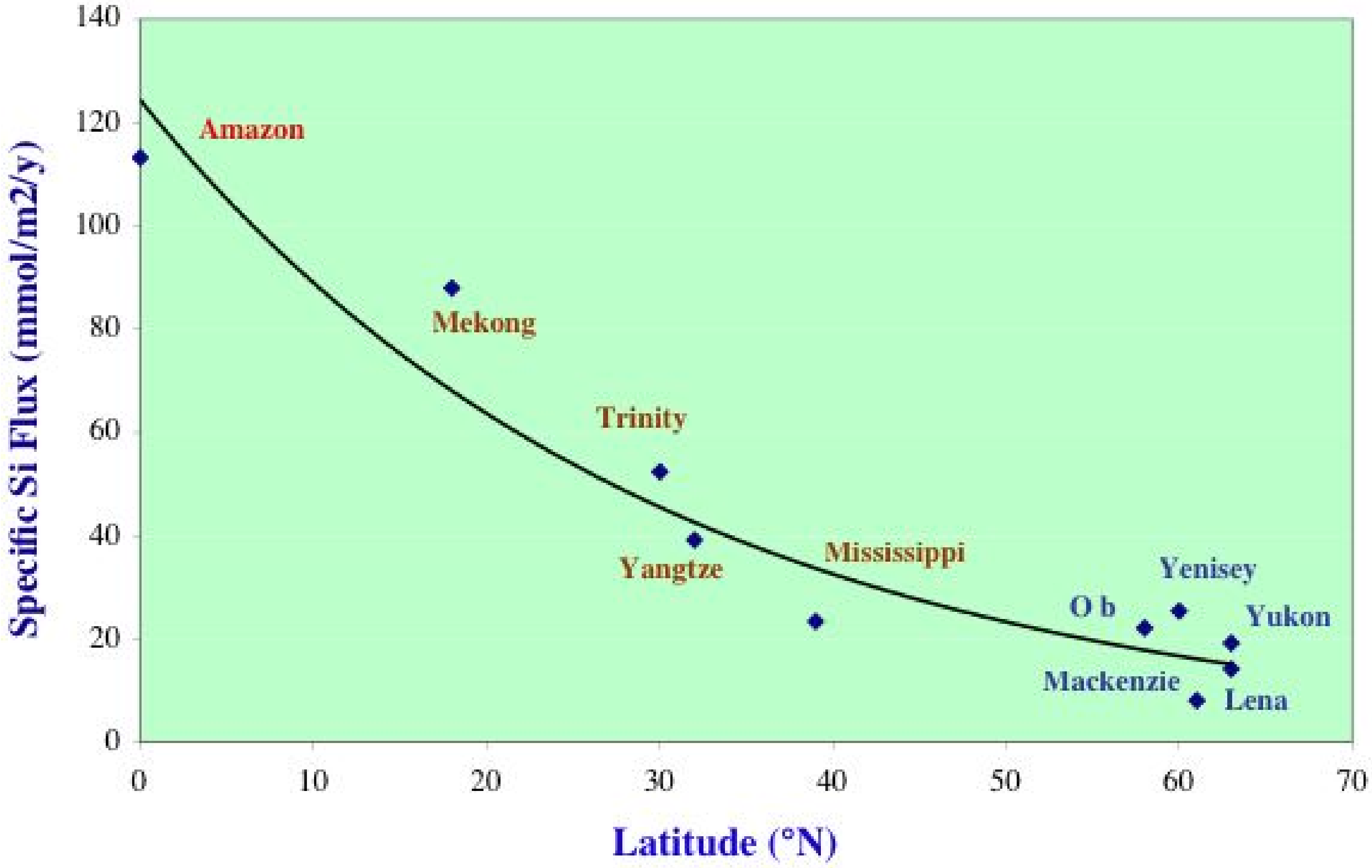
- Freeman et al. (2004, Nature): T, CO_2, PP;
- Frey and Smith (2005; GRL): peatland/permafrost;
- Evans et al. (2006, Global Change Biol): decrease in sulphur deposition and thus surface water acidity.

Flux decrease:

- Striegl et al (2005, GRL): flow path, microbial decomposition;

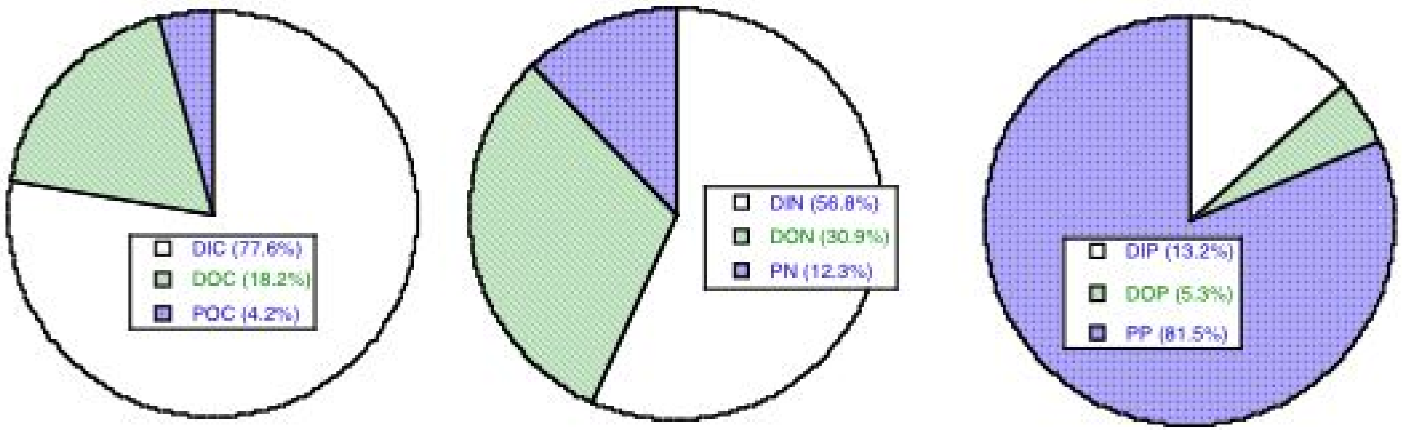
Quantitative flux estimation is important to a better understanding of carbon dynamics across the land/ocean interface

The decrease of specific dissolved silicate flux with increasing latitude implies that a warm climate would likely increase material export fluxes (Guo et al., 2004, GBC)

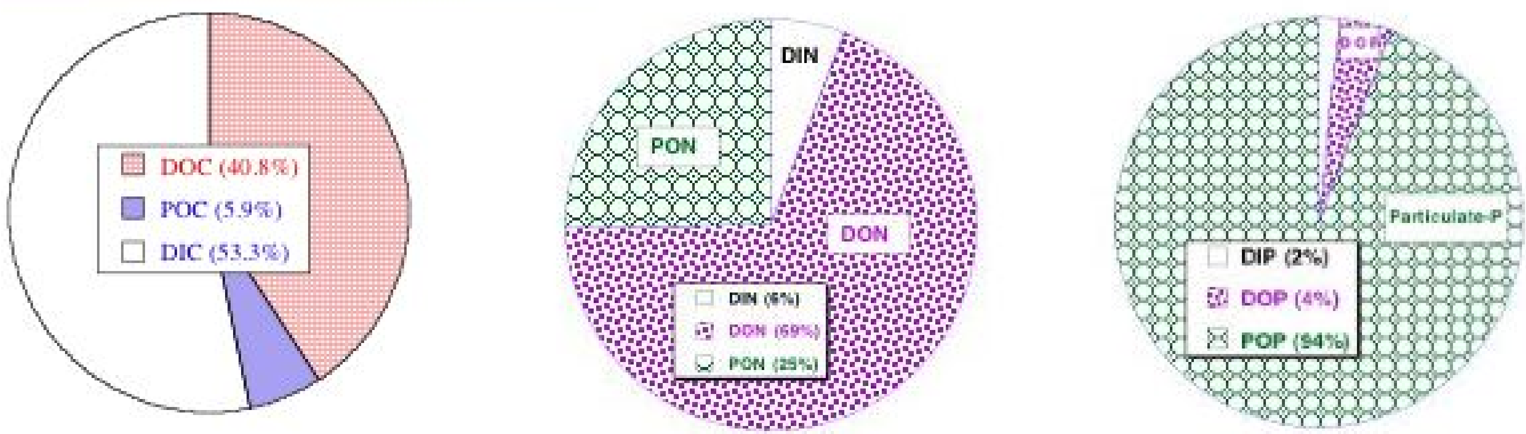


Variations of riverine dissolved silica flux with latitude

Discontinuous permafrost watersheds: high DIC, DIN, and DIP



Comparison of C, N, and P partitioning between organic and inorganic phases

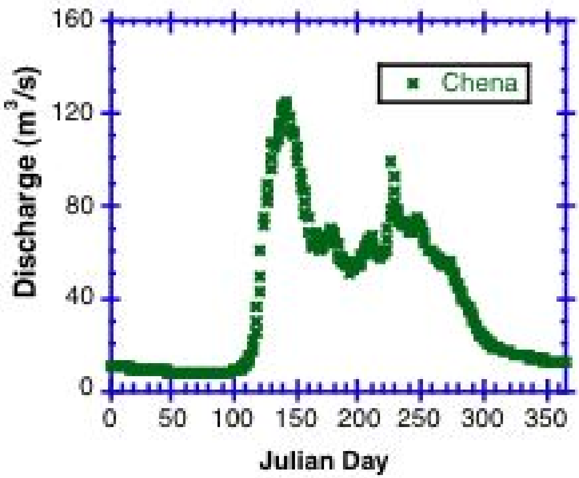


Continuous permafrost:: high DOC, DON and DOP

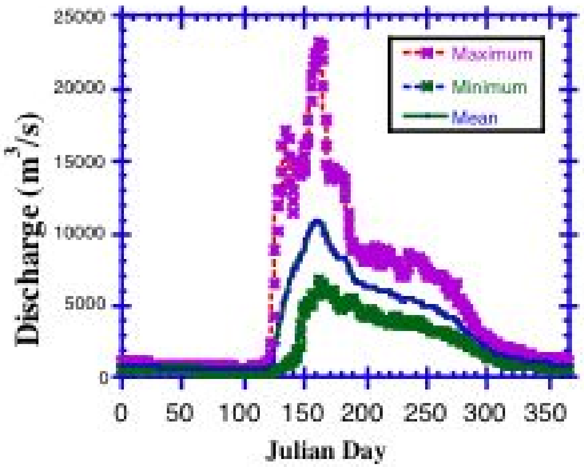
Factors contributing to uncertainties

- Disproportionate distribution in daily stream flow and DOC/POC/DIC concentrations;
- Strong seasonality in solute concentrations;
- Large annual variability in freshwater discharge;
- Variable in water and carbon sources;

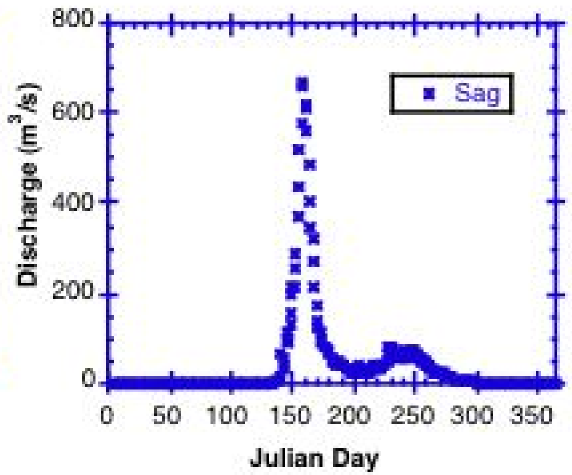
Characteristic of daily stream flow in high latitude rivers



Chena River

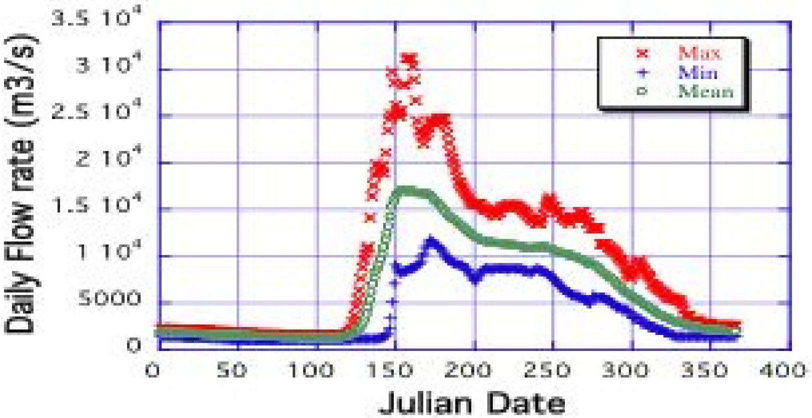


Upper Yukon



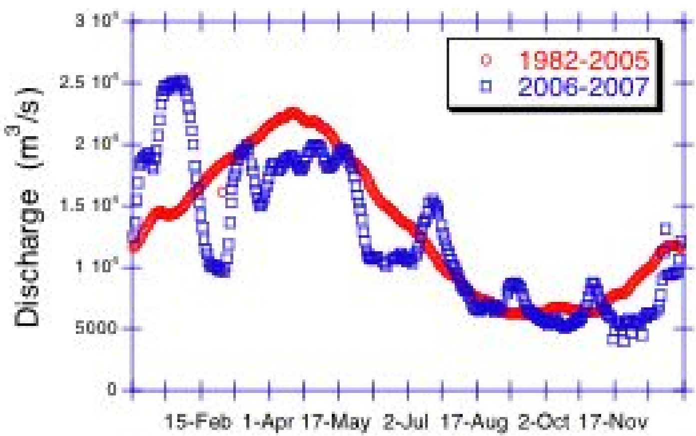
Sagavanirkto River

Different daily flow pattern and large annual variability

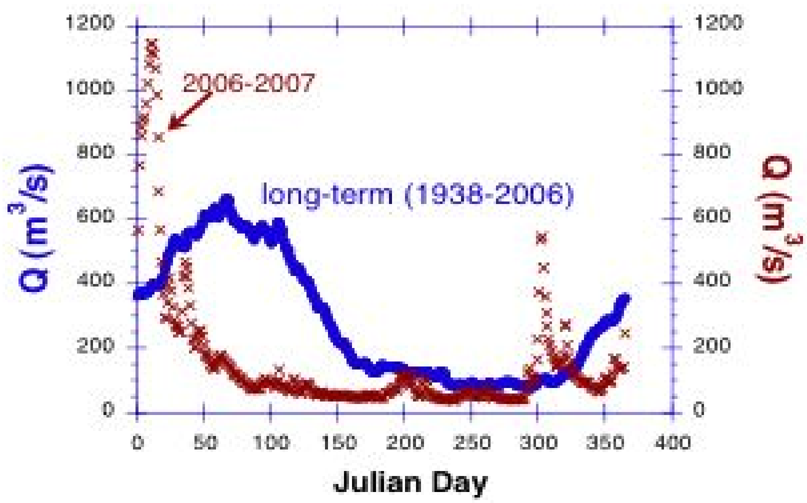


Yukon River, Pilot Station

Mackenzie River



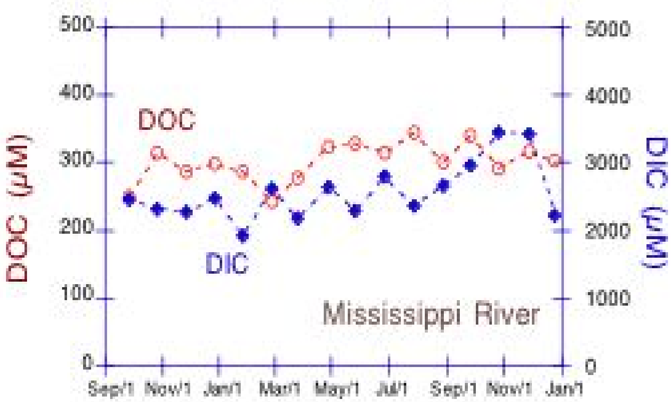
Mississippi River

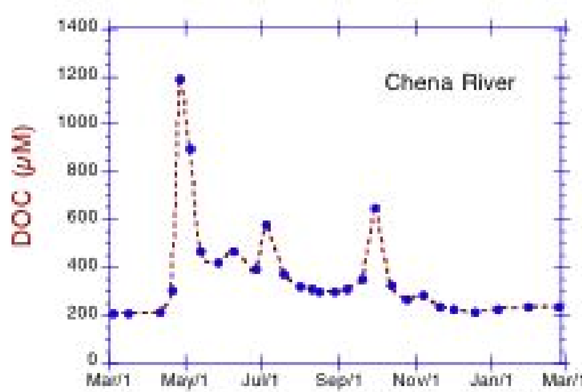


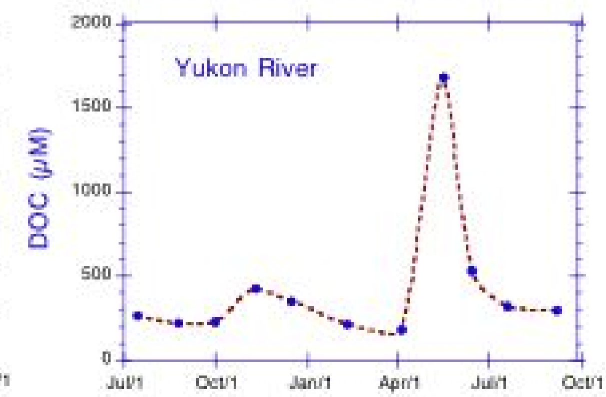
Pearl River, MS

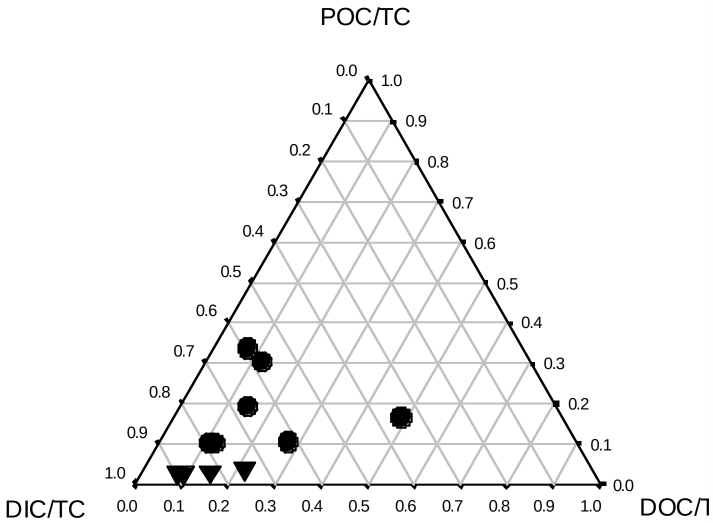
Large DOC concentration range with strong seasonality

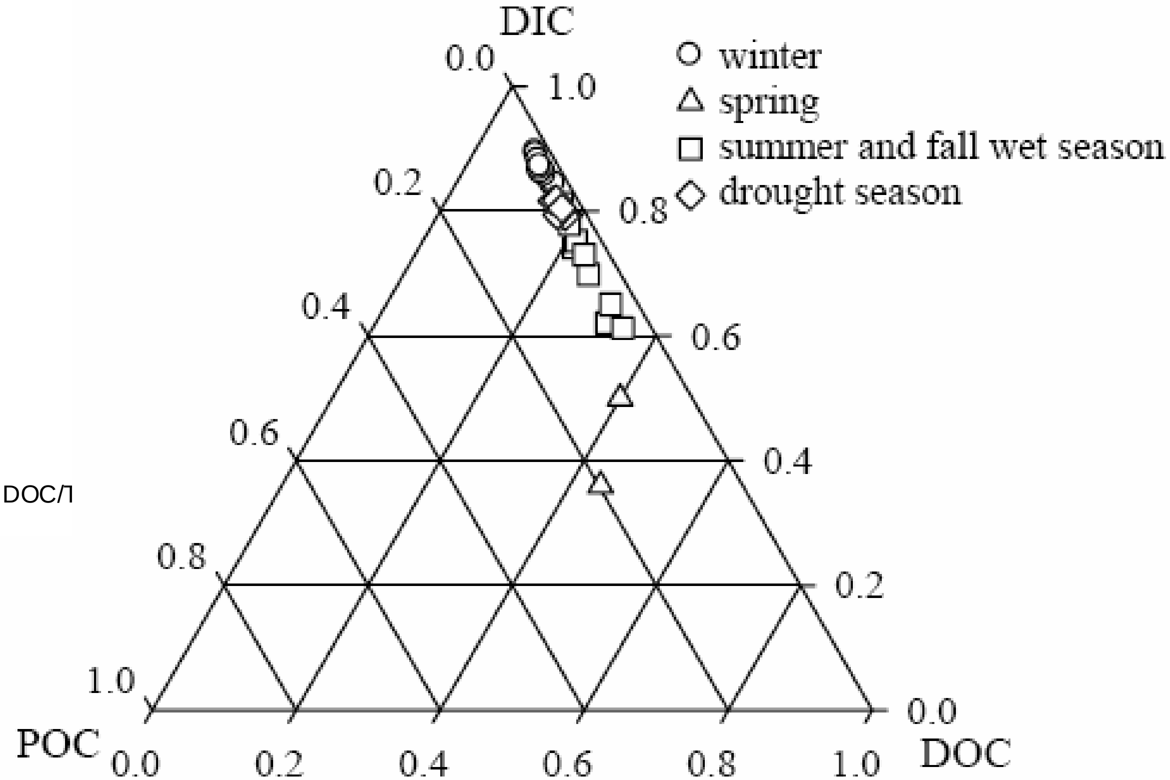
	Yukon	Chena (Alaska)	Pearl (MS)	Mississippi	Trinity (TX)
DOC (µM)	428±429	374±222	397±138	302±29	464±59
Reference	Guo et al. (submitted)	Cai et al. (2008) L&O	Duan et al. (2007)	Unpubl.Data	Warnken (2001)







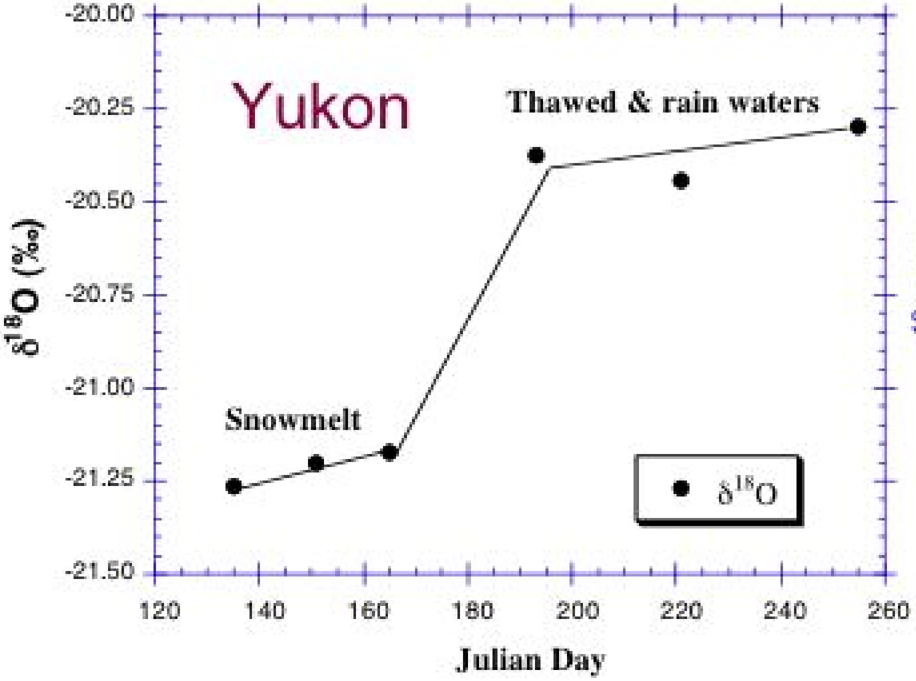


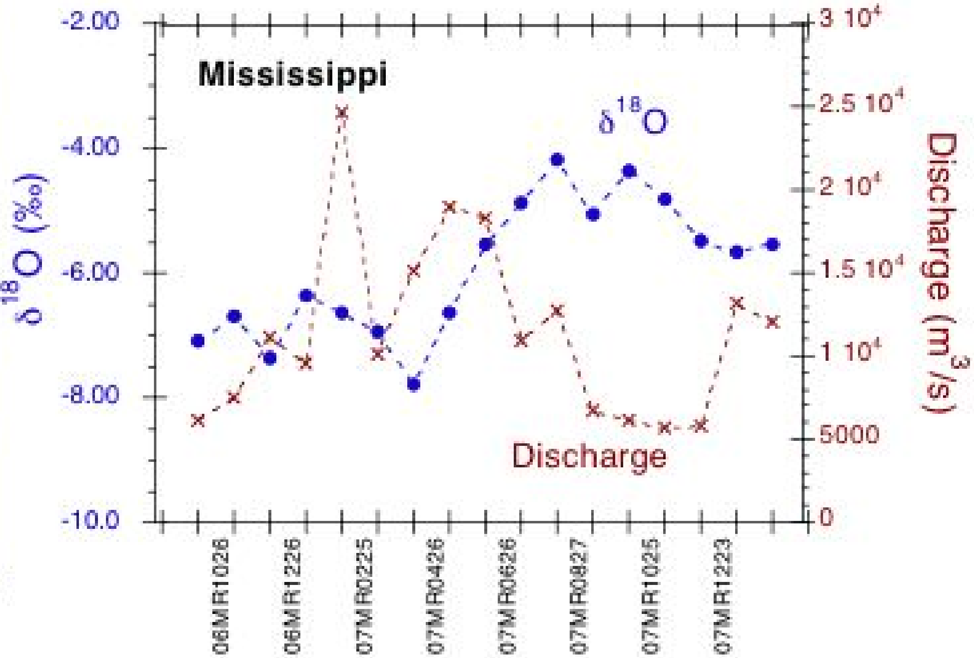


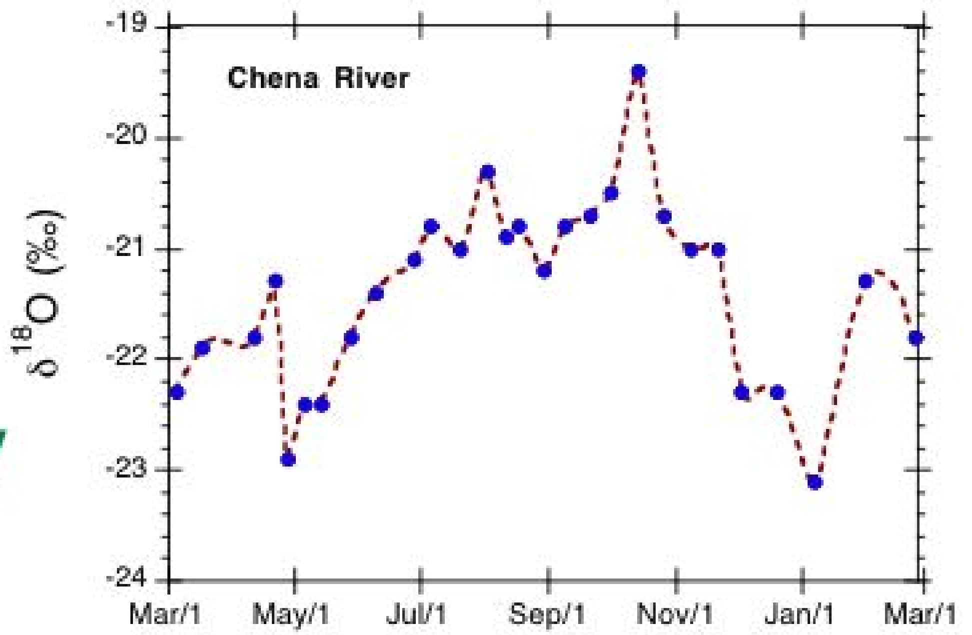
Carbon partitioning between DIC, DOC and POC phases

Large variability in DIC/DOC ratio

	Yukon	Chena (Alaska)	Mississippi
DIC/DOC	0.7 - 11.7	0.81 - 10.5	6.7 - 11.8
Ratio	(5.8±3.2)	(5.5±2.8)	(8.6±1.5)





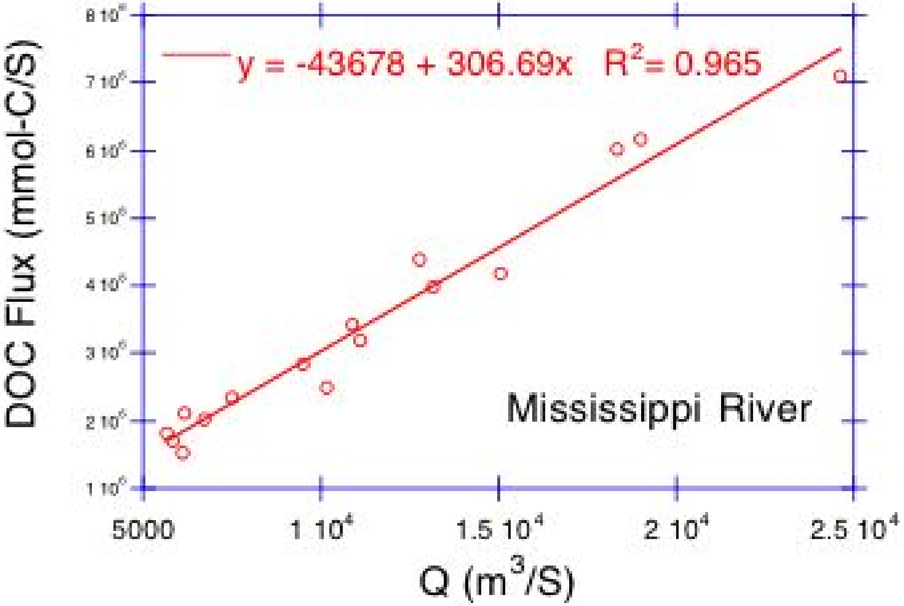


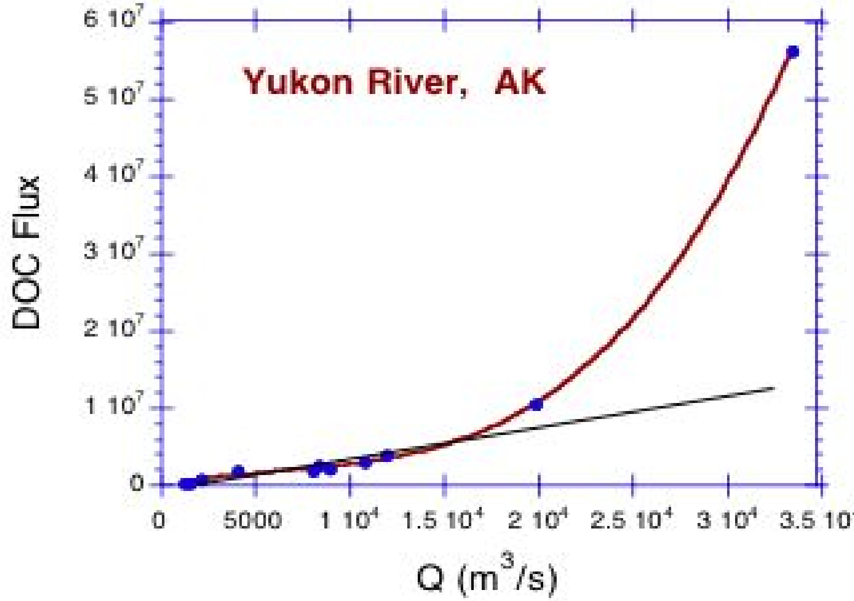
Difference in hydrology

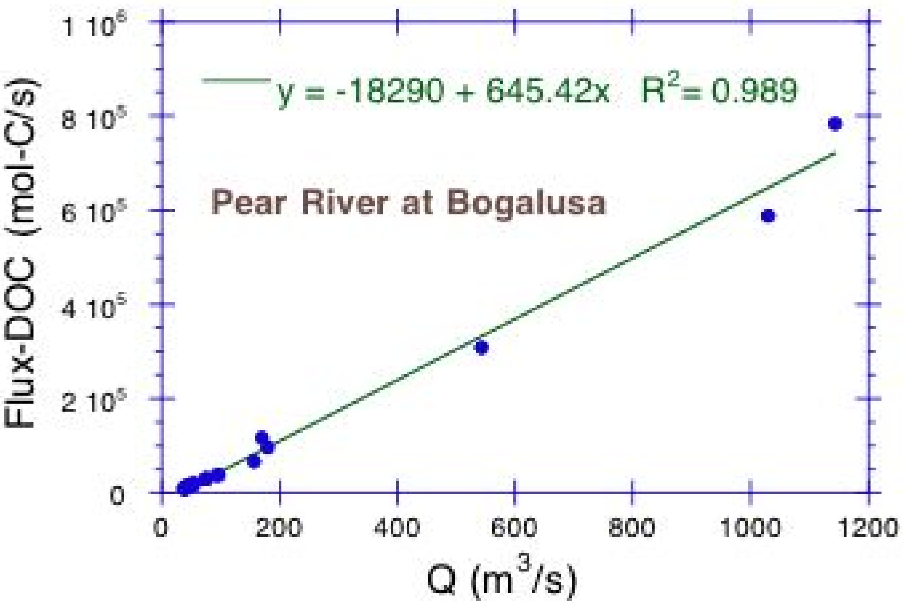
Riverine export flux estimation

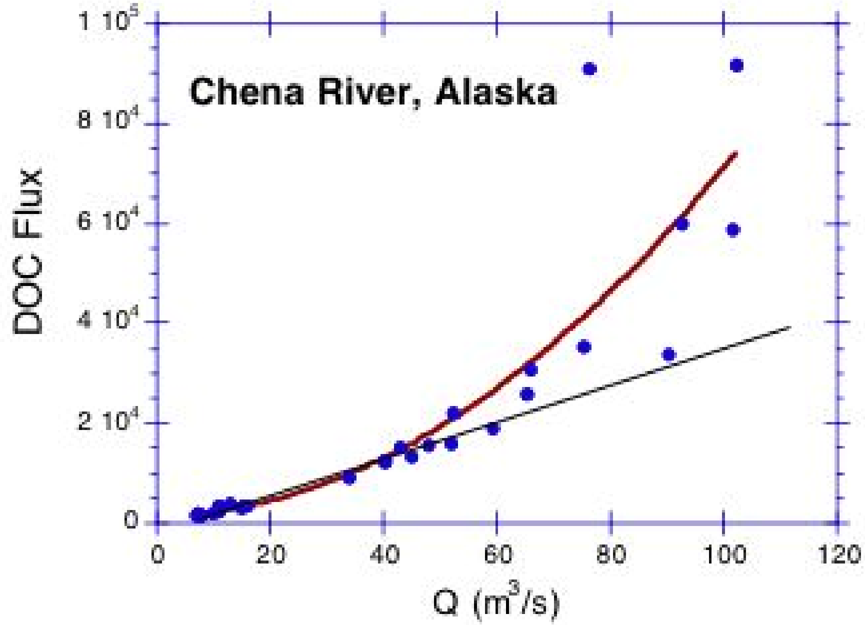
- Product of river DOC/DIC concentration and total freshwater discharge
- Based on regression between instantaneous flux and discharge;
- US Geological Survey LOADEST software (requires at least 11 data points) (http://water.usgs.gov/software/loadest/)

Relationship between instantaneous DOC flux and discharge

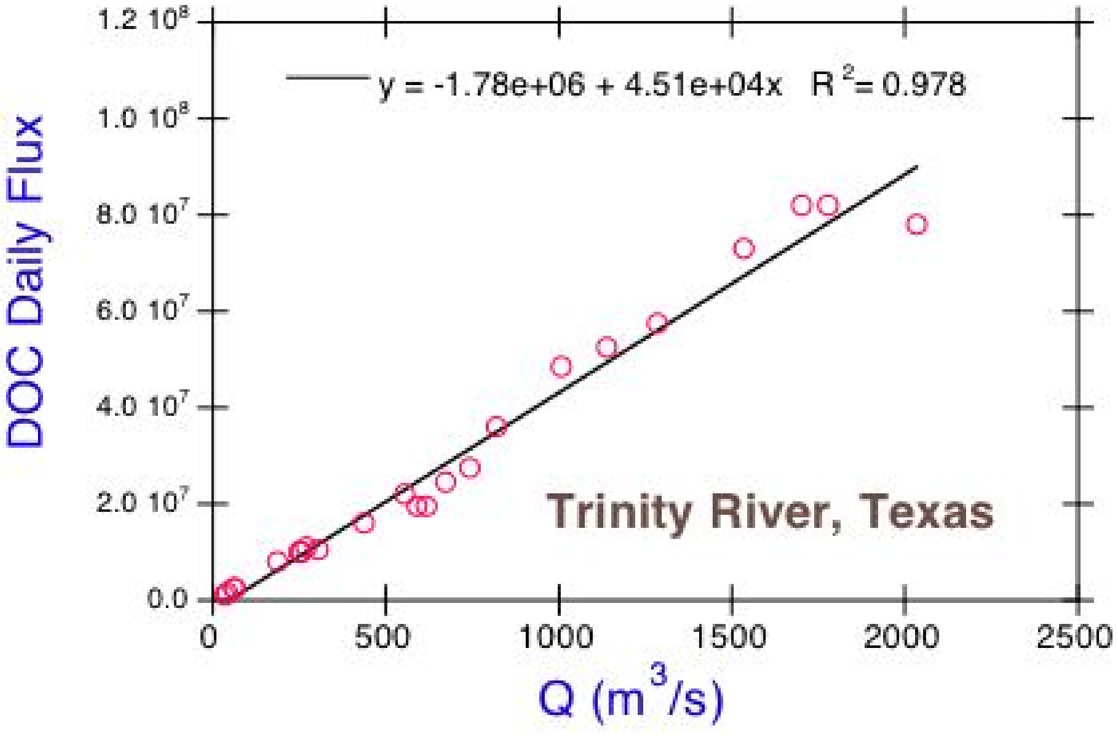








Subtropical and temperate rivers where a significant correlation between solute flux and discharge exists



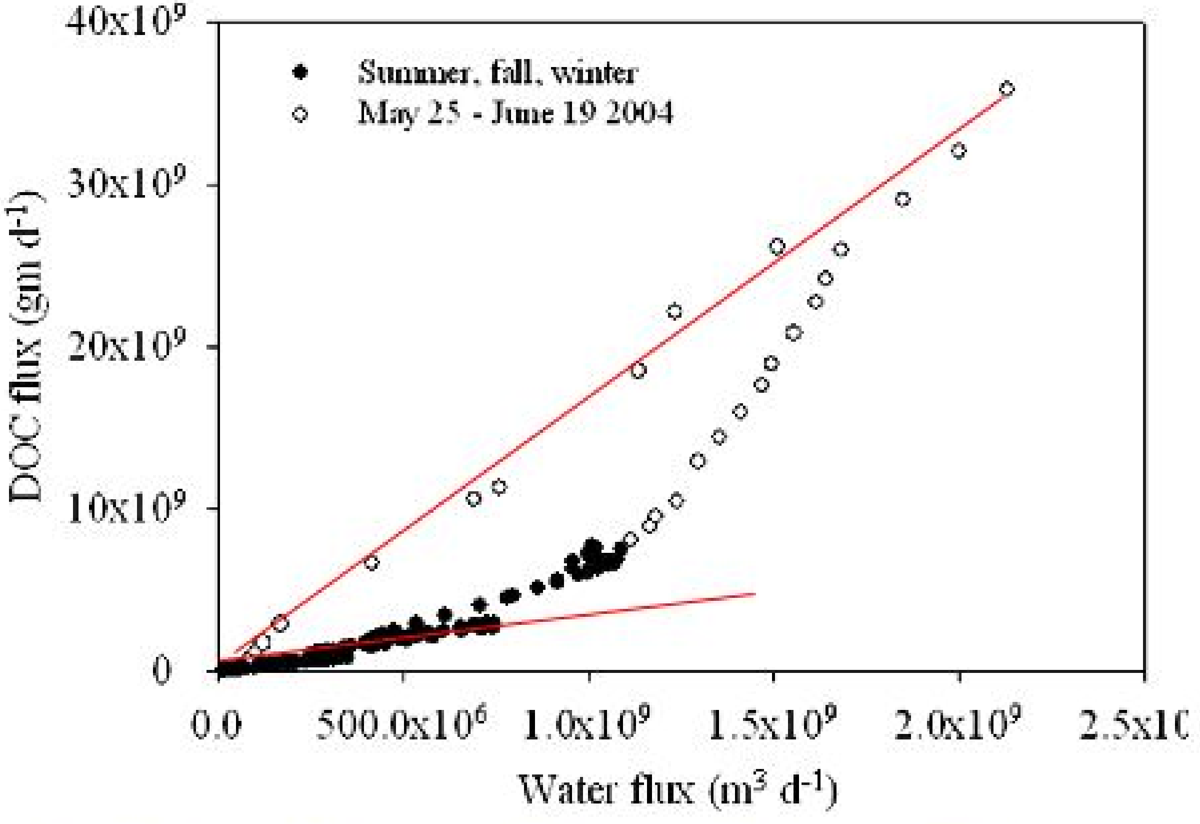
Example -- the Mississippi River

Riverine Export Fluxes from the Mississippi River based on 2006-2008 data

Species	Flux (**10^{12} g/yr**) (based on regression)	Flux (**10^{12} g/yr**) (based on LOADEST)
DOC	1.32	1.44
DIC	10.59	11.6
TDN	0.72	0.79

Note that the difference between two methods is small (usually <10%) in sub-tropic and temperate rivers

High latitude rivers where there is no linear correlation between solute flux and discharge



Example of the Kolyma River, Siberia (Finlay et al., 2006)

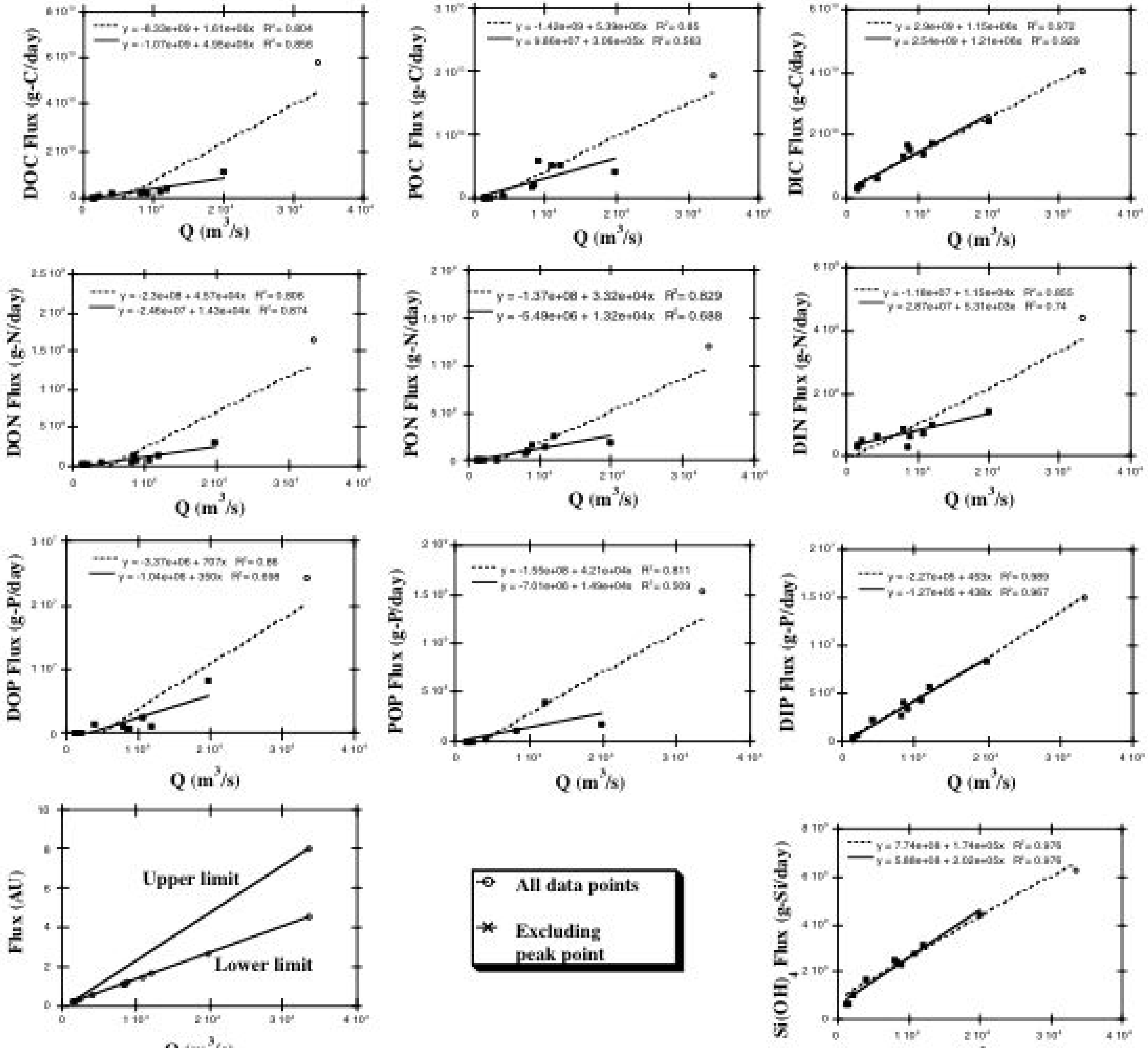
Uncertainties in an extreme scenario

Date	Disch (m3/S)	DOC (ppm)	Wt-DOC (ppm)	No winter	No freshet
15-Jul	10765	3.23	0.31	0.31	0.315
25-Aug	8924	2.62	0.21	0.21	0.212
30-Sep	8068	2.70	0.20	0.20	0.197
10-Nov	4093	5.13	0.19	0.19	0.190
15-Dec	2152	4.22	0.08		0.082
9-Feb	1536	2.56	0.04		0.036
5-Apr	1293	2.18	0.03		0.026
17-May	33428	20.19	6.11	6.11	
14-Jun	19858	6.35	1.14	1.14	1.141
19-Jul	11955	3.79	0.41	0.41	0.410
7-Sep	8414	3.57	0.27	0.27	0.272
Avg=	10044	5.14	0.82	1.1	0.29
Sum	110486	56.53	8.99	8.8	2.88
DOC flux (10^{12} g-C/yr)			1.843	1.813	0.590
Under Estimate:				**-0.016**	**-0.674**

Based on average DOC concentration and annual discharge

Flux distribution between season in high latitude rivers

	% from open season (Yukon River)	% from frozen season (Yukon River)	% from spring freshet (Chena River)
Days	~50%	~50%	4%
DOC Flux	75	25	25
POC Flux	87	13	24
DIC Flux	70	30	8


DOC Flux (g-C/day)
POC Flux (g-C/day)
DIC Flux (g-C/day)
DON Flux (g-N/day)
PON Flux (g-N/day)
DIN Flux (g-N/day)
DOP Flux (g-P/day)
POP Flux (g-P/day)
DIP Flux (g-P/day)
Flux (AU)
Upper limit
Lower limit
All data points
Excluding peak point
Si(OH)4 Flux (g-Si/day)
Q (m3/s)

Over (+) or under (-) estimation in C fluxes derived from the LOADEST method

	Yukon		Chena	
	No spring freshet	No winter data	No spring freshet	No winter data
DOC Flux	-16%	+3%	-12%	+2%
POC Flux	-8%	-2%	-36%	+50%

Conclusion

- Spring freshet, representing 4-5% of the time in a year, could contribute up to 25% of the annual DOC flux;
- Both DOC concentration and source in arctic river waters have a strong seasonality: high in the spring and derived from surface soils but low in winter and derived mostly from groundwater.
- River export fluxes of organic carbon can be considerably under-estimated without sampling during spring freshet, but over-estimated without sampling in the winter under the ice.
- Northern high latitude watersheds are sensitive to climate changes, likely resulting in an increase in river C export fluxes across the land/ocean interface;
- Long-term, accurate flux estimation using time series observation should provide insights into a better understanding of biogeochemical consequences of amplified warming in the north;

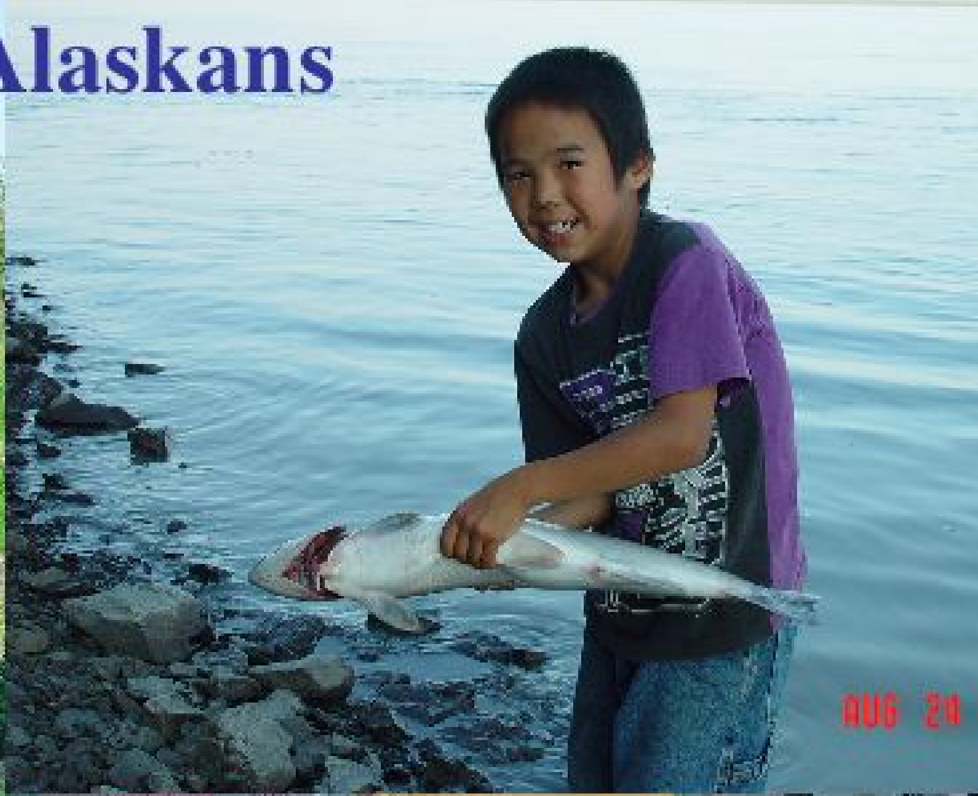
Acknowledgements

- Coauthors: Yihua Cai; Tom Douglas
- Field sampling assistance: Mindy Juliana, Chunhao Xu.
- Funding support: NSF, IARC, and USM

Thank You

Sampling arctic rivers

Native Alaskans

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Warm winter in Alaska