ЛАБОРАТОРИЯ
биогеохимических циклов
в лесных экосистемах

Controls of dissolved inorganic and organic carbon discharge from permafrost ecosystems

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ИЛ СО РАН: **School of the young scientists on Biogeochemical Matter Cycling In Permafrost Ecosystems**

Presentation structure:

- Terms
- Processes

- Dissolved carbon in watersheds of Siberian rivers : interactions of hydrology, vegetation, permafrost, fires and C fluxes

- from Latin dissolvere :

dis- + solvere, *to release*

Physicochemical background:

Wikipedia: Dissolution is the process by which a solute forms a solution in a solvent. The solute, in the case of solids, has its crystalline structure disintegrated as separate ions, atoms, and molecules form. For liquids and gases, the molecules must be adaptable with those of the solvent for a solution to form. The outcome of the process of dissolution (the amount dissolved at equilibrium, i.e., the solubility) is governed by the thermodynamic energies involved, such as the heat of solution and entropy of solution, but the dissolution itself (a kinetic process) is not. Overall the free energy must be negative for net dissolution to occur. In turn, those energies are controlled by the way in which different chemical bond types interact with those in the solvent.

Dissolved carbon species:

- Dissolved inorganic carbon

[CO2*] + [HCO3−] + [CO32−]

- Dissolved organic carbon

Complex mixture of organic volecules

- Dissolved gases

CO2, CH4

<u>Other portion of C in waters is called particulate C:</u>

Particulate organic C

Particulate inorganic C

Dissolved carbon: definitions and species

Initially in hydrochemistry dissolved matter is operationally defined as

matter which is passed through 0.45 um pore-size filter

Wikipedia: …The "dissolved" fraction of organic carbon is an operational classification. Many researchers use the term "dissolved" for compounds below 0.45 micrometers, but 0.22 micrometers is also common... A practical definition of dissolved typically used in marine chemistry is all substances that pass through a GF/F filter (0.7 um pore size!).

So, to work with dissolved carbon in a sample one need first to filter sample!

Advantages and disadvantages of filters:

- 0.22 micrometers: to get rid of microbes… less loss during storage, but may contaminate with C (nitrocellulose, acetate cellulose matrix)

- 0.7 um precombusted glass fiber filters (GF/F): miserable or no contamination by OC, but microbes…

How to measure?

- DOC (TOC = TC-IC, NPOC – nonpurgeable OC)

- The recommended measure technique is the high temperature catalytic oxidation (IR detection)

- Previous technique (still in use by Roshydromet) Bichromate/permanganate oxidation

How to measure?

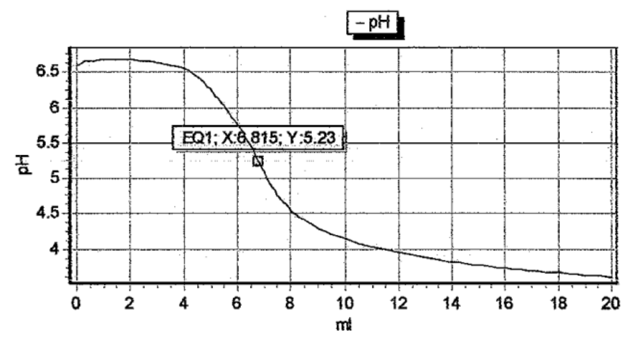
- DIC

- The recommended measure technique is acidification with further IR detection

- Potentiometric titration with HCl for alkalinity

$H^+ + HCO_3^- = H_2CO_3 = H_2O + CO_2$

Property	Value
position	4
état	terminé
méthode	
identification	NT 26.12.10
quantité	2.457
donnée des mesures	12/06/2012 17:15:19
utilisateur	liudmila
Titre HCl 0.001M	0.00097
V EQ1 ml	6.866
[alcalinité] mol/l	0.00269

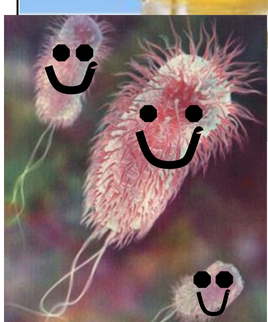


Why it is important?

- DOC loss from terrestrial ecosystems to fresh waters constitutes 1-15% of NEP
- DIC and specifically dissolved CO_2/CH_4 fluxes is not still well counted …
- C exported from terrestrial ecosystems to rivers are rarely included in NEP estimates, causing its underestimation
- DOM (DOC, DON, DOP etc…) is important driver of foodwebs in both terrestrial and aquatic systems

Dissolved organic C

- To be microbially mineralized to CO_2/CH_4 all organic matter must be dissolved



Dissolved inorganic C

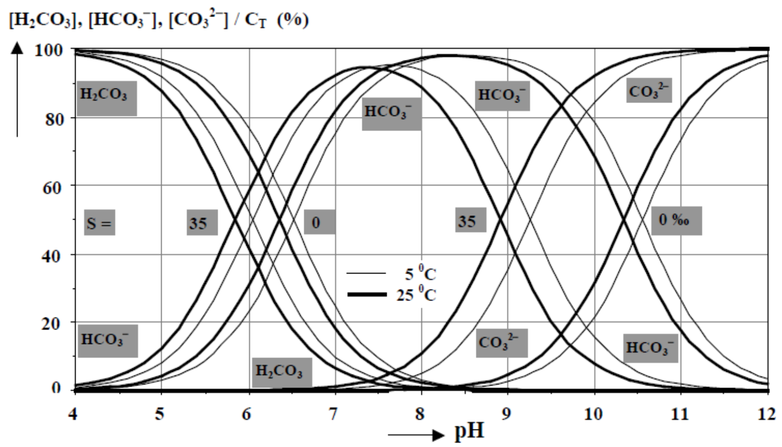


Fig.9.6 Distribution of the carbonic acid fractions as percentages of the total carbon content, C_T. The values are calculated using Eqs.9.37, 9.38, 9.39 for temperatures of 5 and 25 °C and for salinities of 0 and 35 ‰ as a function of the pH. Seawater has pH values around 8.2. However, the carbon distributions are shown for an (unrealistic) wider range of pH values, to illustrate the dependence of the carbon distribution on salinity.

Carbonate weathering…

H2CO3 + CaCO3 → Ca(HCO3)2

Silicate weathering…

2 KAlSi3O8 + 2 H2CO3 + 9 H2O ⇌ Al2Si2O5(OH)4 + 4 H4SiO4 + 2 K+ + 2 HCO3−

Temperature dependent process

high potential for sequestration of atmospheric CO2…

- Weathering of basalts of Central Siberian Plateau may be important factor for atmospheric CO2 sequestration

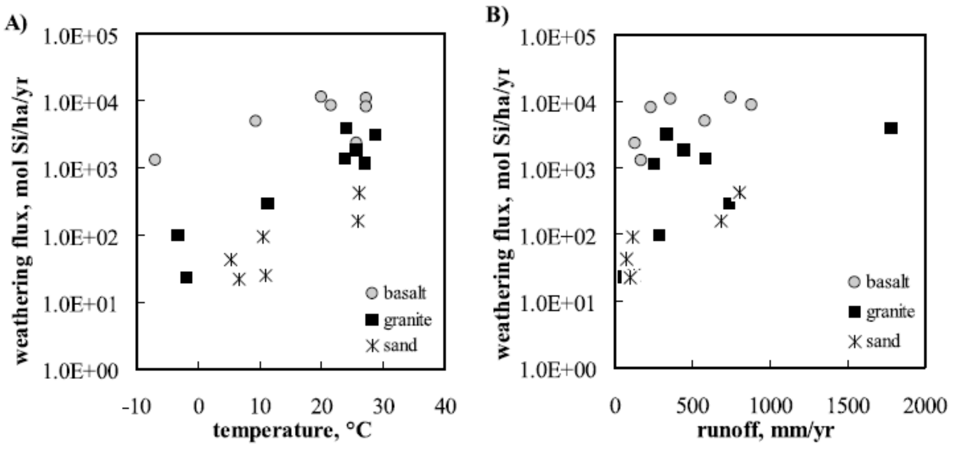
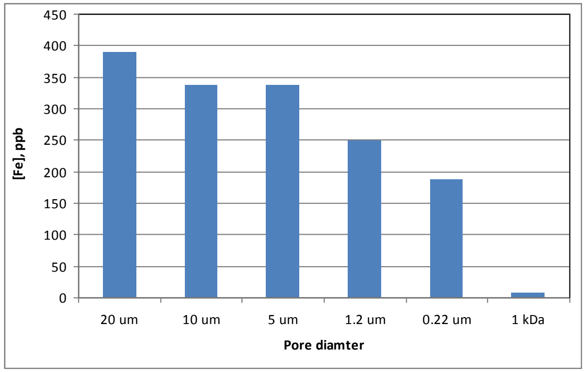


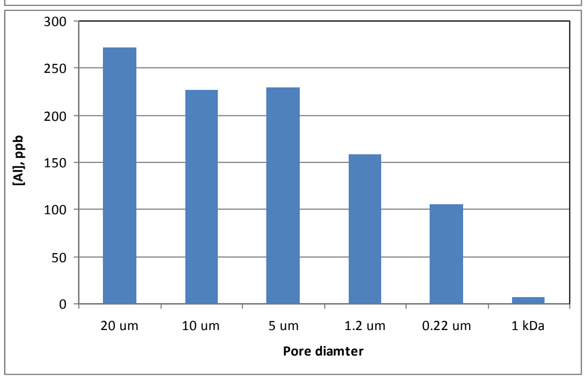
Illustration of the correlations between weathering fluxes and (A) thermal regimes and (B) hydrological regimes for 22 representative silicate sites around the world (excerpt from Beaulieu et al., 2010).

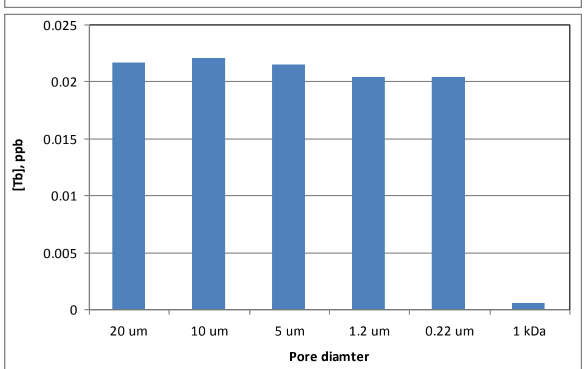
Our study shows clear increase of DIC annual yield from 1.04 gC m^{-2} yr^{-1} for Tembenchi River (MAAT = −10.9 ◦C) to 2.77 gC m^{-2} yr^{-1} for Nizhnyaya Tunguska River (MAAT = −7.5 ◦C).

The other basaltic boreal rivers such as Kamchatka River and its tributaries (MAAT = −2.5 ◦C) exhibit significantly higher annual fluxes of DIC: 4.8 gC m^{-2} yr^{-1}

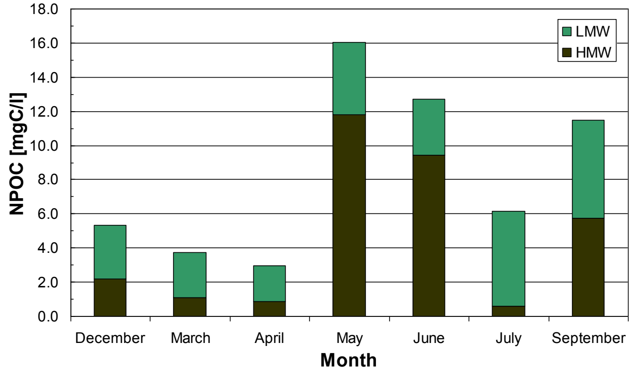
Dissolved organic C: dissolved or colloidal?

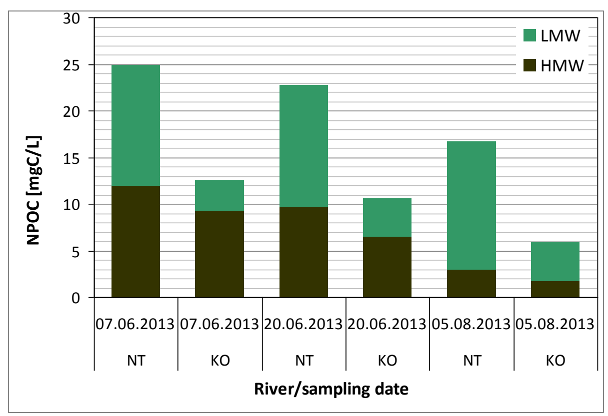


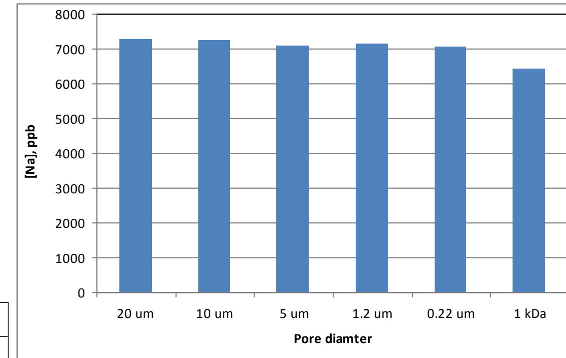


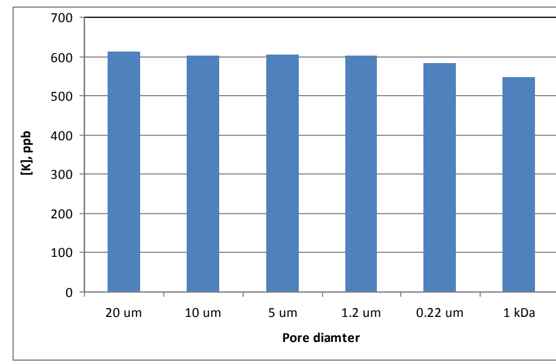


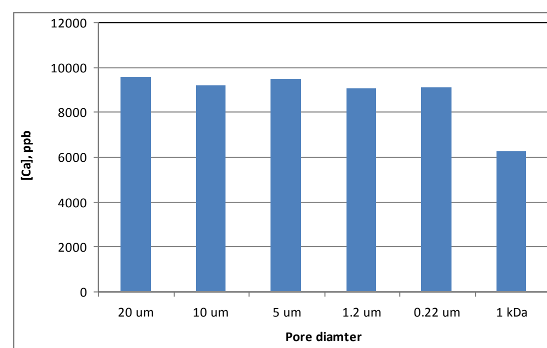
LMW = 1 kDa
(Dialysis)









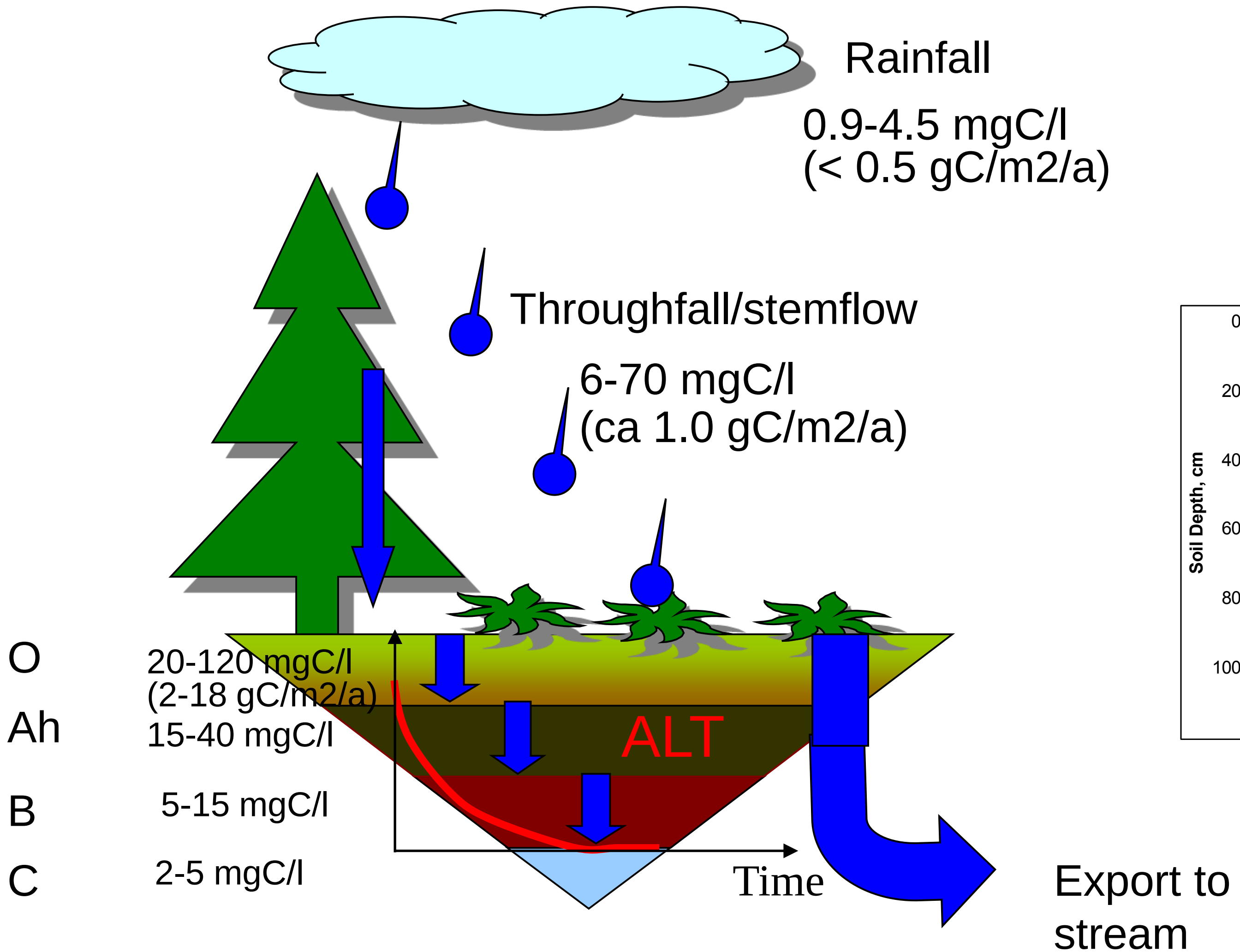


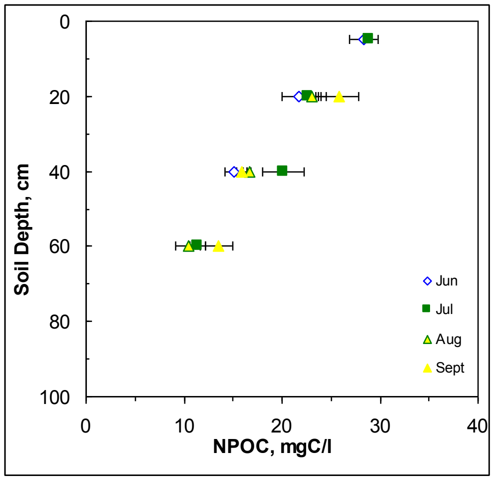
What is DOC? How to investigate the composition?

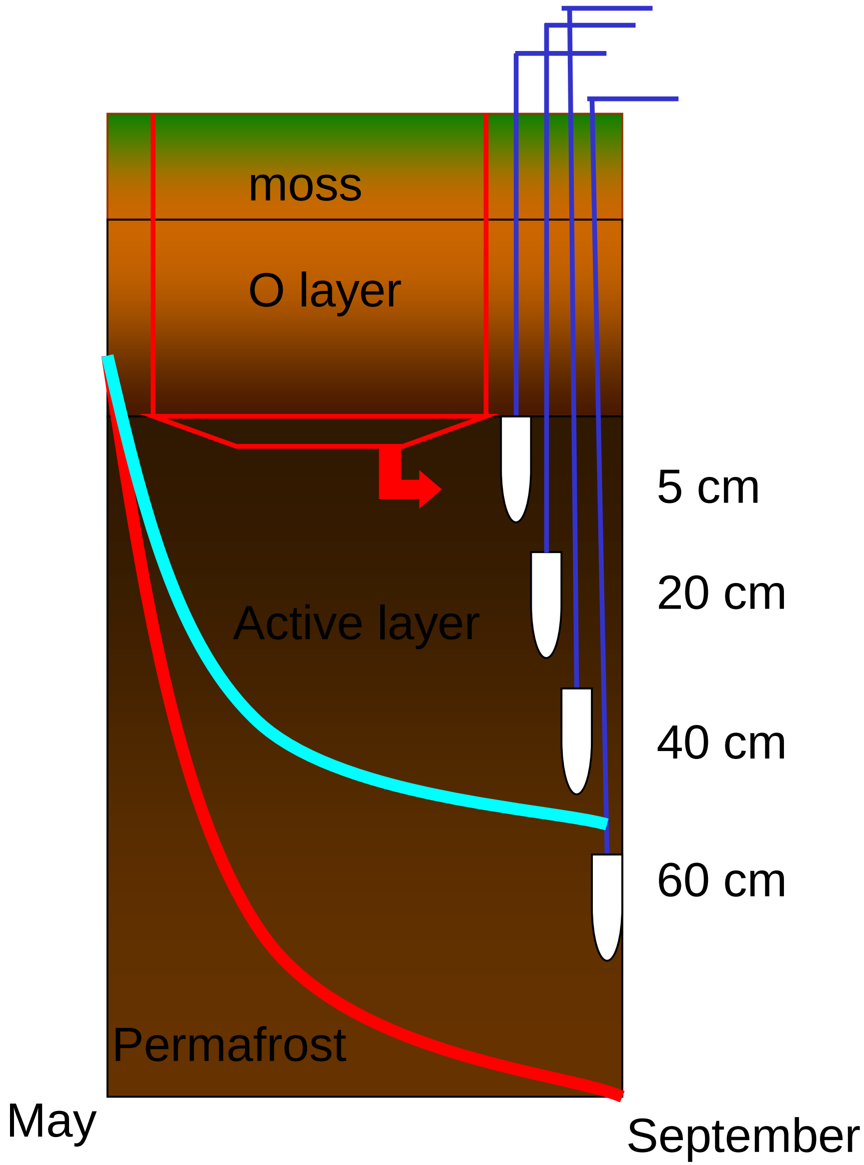
- Complex mixture of organic molecules
- Fulvic acids (dissolved at pH 2)
- Hydrophobic acid (by XAD fractionation)

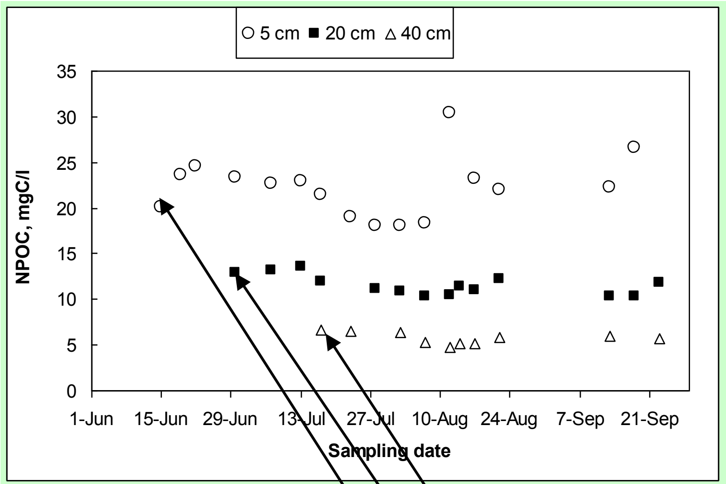
- Spectral characteristics (e.g. SUVA, spectral slope)
- Fluorescence (chromatophoric groups)
- Biomarkers (e.g. lignin, sugars etc.)
- Isotopic composition (i.e. $\delta^{13}C$)
- Radiocarbon age (compound specific)
- Pyr-GC/MS-IRMS, ^{13}C NMR CP MAS, electrospray ionization Fourier transform ion cyclotron resonance mass spectrometry (ESI-FT-ICR-MS)
- etc.

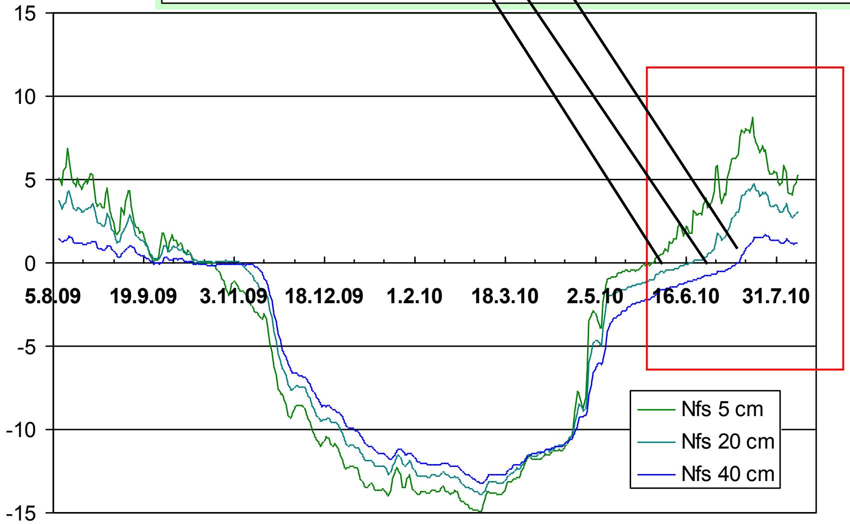
Dissolved organic carbon in terrestrial systems





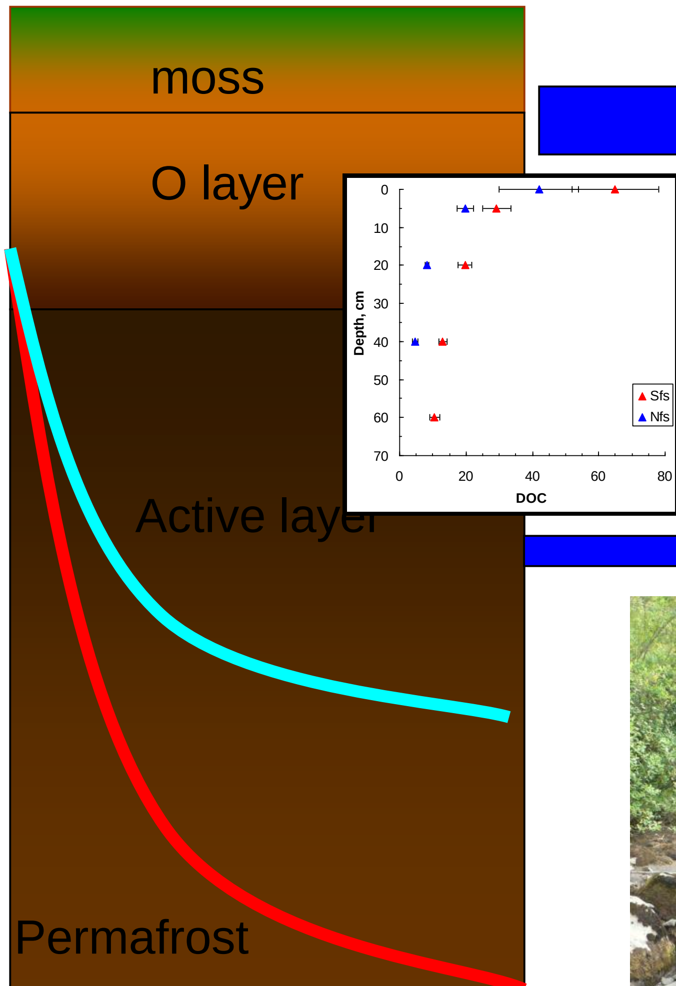


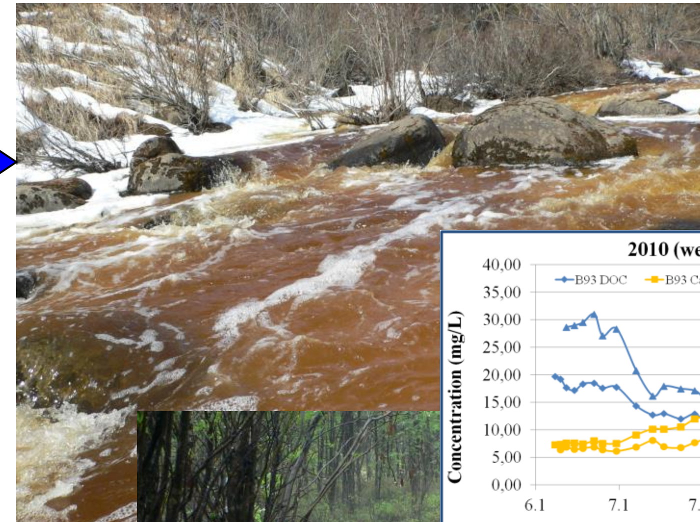


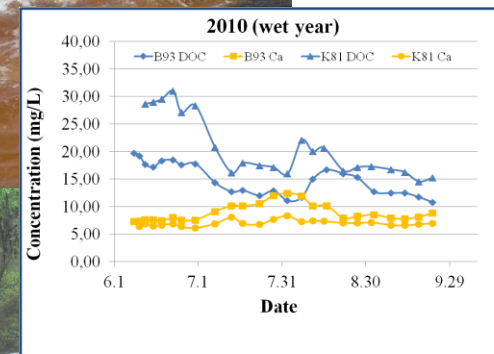


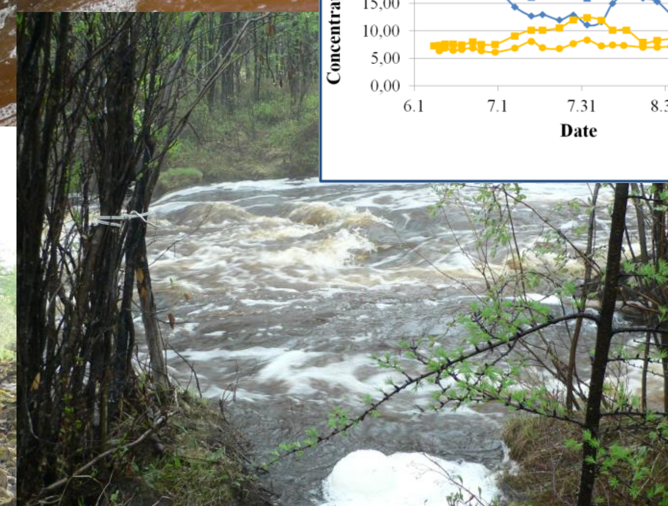
Soil solution sampling and temperature monitoring

Terrestrial C links to aquatic









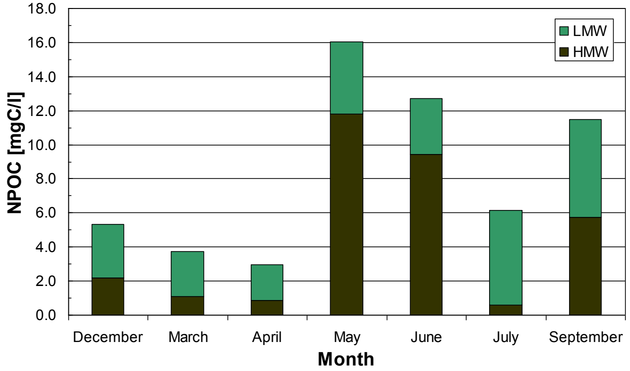
Dissolved organic carbon in aquatic systems

- **Authochtonous**

low C:N, high ^{15}N, LMW, specific biomarkers

- **Allochtonous (terrigenic)**

High C:N, low 15N, low 13C, HMW, specific biomarkers



DOC production

- Biological

- Exudates

- Cell lysis

- Microbial breakdown of SOM $\longrightarrow$ DOM

- Physical

Freeze-thaw cycles SOM $\longrightarrow$ DOM

Terrestrial controls over C export: soil C stocks and C:N ratio

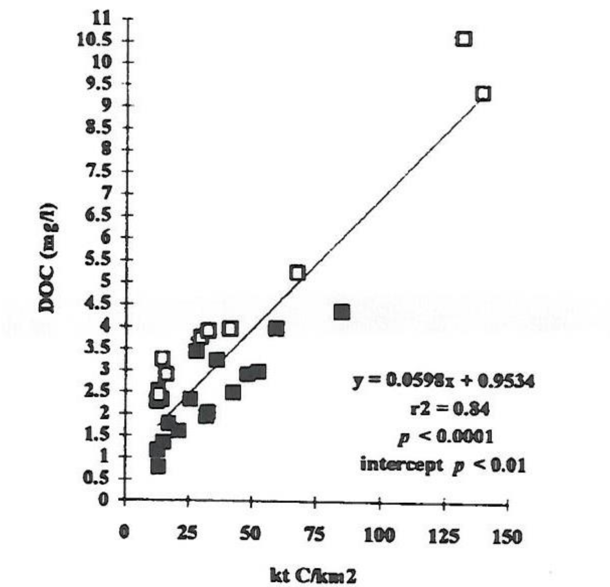


Figure 1. The relationship between mean stream water DOC concentration and (a) peat cover, (b) AU soil carbon content, (c) DoE soil carbon content and (d) WISE soil carbon content at all catchment scales. Filled squares indicate upland (maximum altitude > 700 m) and unfilled squares lowland (maximum altitude < 700 m) catchments

J. A. AITKENHEAD, D. HOPE AND M. F. BILLETT
HYDROLOGICAL PROCESSES
Hydrol. Process. 13, 1289–1302 (1999)

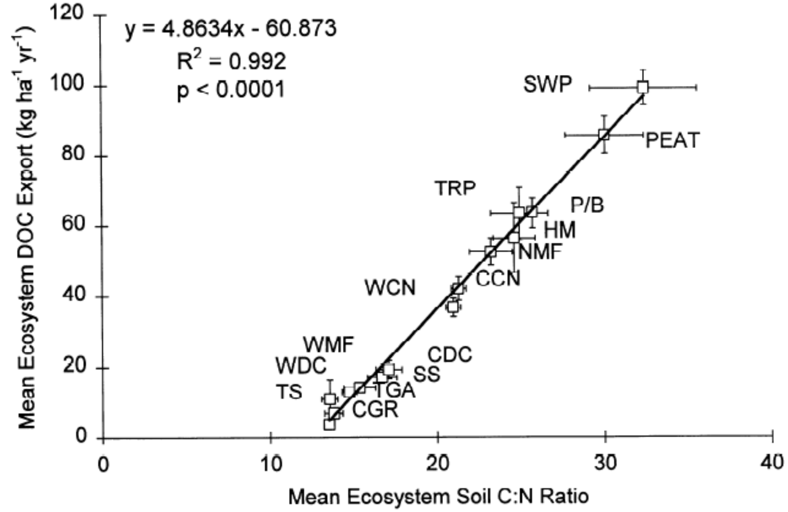
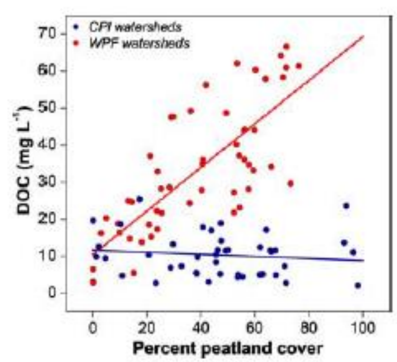


Figure 1. The relationship between mean (± SE) annual riverine DOC flux and mean (± SE) soil C:N for the 15 biome types used in the model construction. (CGR, cool grasslands; TS, tropical savanna; TGA, taiga; SS, Siberian steppe; WDC, warm deciduous forests; WMF, warm mixed forests; CDC, cool deciduous forests; WCN, warm conifer forests; CCN, cool conifer forests; NMF, northern mixed forests; HM, heath moorland; TRP, tropical forests; P/B, peat/boreal mix; PEAT, peatland; SWP, swamp forests). The regression is based upon the average soil C:N and average DOC export for each of the 15 biomes.

J. A. Aitkenhead and W. H. McDowell

GLOBAL BIOGEOCHEMICAL CYCLES, VOL. 14, NO. 1, PAGES 127-138, MARCH 2000



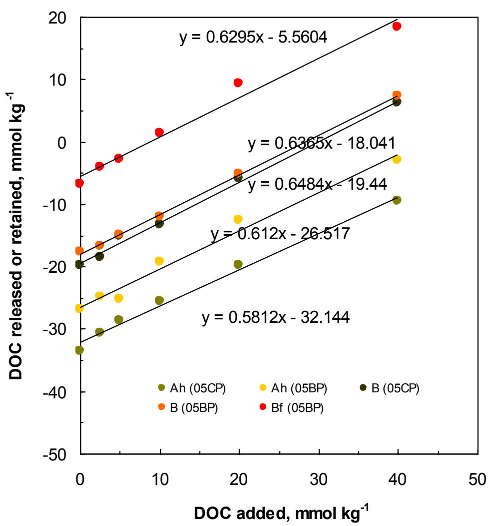
Frey and Smith 2005, GRL

DOC "consumption"

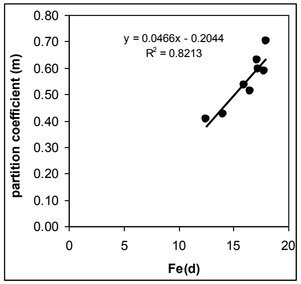
- Microbial mineralization

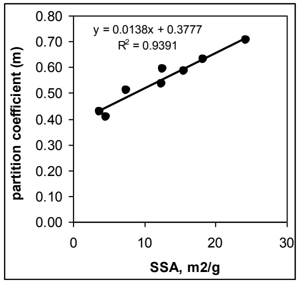
$DOC = CO_2/CH_4 + H_2O$

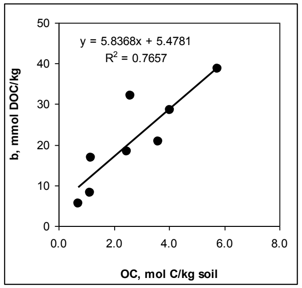
- Sorption to mineral matrix



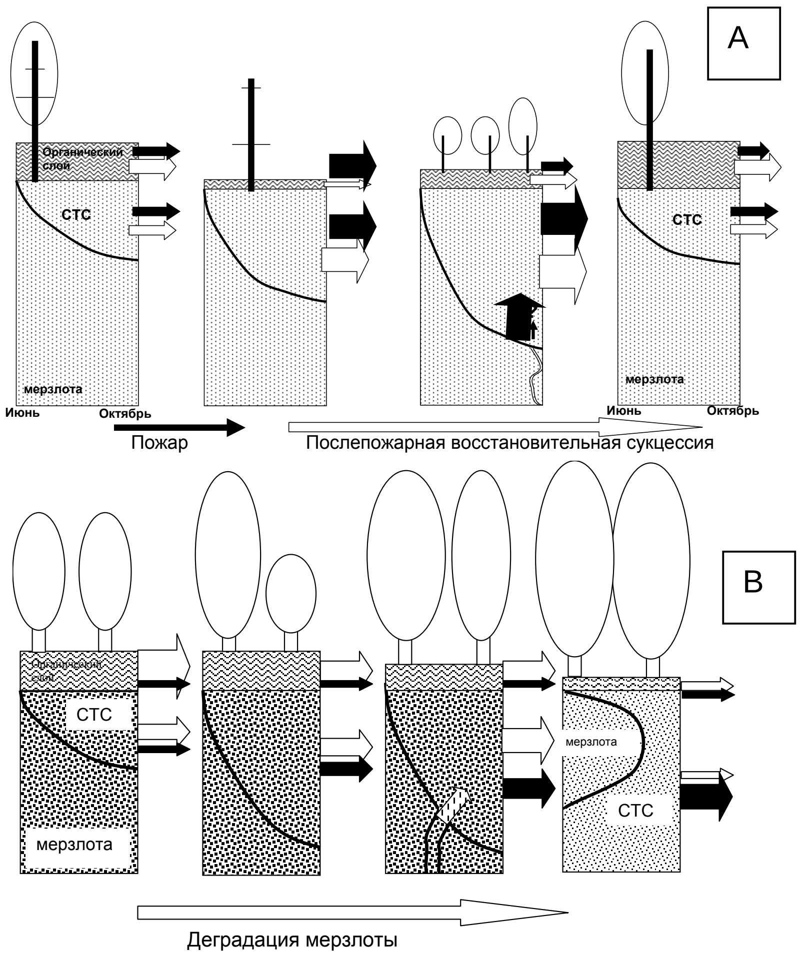
- Precipitation







Permafrost and dissolved C:



Periodic forest fires

Permafrost degradation

DOC DIC

Arctic and subarctic ecosystems: why dissolved carbon is important

- Largest amount of carbon (of which 1-2% is dissolved) locked in soils and particularly conserved within the frozen ground

  (SOC = 1672 PgC, Tarnocai *et al* 2009)

- Dissolved carbon is most labile and indicative component of soil C reservoir

- Highest rates of warming and permafrost degradation

- Highest sensitivity of ecosystem processes to ongoing climate change

- Little is known about behavior of dissolved carbon in arctic and subarctic watersheds

Global change: permafrost degradation and an increase of active layer thickness

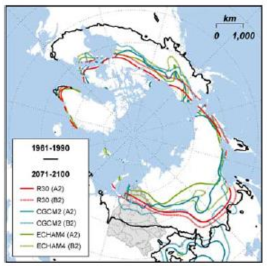
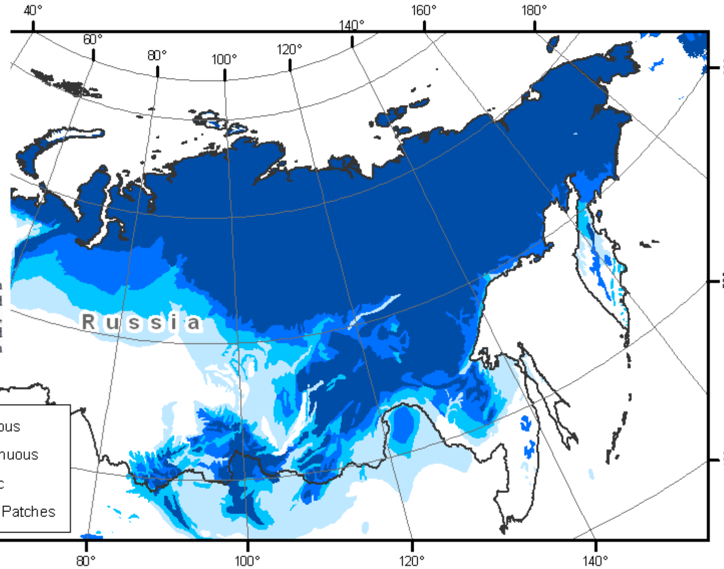
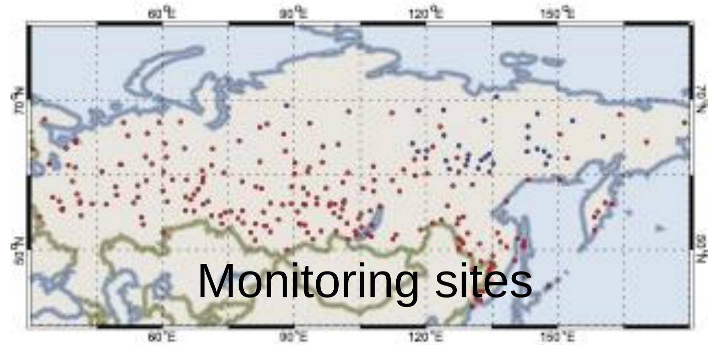
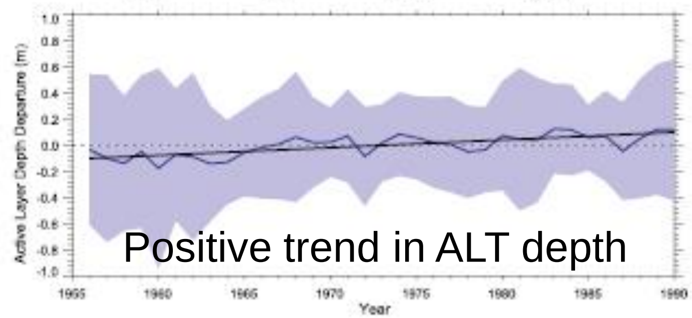


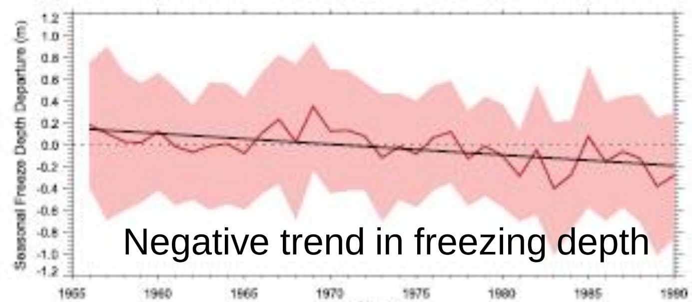
Figure 4. Locations of −2°C MAAT isotherms, based on observational data from 1961–1990 [*New et al.*, 1999] and modelled data from 2071–2100 (using the R30, CGCM2, and ECHAM4 models). Both the A2 (less conservative) and B2 (more conservative) IPCC greenhouse gas emission scenarios are shown for each model.



By 2091-2100, permafrost extent will be decreased 30-75% and active layer thickness increased about 55-125 cm, compared to 1991-2010 (Park and Walsh 2013, EGU General Assembly)



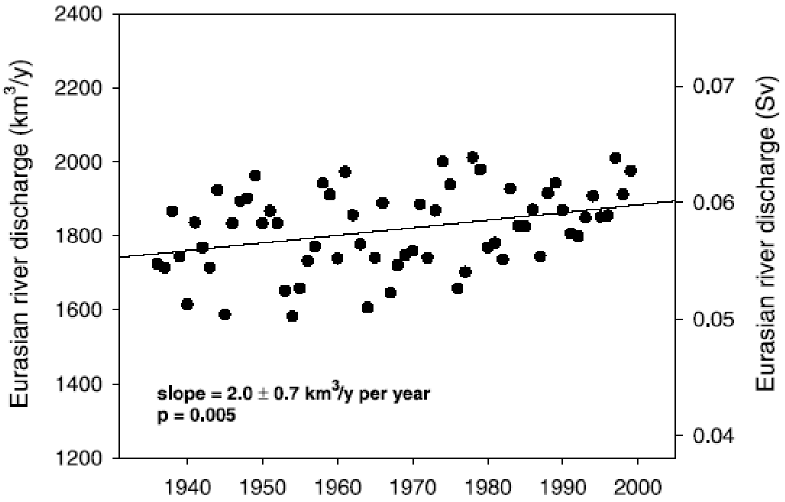




IPCC 2007,
from Frauenfeld *et al* 2004

Implications for C export:
Higher retention times in soil (DOC negative)
Higher mineralization rates (DIC, pCO_2 positive)
Higher weathering rates (DIC positive)

Global change: hydrology



Eurasian river annual runoff to the Arctic Ocean tends to increase for ca. 2.0 km^3/year/year

(Peterson *et al* 2002, Science)

Implications for C export:
causes are debatable, but C export is considered to be increased
(e.g. Gordeev and Kravchishina 2009)

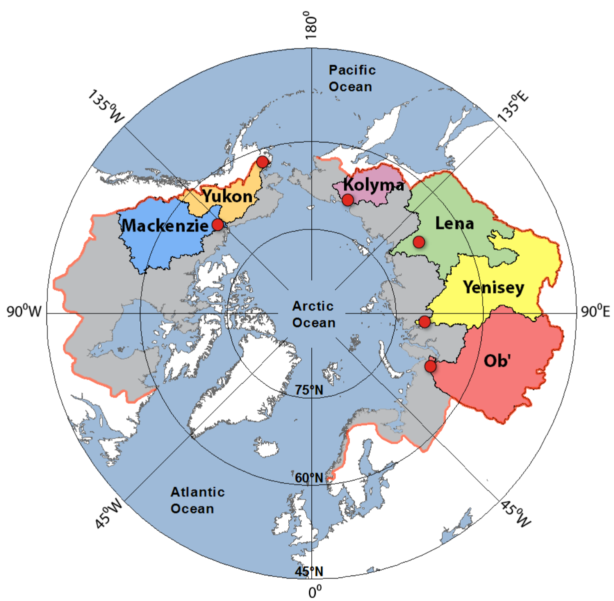
Global change: vegetation

Figure from Dolman et al 2012, Biogeosciences

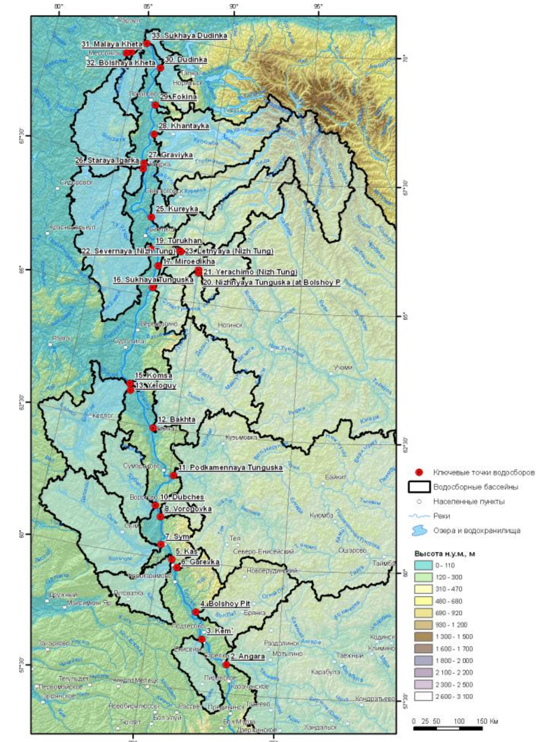
Changes and their effects on C export:
Net ecosystem productivity (likely +)
Northward shift of vegetation zones (likely +)
Desertification in Eastern and Central Siberia (-)
Shortened Fire Return Interval (-)

Studies of projected changes on riverine C export

- Long-term monitoring data
- Space-for-time approach

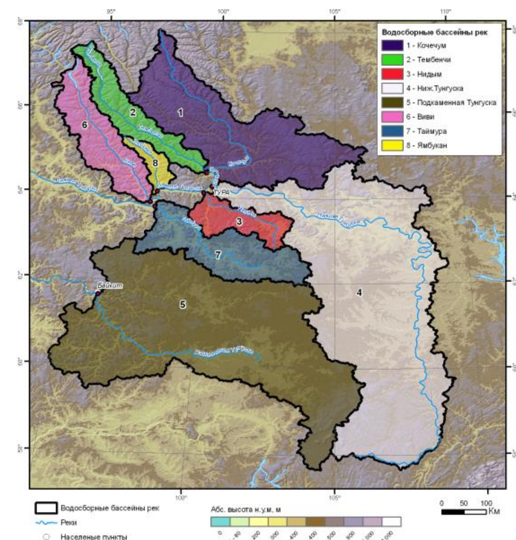


Circum-polar studies: Arctic-GRO (PARTNERS), Rosgydromet data (Gordeev *et al* 1996)



Yenisey River basin: “Megaprojects”, RSF project

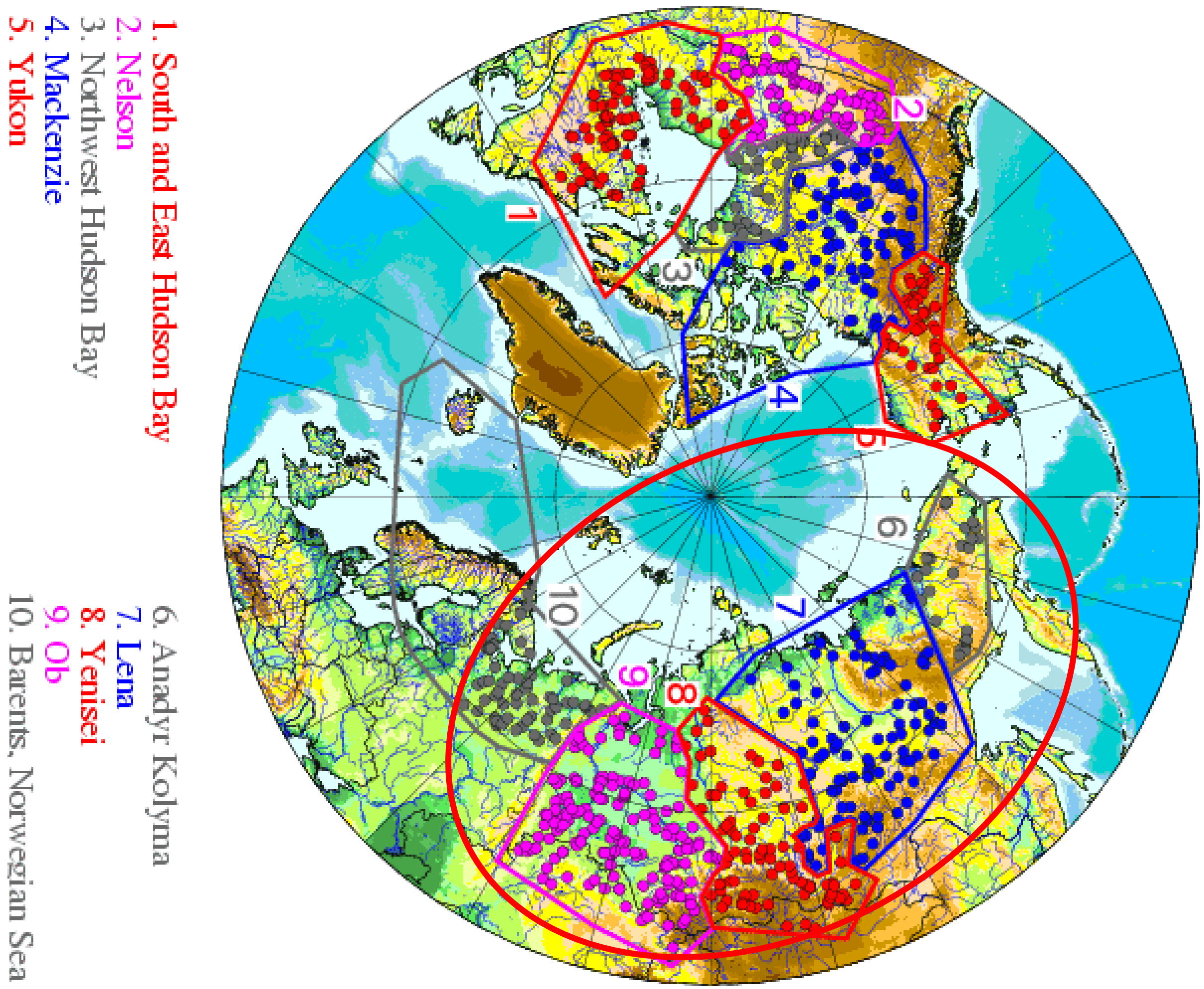
2010-2012, 2013-2015…



Central Siberian Plateau: RFBR-CRDF RUG1-2980-KR-10 “Megaprojects”, RSF project

2005 -…

Long-term monitoring: Rosgydromet



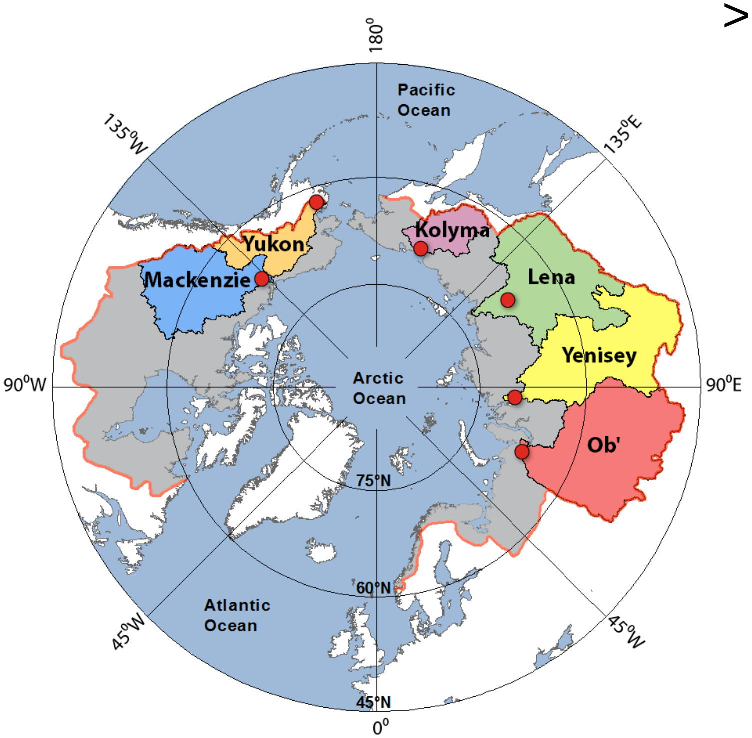
R-ArcticNet - A Database of Pan-Arctic River Discharge

http://www.r-arcticnet.sr.unh.edu/v4.0/main.html

General characteristics of Arctic rivers

~11% of global freshwater input to the world ocean

>10% of global C export to the world ocean



Siberian sector:

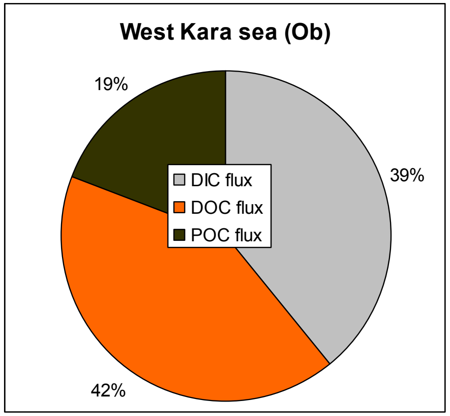
	Ob’	Yenisey	Lena	Kolyma	sum	% of 6 major Arctic rivers	% of total to the AO
Q, km^3/a	427	636	581	111	1755	77.6	35.1
DOC, Tg/a	4.12	4.65	5.68	0.82	15.3	84.3	44.8
DIC, Tg/a	6.15	6.66	5.43	0.70	18.9	67.0	

Source: Gordeev *et al* 1996, 2009, Raymond *et al* 2007, Striegl *et al* 2007, Cai *et al* 2008, Cooper *et al* 2008, McGuire *et al* 2009, Holmes *et al* 2011, Prokushkin *et al* 2011, Amon *et al* 2011

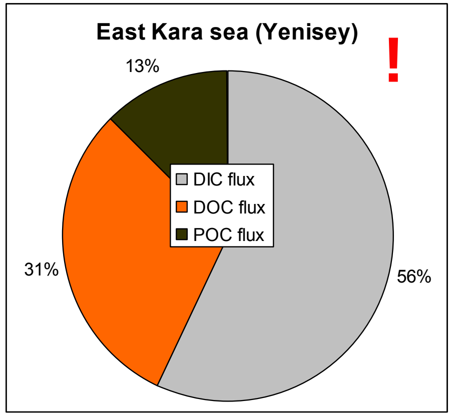
Tg = 10^{12} g

Recent estimates of carbon in rivers…

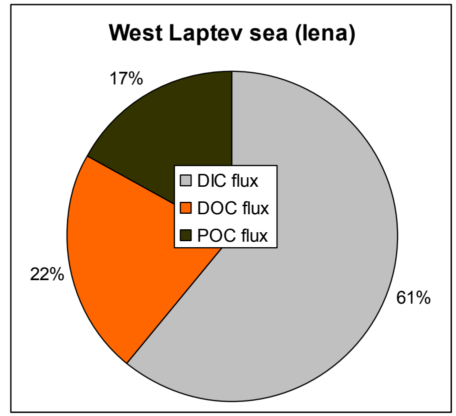
Dolman et al. 2013 Biogeosciences (based on Meybeck et al., 2006)



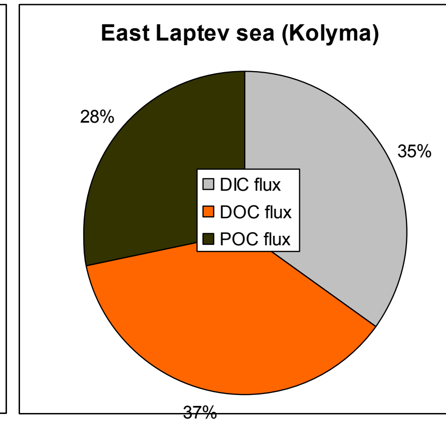
7.7 TgC/a



9.6 TgC/a

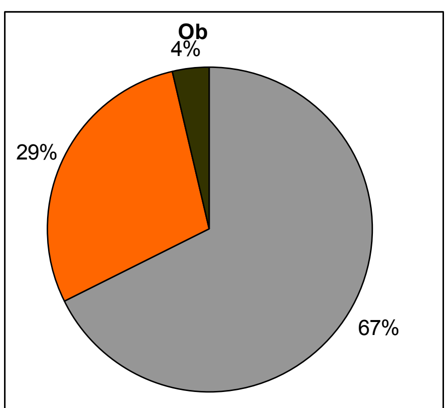


11.1 TgC/a

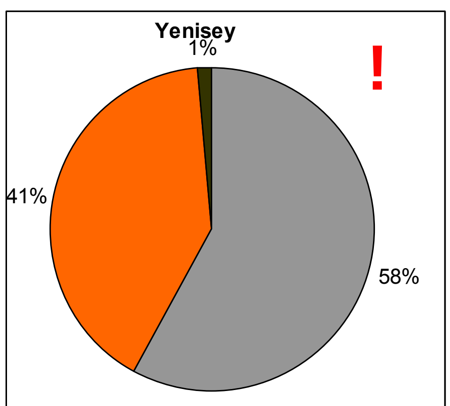


2.4 TgC/a

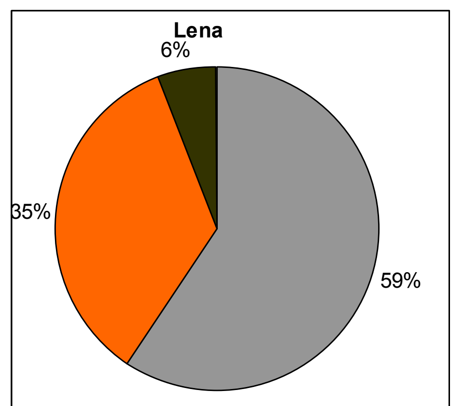
McGuire et al. 2009, Ecol Monogr (based on numerous sources)



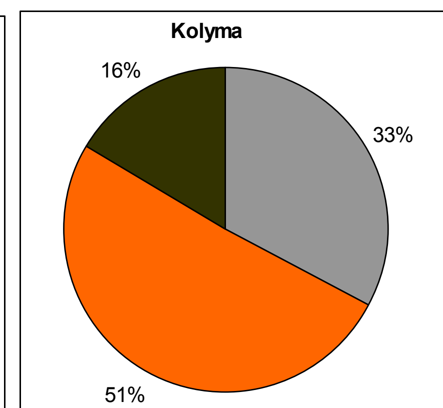
9.9 TgC/a



12.8 TgC/a



9.9 TgC/a



2.3 TgC/a

Basin characteristics

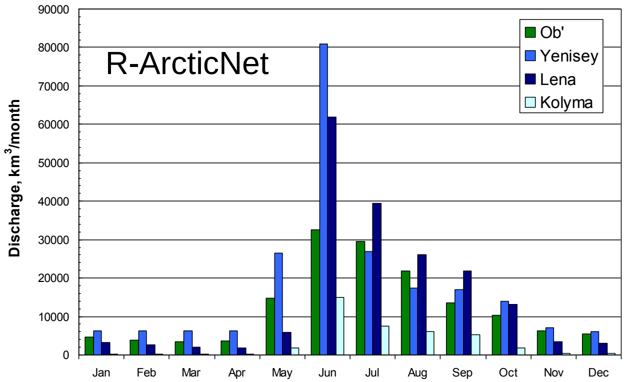
Table 1
Geographical, climatic and geochemical characteristics of the different river/watershed systems.

River and Watershed characteristics	Yukon	Mackenzie	Ob	Yenisey	Lena	Kolyma
Discharge ($km^3\ yr^{-1}$)[a]	208	298	427	636	581	111
Length (km)[a]	2716	3679	3977	4803	4387	2091
Catchment ($10^6\ km^2$)[a]	0.83	1.78	2.99	2.54	2.46	0.65
MAAT (°C)	−0.4	0.7	1.4	−1.0	−6.5	−10.1
Mean slope ($m\ km^{-1}$)	2.93	2.23	1.28	1.94	1.83	2.16
SPM (10^6 t/y)[b]	60	124	15.5	4.7	20.7	10.1
Southernmost Lat. (°N)	58.8	52.2	45.3	45.7	52.2	60.6
Cont. permafrost (%)[a]	19	13	1	31	77	99
Deciduous BL forest (%)[c]	0.4	1.4	10.2	3.4	1.1	0.4
Evergreen NL forest (%)[c]	17.5	23.7	14.9	20.6	7.4	0.2
Deciduous NL forest (%)[c]	0	0	1.5	32.7	58.8	49.1
Mixed forest (%)[c]	1.9	9.2	12.0	10.6	4.9	0.2
Total forest (%)[c]	19.7	34.4	38.6	67.3	72.1	49.9
Forest – MODIS (%)[c]	26	35	25	35	32	10
Shrubland (%)[c]	19.2	10.5	2.6	9.0	12.5	32.1
Grassland (%)[c]	42.9	30.0	15.9	7.2	0.8	0.1
Cropland (%)[c]	0.3	2.4	22.9	6.2	0.6	0
Wetlands (%)[c]	0.4	0.1	8.5	2.6	3.3	3.8
Water bodies (%)[c]	7.0	10.3	2.4	2.1	1.7	1.6

For reference see: Modis VCF – http://glcf.umiacs.umd.edu/data/vcf/ and GLC – http://ies.jrc.ec.europa.eu/global-land-cover-2000 and http://bioval.jrc.ec.europa.eu/products/glc2000/products.php; MAAT = mean annual air temperature, BL = broad leaf, NL = needle leaf.
[a] Holmes et al. (2012).
[b] Holmes et al. (2002).
[c] We used both Modis vegetation continuous fields (VCF) data and global land cover (GLC) data to generate the vegetation statistics.

Amon *et al* 2011, GCA

Seasonality of Hydrology and C fluxes in major Siberian Rivers



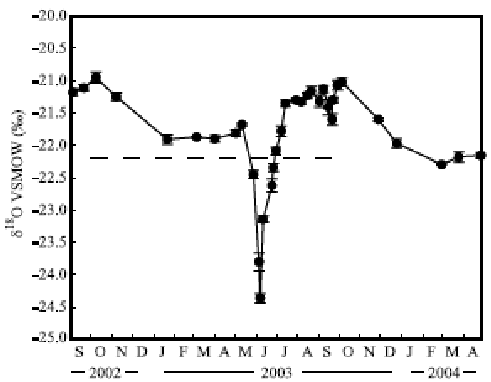
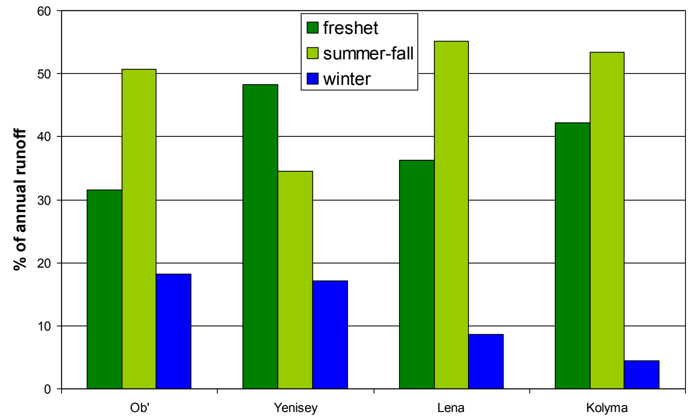
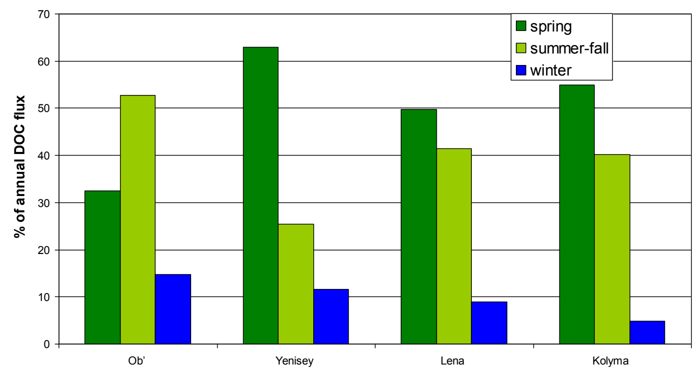


Figure 2. δ^{18}O of the Kolyma sampled at Cherskii, from September 2002 through April 2004. Error bars represent the analytical standard deviation of each sample. The *Q*-weighted mean for the one-year period from October 2002 to September 2003 was −22.2‰, marked by the dashed line.

Welp *et al* 2005, GRL

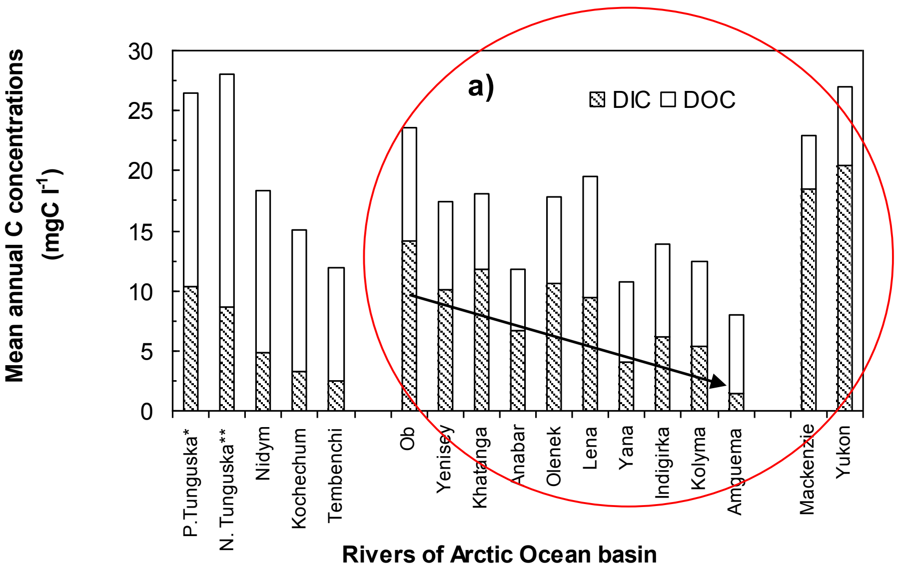


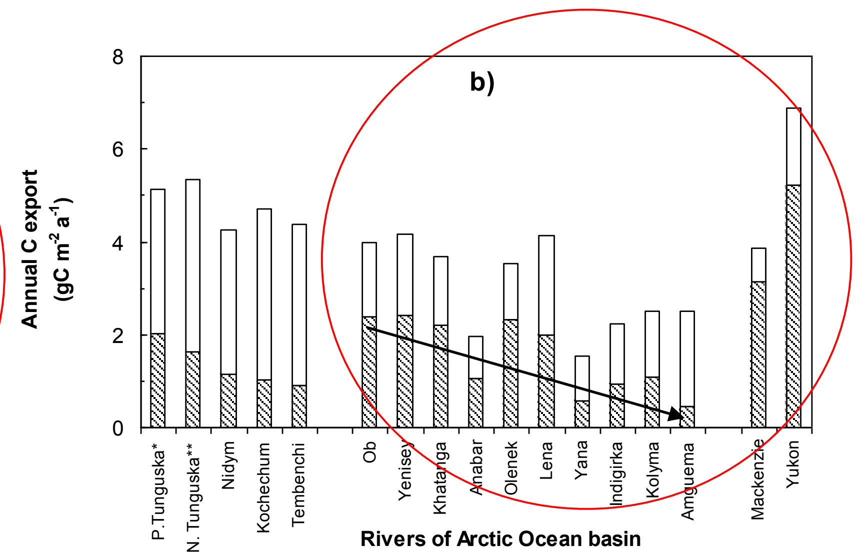


Freshet (May-June)
water flux: 30-50%
C flux: 30-60%
Holmes *et al* 2011 Estuaries and Coasts

Major Arctic Rivers Dissolved C: annual values

Gordeev *et al* 1996, 2009, Raymond *et al* 2007, Striegl *et al* 2007, Cai *et al* 2008, Cooper *et al* 2008, McGuire *et al* 2009, Holmes *et al* 2011, Prokushkin *et al* 2011, Amon *et al* 2011

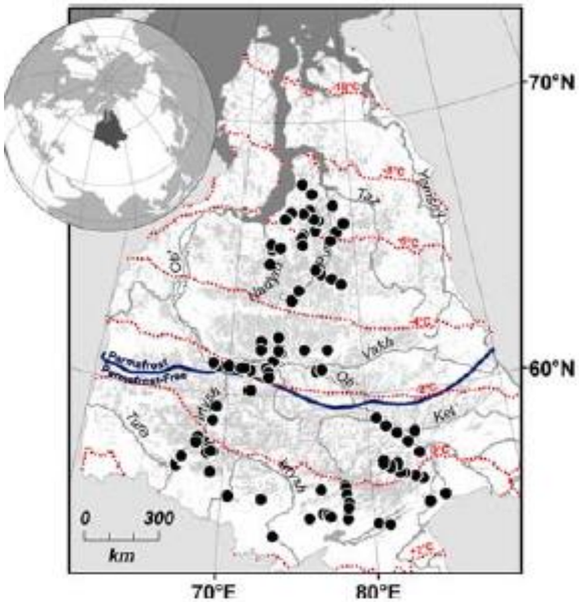




Decreasing trend of concentrations and annual fluxes from West to East, specifically for DIC

Limitation for response prediction:
-Data quality
-Different parent materials
-Disturbances

Case study in Western Siberia: Ob’ basin (Frey and Smith 2005, GRL)



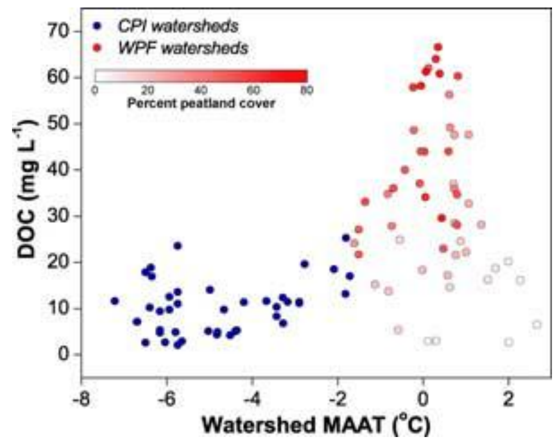


Figure 3. Dependence of DOC concentration on watershed MAAT. A sharp increase in concentrations occurs in watersheds with a MAAT warmer than −2°C. Low concentrations in WPF watersheds are due to sparse peatland coverage.

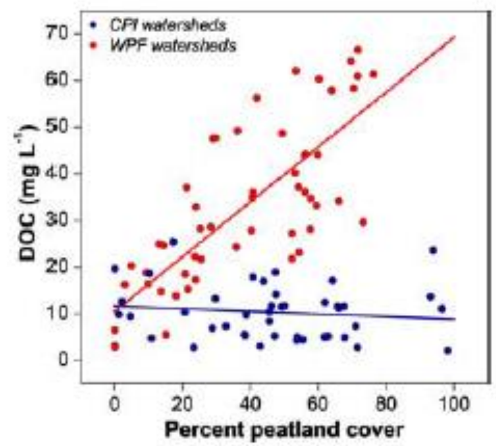


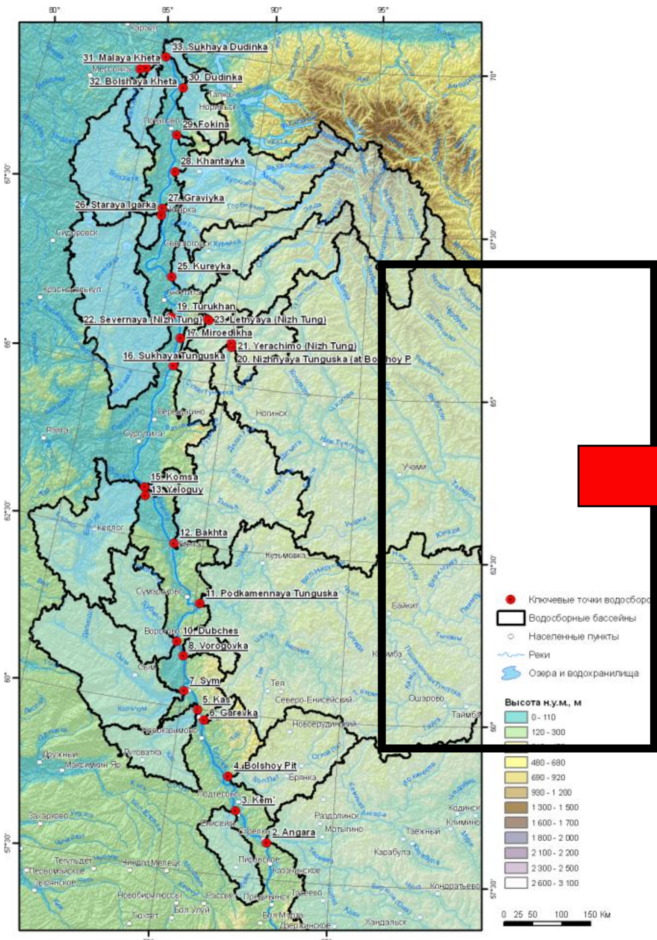
Figure 2. Dependence of DOC concentration on the percent peatland cover ($P_{\%}$) within the sampled watershed. Concentrations in cold permafrost-influenced (CPI) watersheds are uniformly low, with a mean value of 10.29 mg L^{-1} and no statistically significant correlation with $P_{\%}$ ($DOC_{CPI} = -0.03 \cdot P_{\%} + 11.62$; $p = 0.42$; $r^2 = 0.02$). However, concentrations in warm permafrost-free (WPF) watersheds rise significantly with $P_{\%}$ ($DOC_{WPF} = 0.59 \cdot P_{\%} + 10.42$; $p < 0.0001$; $r^2 = 0.60$).

Projected “~2.7–4.4 Tg yr^{-1} increase in terrestrial DOC flux (from ~9.2 Tg yr^{-1} to ~11.9–13.5 Tg yr^{-1}) from West Siberia to the Arctic Ocean by 2100.

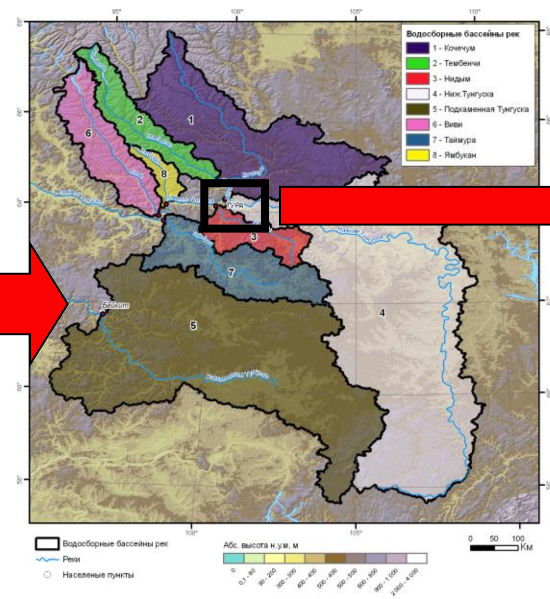
These estimates are in fact conservative if DOC concentrations peak during spring flood. Furthermore, if the recently observed increases in Siberian precipitation [Serreze et al., 2000; Frey and Smith, 2003] and river discharge [Peterson et al., 2002; Wu et al., 2005] continue, even larger increases are likely.”

Central Siberian River basins and study goals

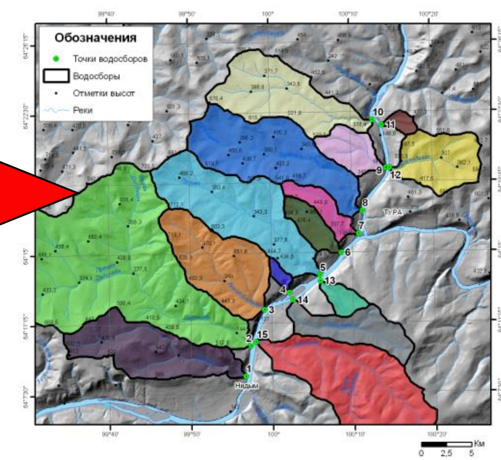
Yenisey River basin



Central Siberian Plateau river basins



Stream basins within Nizhnyaya Tunguska river watershed

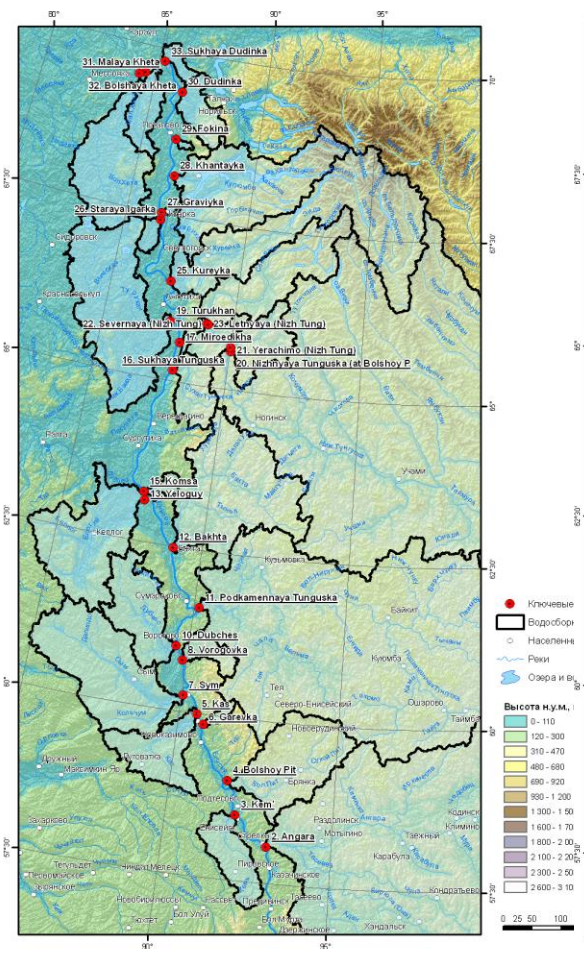


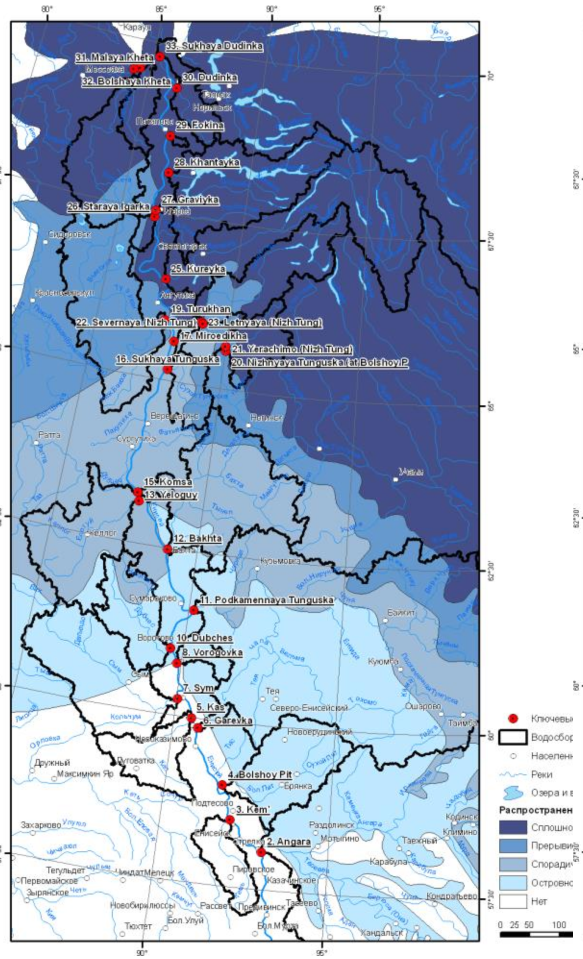
Gradients:
Climate, permafrost, vegetation, parent rocks

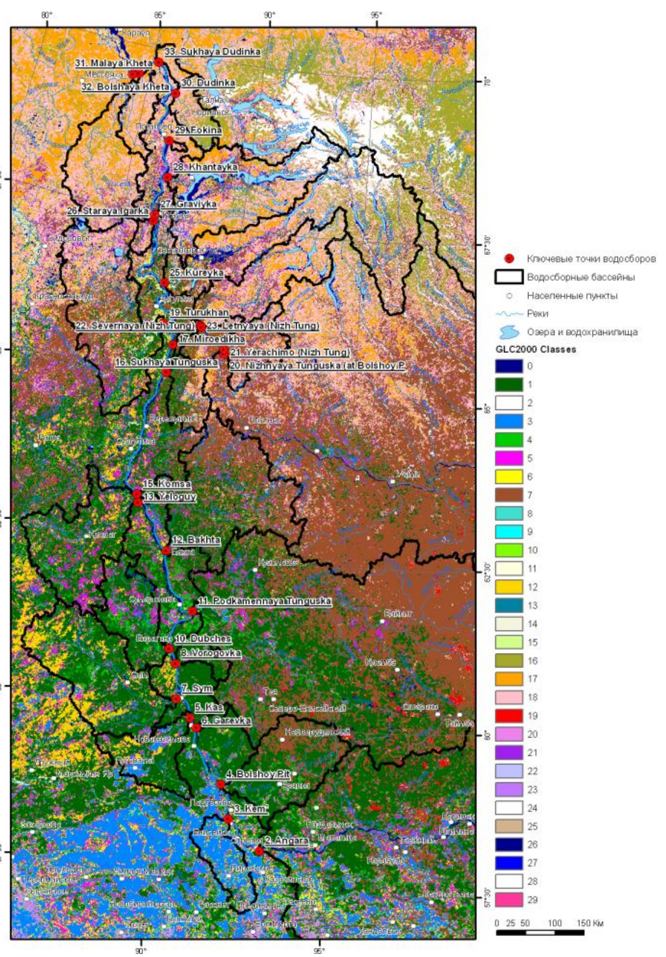
Gradients:
Climate, permafrost, vegetation,
SIMILAR parent rocks (Siberian basalts)

Gradients:
Fire history (burned 0, 4, 20, 50 and >100 years), permafrost, vegetation, size,
SIMILAR: climate, parent rocks (Siberian basalts)

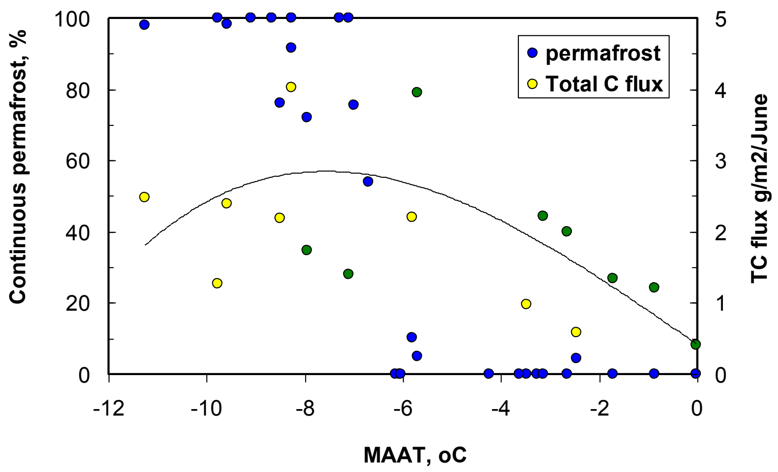
Yenisey River basin characteristics



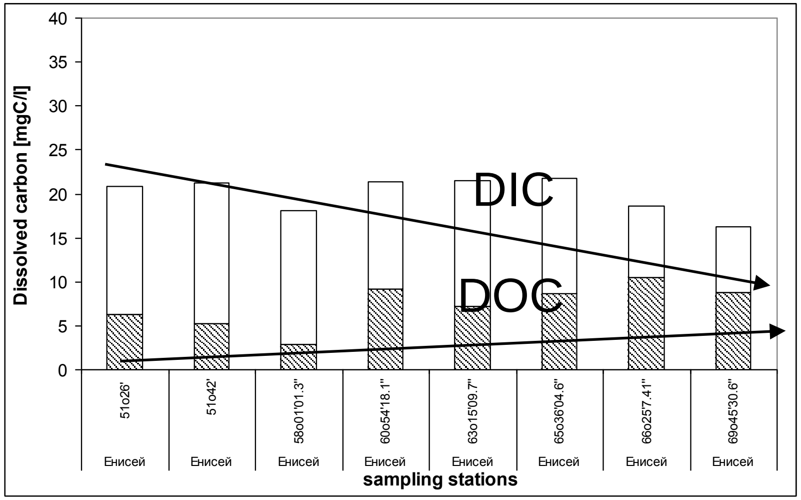




Yenisey basin: DOC and DIC

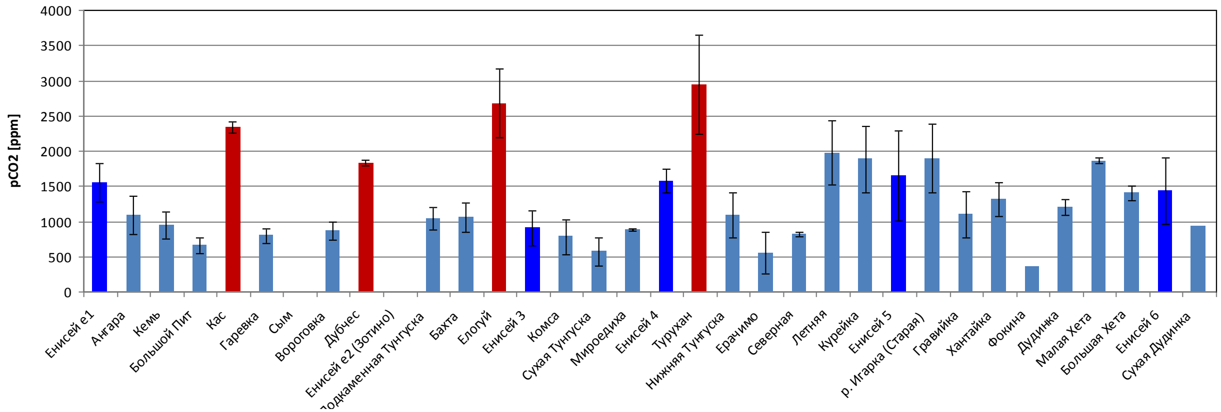


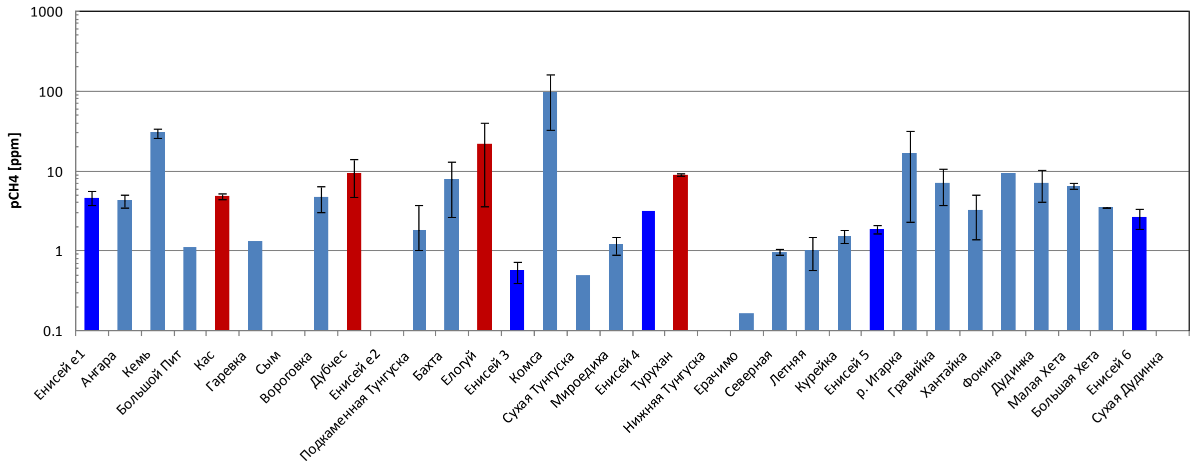
Cryohydromorphic landscapes of 61-65^{o}N latitude zone produce elevated C fluxes



Total C flux in Yenisey River from South to North shows substitution of IC to OC

Yenisey basin: dissolved gases





River flows showed supersaturation by GHG (relative to atmospheric levels), reflecting large flux of C to the Arctic Ocean in gaseous form

River basins of Central Siberian Plateau

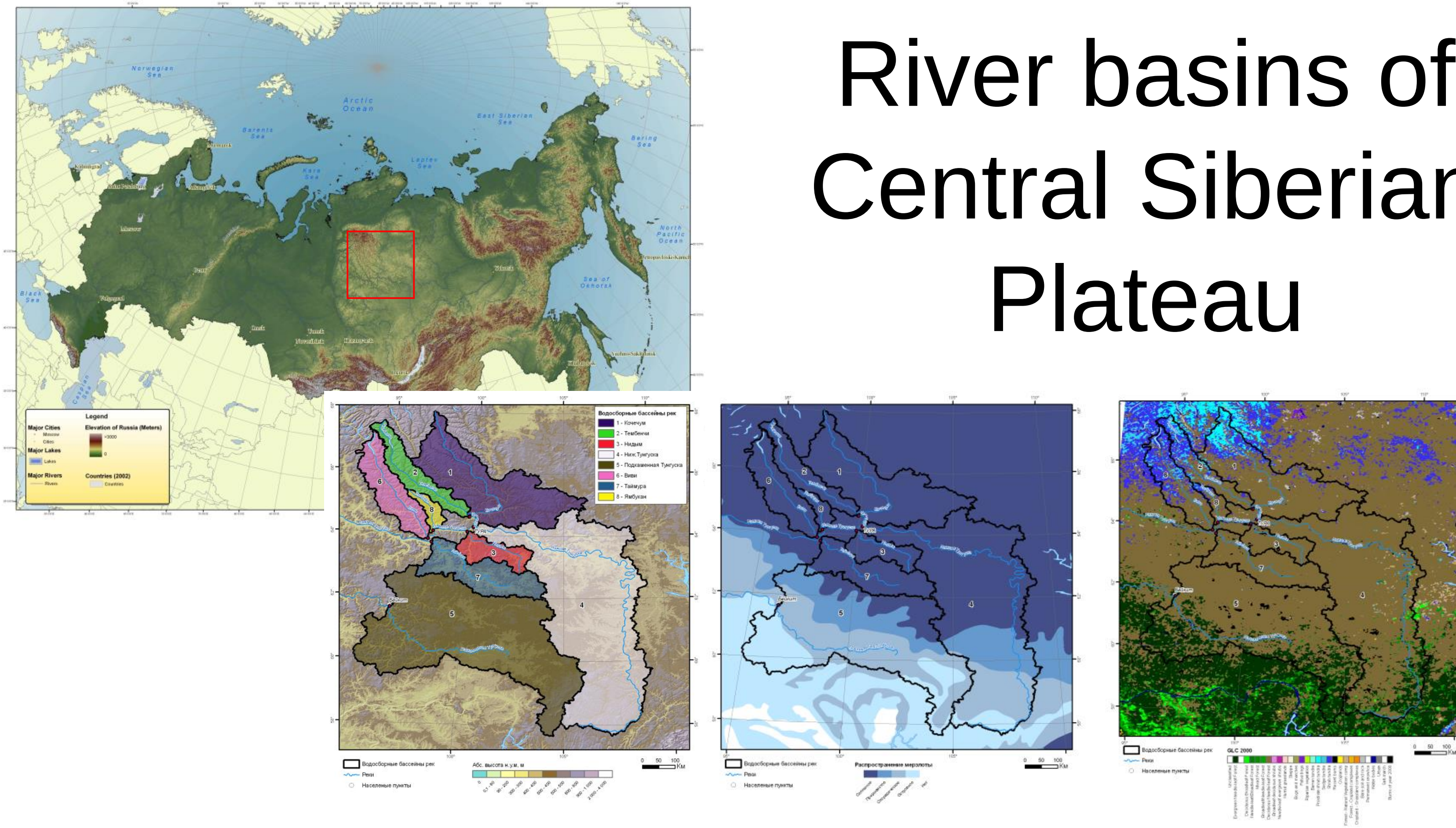


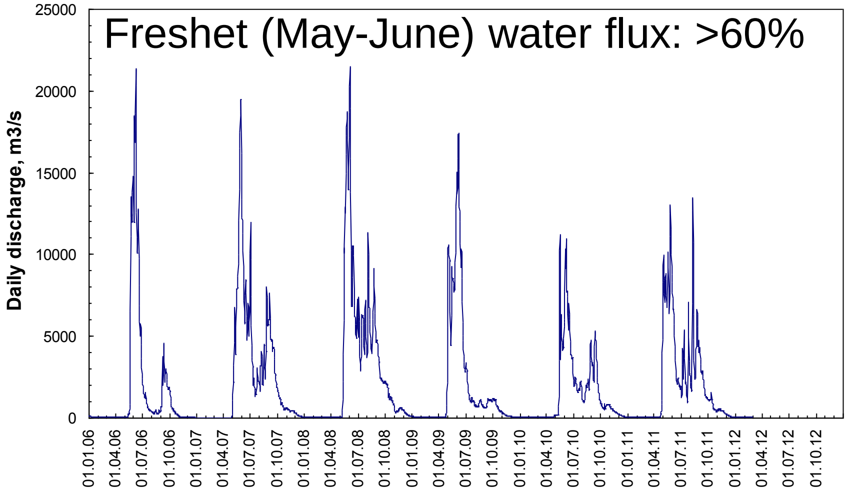
Table 1. Geographical, climatic, vegetation and geomorphological characteristics of the different river/watershed systems.

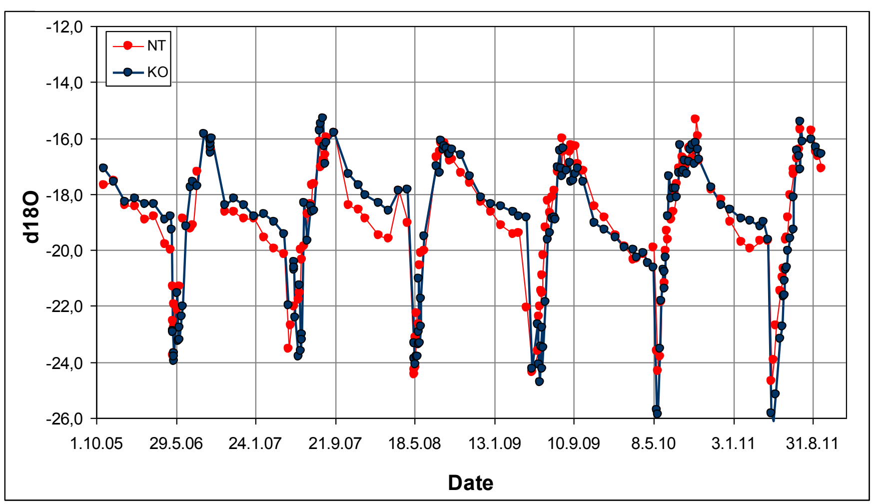
River name (sampling station)		Coordinates of river mouths (sampling station)		MAP[a] (mm)	MAAT[a] (°C)	Basin area, 10^3 km^2	Mean annual discharge (km^3 a^{-1})	Permafrost distribution[b] C	D + S	I	Vegetation cover[c] (%) Tundra	Forest
Tembenchi (f. Tembenchi)	TE	64°36′33″	99°55′19″	465	−10.92	22.4	7.9	100	0	0	53	45
Kochechum (Tura)	KO	64°17′10″	100°11′37″	386	−10.92	96.4	29.9	100	0	0	30	69
Nidym	ND	64°07′12″	99°57′52″	399	−8.80	14.7	3.3	100	0	0	3	91
Nizhnyaya Tunguska (Tura)	NT	64°16′14″	100°15′16″	380	−7.46	174.3	51.0	62	34	5	2	95
Podkamennaya Tunguska (Baikit)	PT	61°39′00″	96°24′01″	431	−6.28	163.1	30.7	15	46	39	1	94

[a] 0.5° × 0.5° grid data for entire watershed (2001–09, CRU TS3.1, Mitchell and Jones 2005).
[b] C—continuous, D + S—discontinuous and sporadic, I—isolated patches permafrost (Brown *et al* 1998).
[c] Aggregated classes according to GLC2000 (Bartholomé and Belward 2005).

Prokushkin et al 2011, ERL

Hydrology of rivers of Central Siberian Plateau





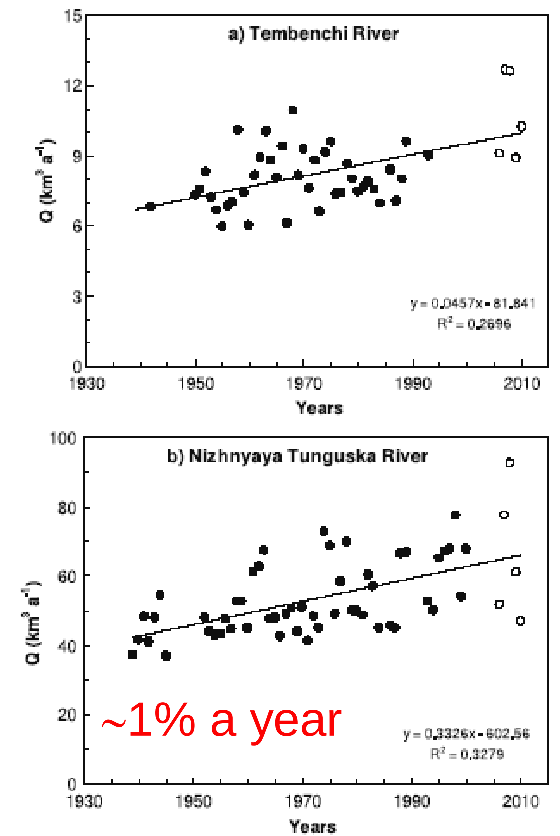
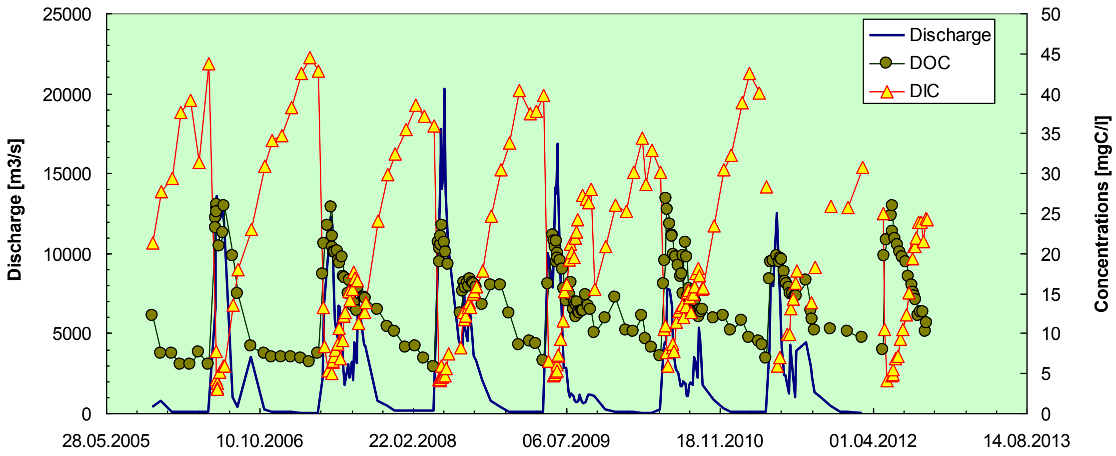


Figure 3. Changes of annual runoff (Q) of (a) Nizhnyaya Tunguska and (b) Kochechum Rivers during 1939–95 (www.r-arcticnet.sr.unh.edu/v4.0/main.html). White dots represent the period of this study (2006–10, data of Srednesibirskoe UGMS, Krasnoyarsk).

Prokushkin *et al* 2011, ERL

Dissolved carbon in Central Siberia



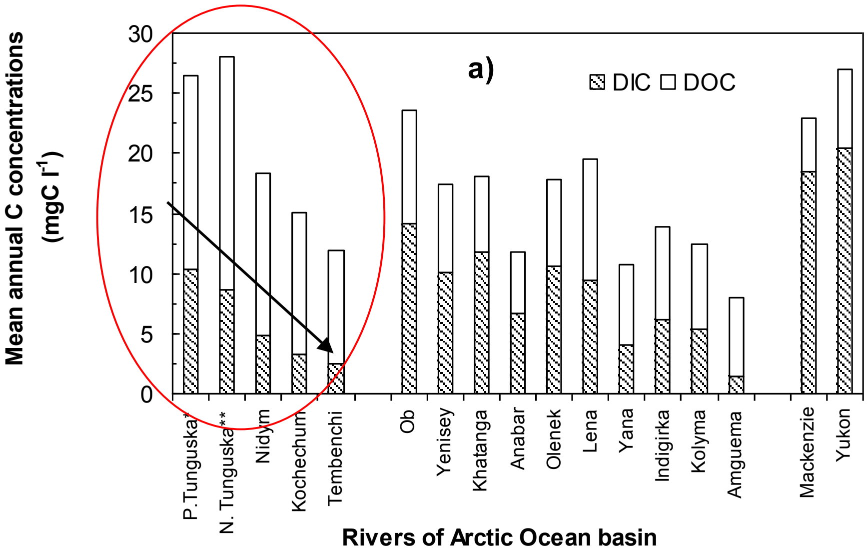
Freshet (May-June)
55–71% for water runoff
64–82% for DOC
37–41% for DIC

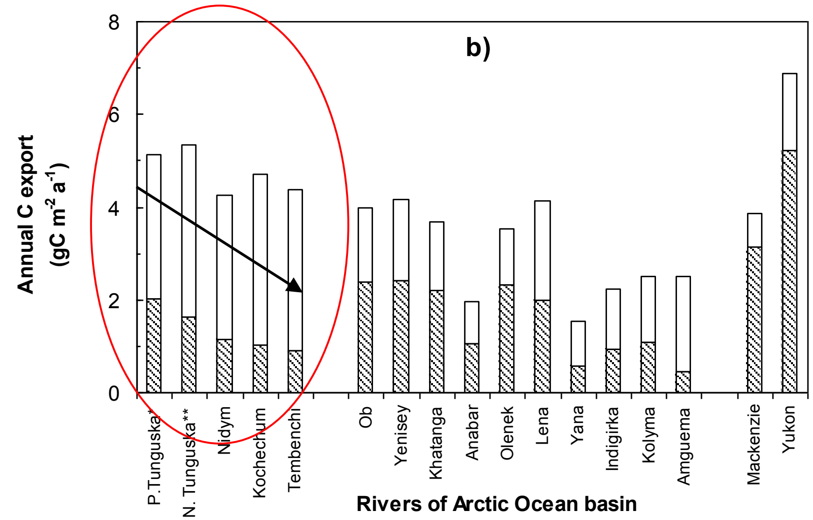
Temporal and Spatial variation of DOC, DIC:

Dominance of snowmelt season and increased flux in wet years

Large differences in amounts of DIC and DOC among rivers (for DIC causes are still questionable)

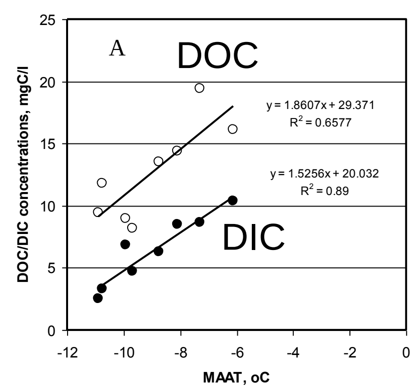
Dissolved carbon in rivers of Central Siberian Plateau

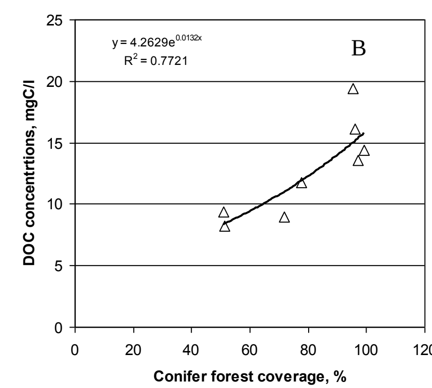




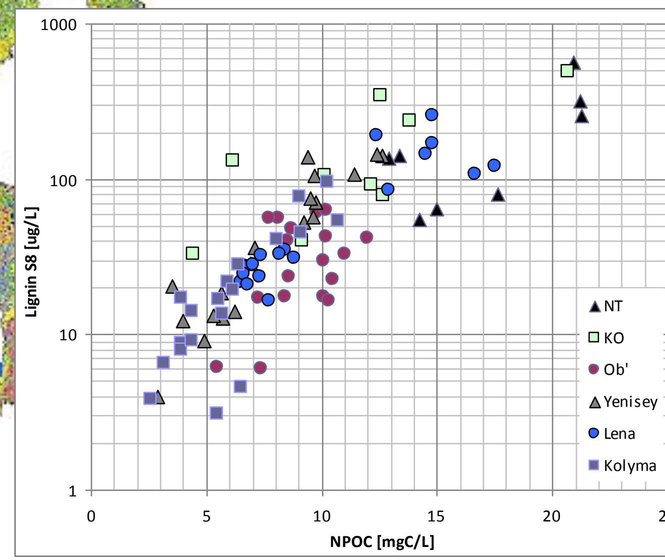
Decreasing trend of concentrations and annual fluxes from South to North

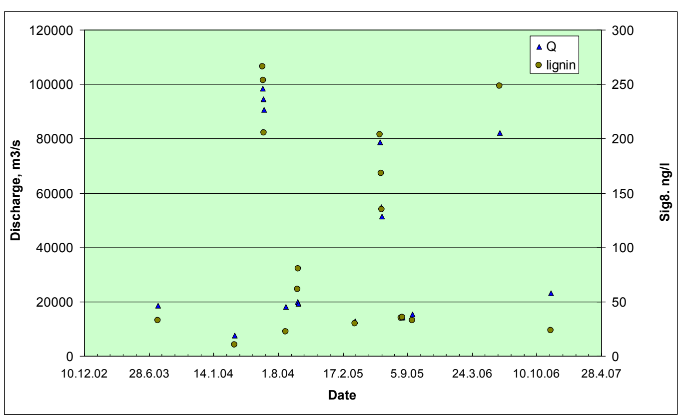
Positive correlation with MAAT, forested areas (Prokushkin *et al* 2011, ERL)

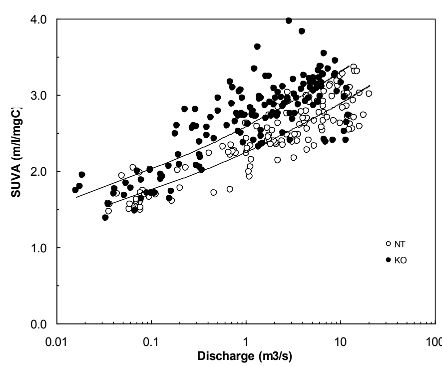




Coniferous forests are the major source of DOC!

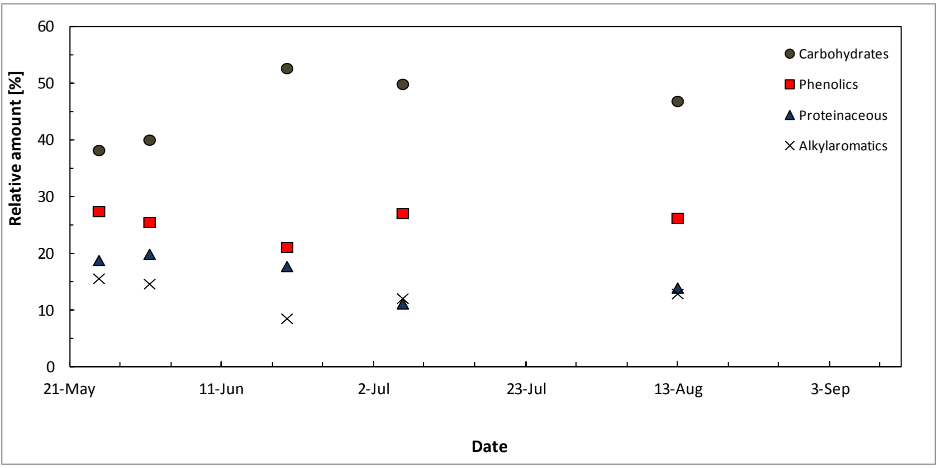


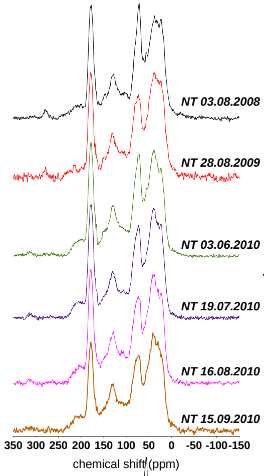


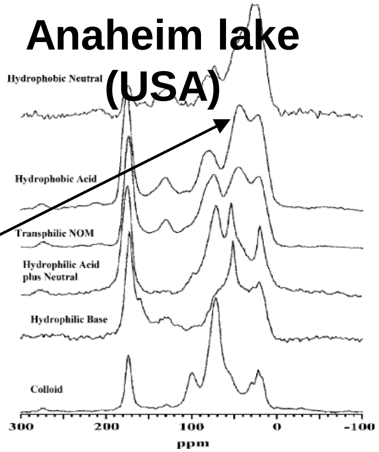


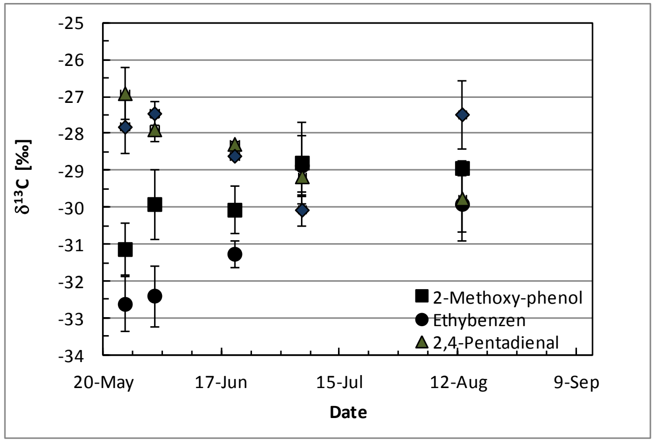
Data:
ArcticGRO, PARTNERS
(http://www.arcticgreatrivers.org/data.html)
Prokushkin et al unpublished

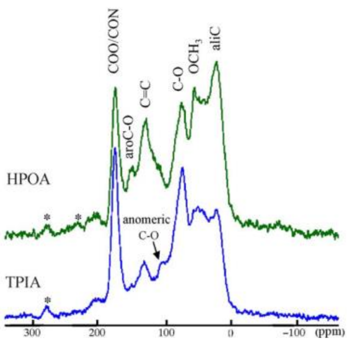
DOC composition (unexplained patterns): Pyr-GC/MS-IRMS, ^{13}C NMR CP MAS data

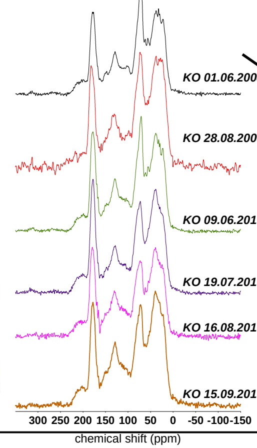


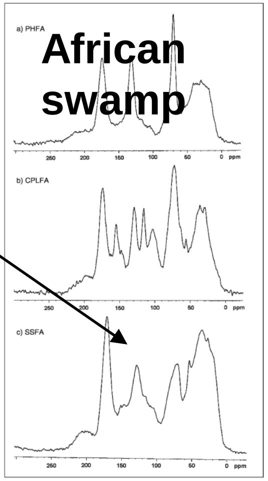






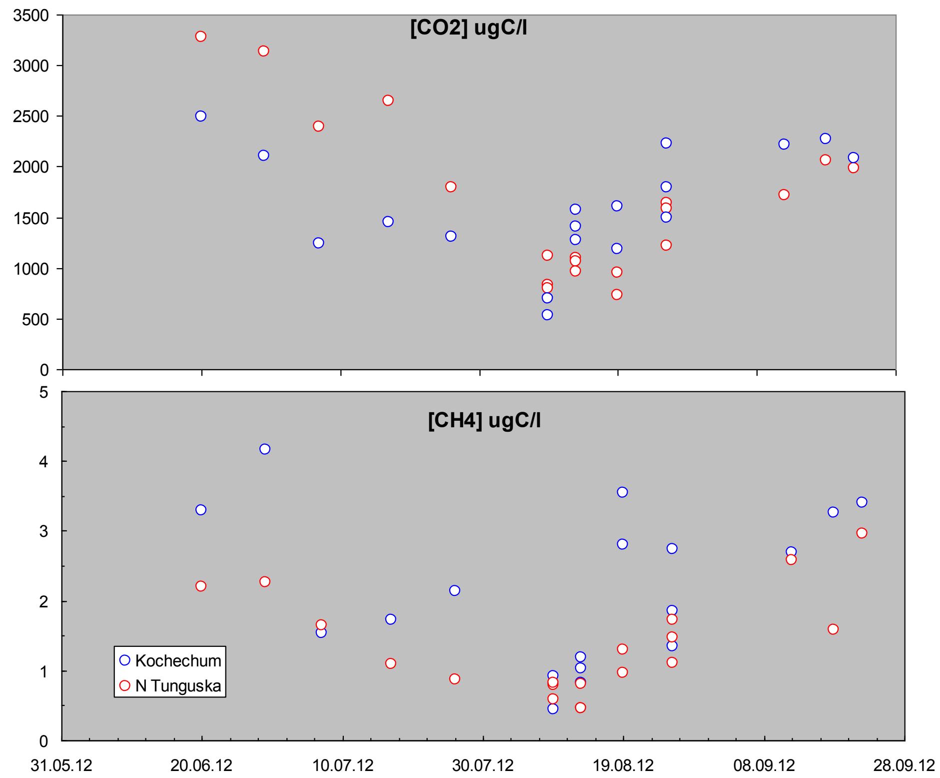






- Surprisingly little seasonal and geographic variation in riverine DOM composition
- Large temporal changes in ^{13}C signature of individual compounds

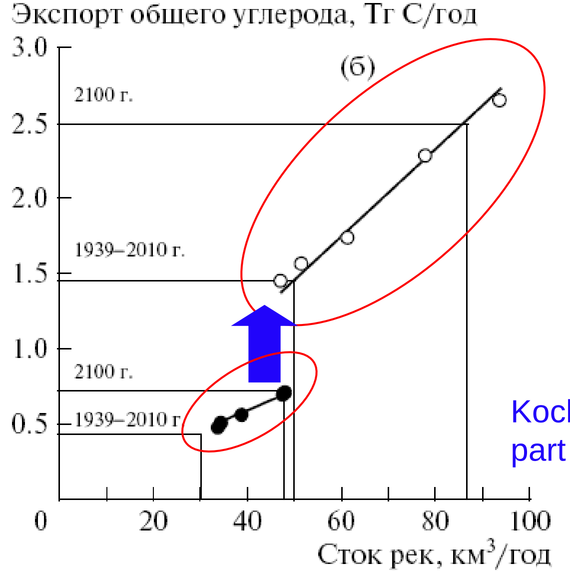
Dissolved GHG



River waters are supersaturated with GHG

Dissolved GHG is important portion in total C flux (~10% of total DC)

Future of C export from Central Siberian Plateau



N Tunguska River: the Southern part of Central Siberian Plateau

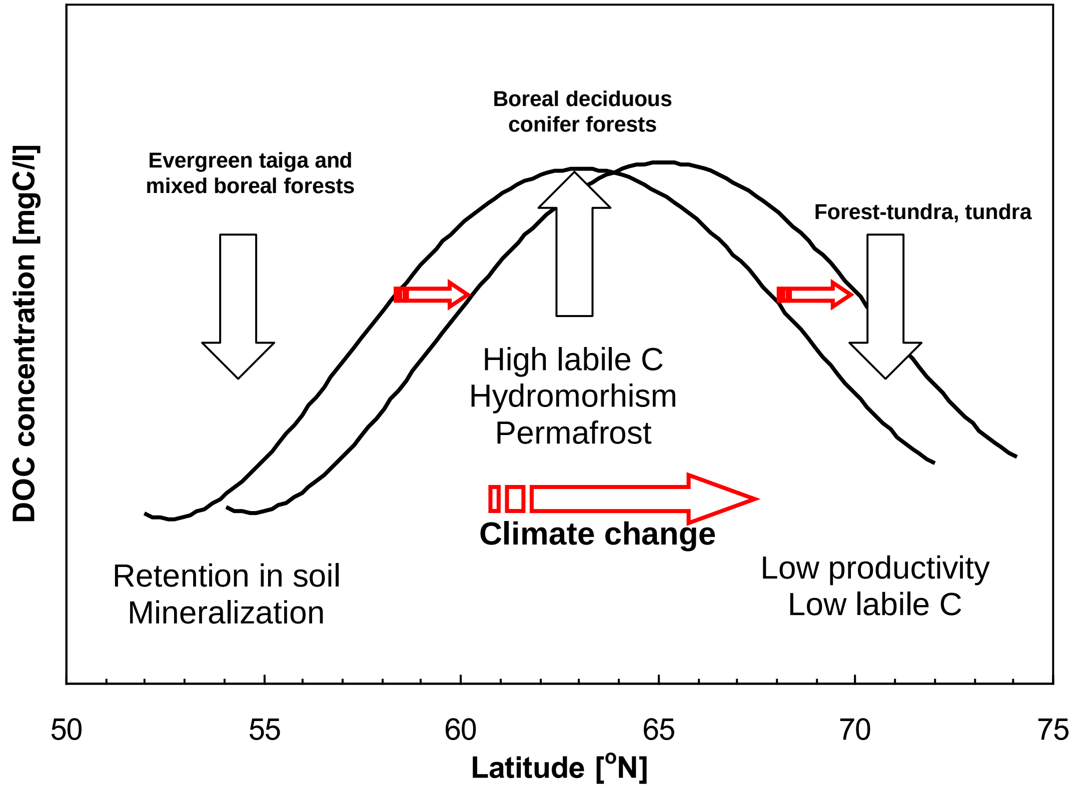
Kochechum River: the Northern part of Central Siberian Plateau

Only projected increase in water flux to 2100 (e.g. 0.33 km^3/year/year for N Tunguska River) may almost double terrestrial C export to rivers

Together with an increase in NEP/terrestrial C accumulation of Northern territories it may increase total C flux up to 700% of current values (e.g. Gordeev and Kravchishina, 2009, Frey and Smith, 2005)

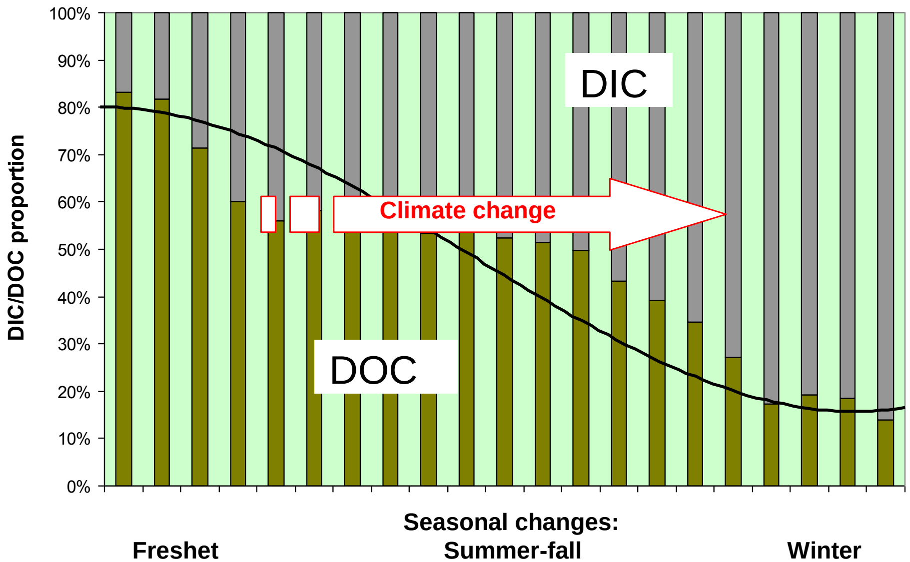
Prokushkin *et al* 2011, Doklady Earth Sciences

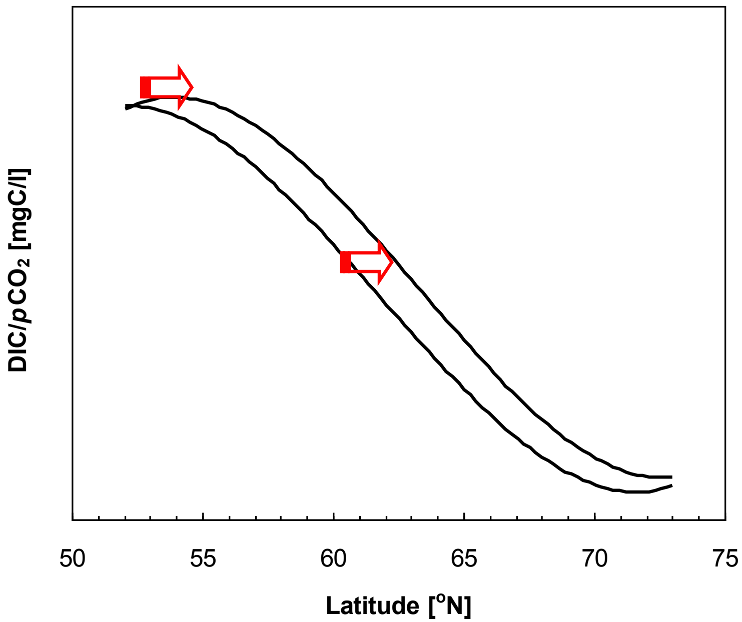
DOC behavior concept: latitude



Gymnosperm vegetation (the middle of boreal belt) is the primary source of DOC in Arctic rivers (A. Myers-Pigg *et al* submitted).

DOC/DIC/pCO_2 behavior





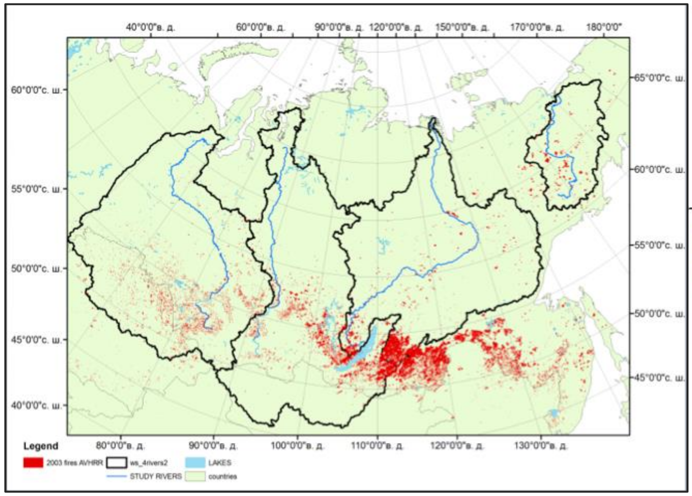
Retention in soil, DOC mineralization and rock weathering rates tend to increase

Result: substitution of DOC for DIC in total carbon flux

(TC changes might be negligible (Striegl et al., 2005, 2007))

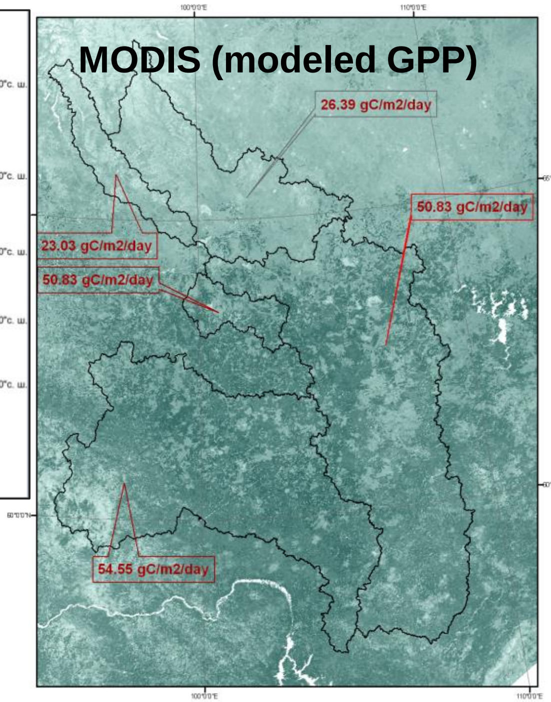
Wildfire effects

ca. 1% of territory burned annually

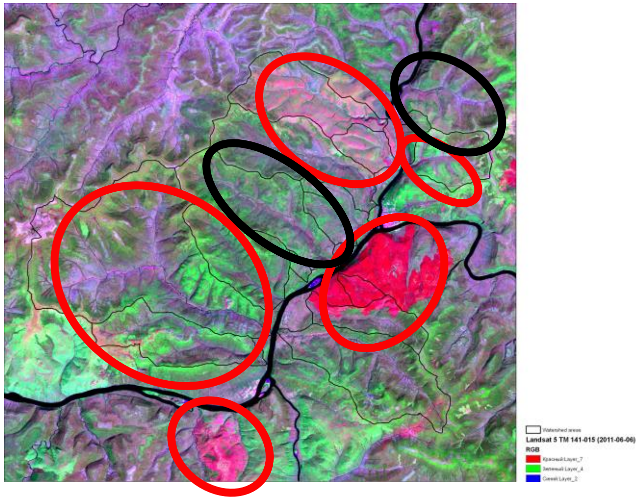


Major Siberian Rivers:

Fire year of 2003



Central Siberian Rivers



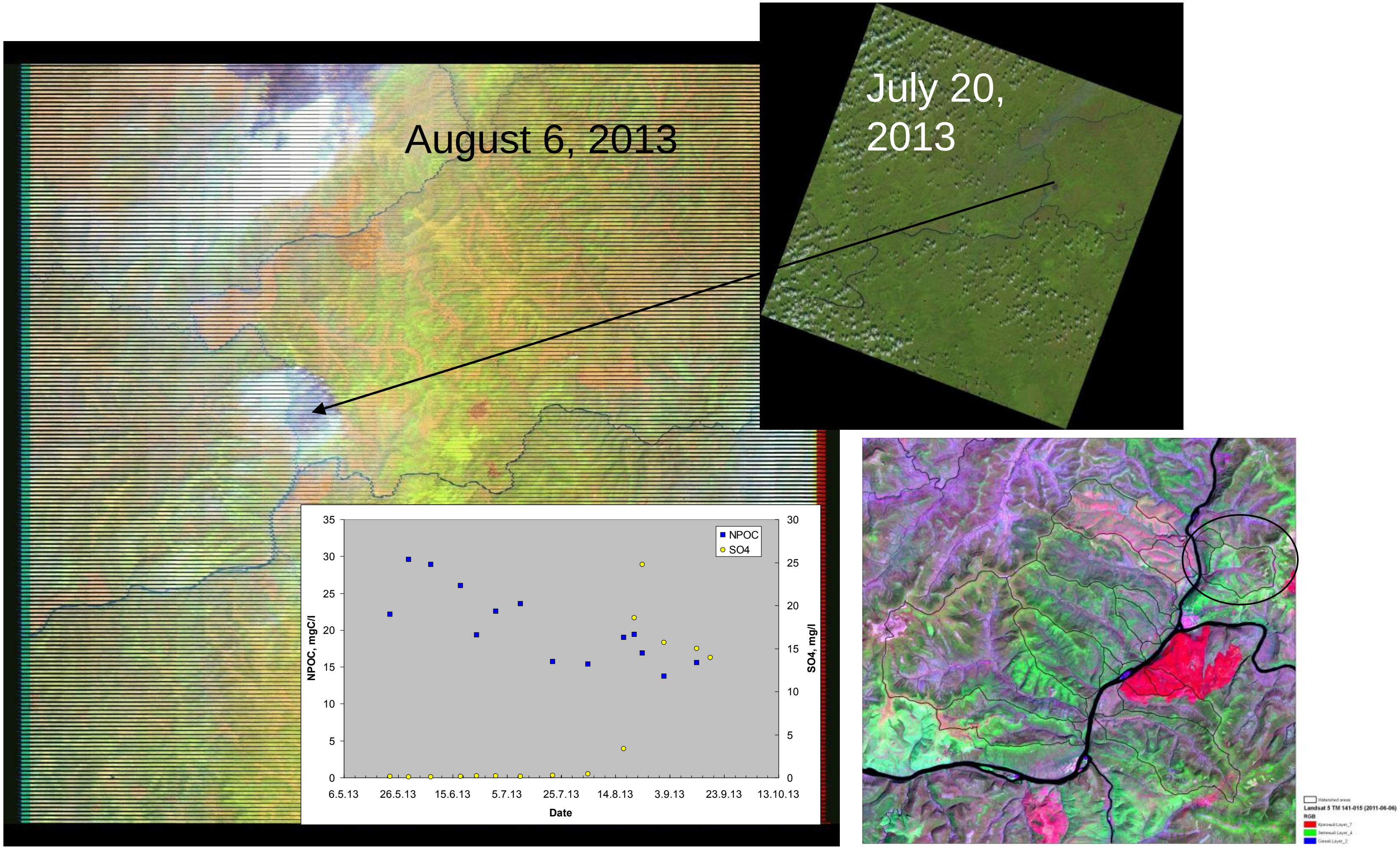
Central Siberian streams

burned 4, 20, 65 and >100 years ago

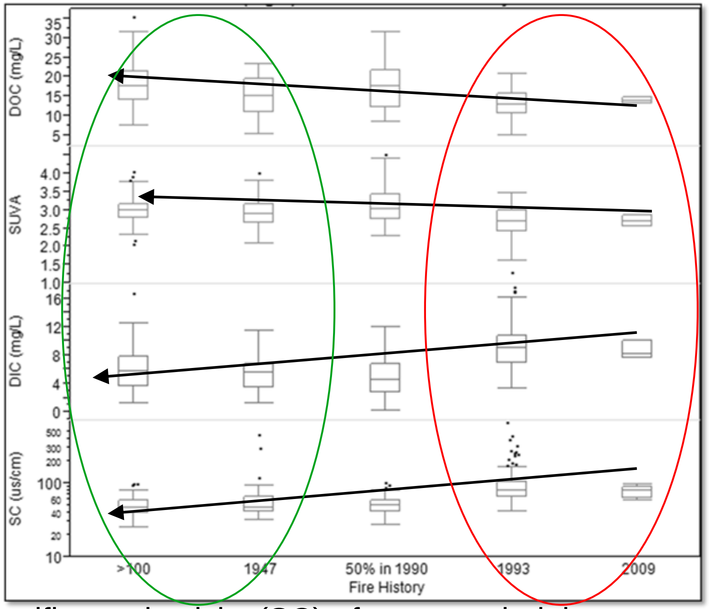
Fire scars demonstrate low NPP:

territories have potentially higher DOC production at no fire scenario

2013…


August 6, 2013
July 20, 2013
NPOC
SO4
NPOC, mgC/l
SO4, mg/l
Date
35
30
25
20
15
10
5
0
6.5.13
26.5.13
15.6.13
5.7.13
25.7.13
14.8.13
3.9.13
23.9.13
13.10.13

Stream C fluxes in post fire chronosequence

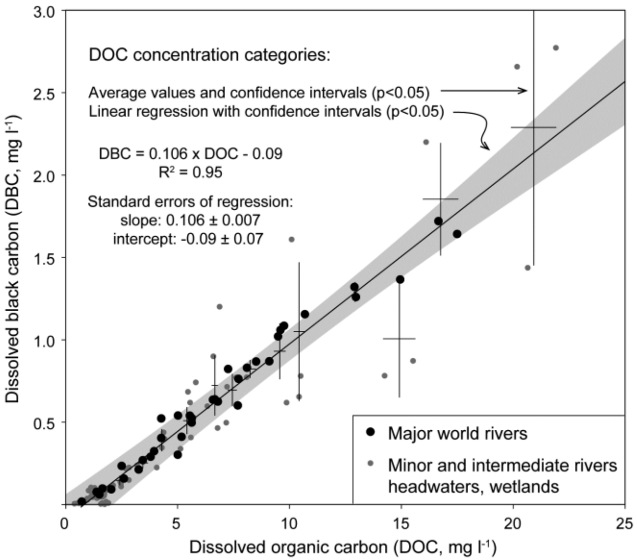


Changes in DOC, SUVA, DIC and specific conductivity (SC) of streams draining watersheds of different fire history. Note log scale for SC. Parham *et al*, 2013, submitted to Biogeochemistry

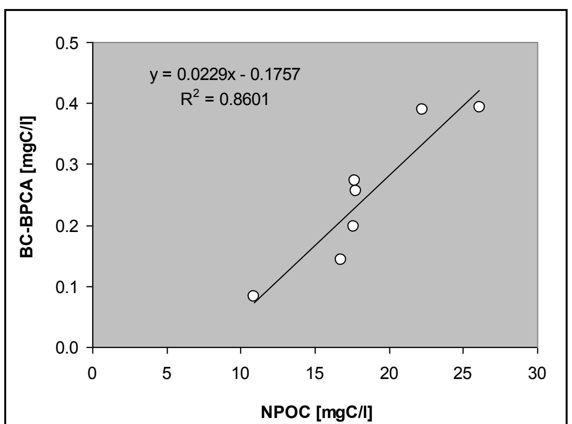
Fires combusting OM and deepening the ALT
- decrease DOC release from basins,
- increase the release of DIC and other inorganic solutes
- change in DOM composition (e.g. lower aromaticity of released DOC)

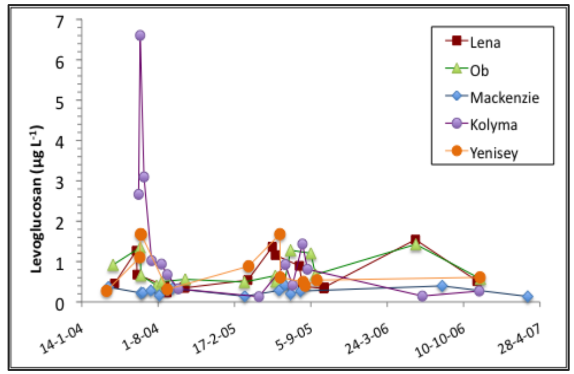
Recovery of ecosystem structure in ca. 50 years after a fire coincides with the recovery of stream C fluxes

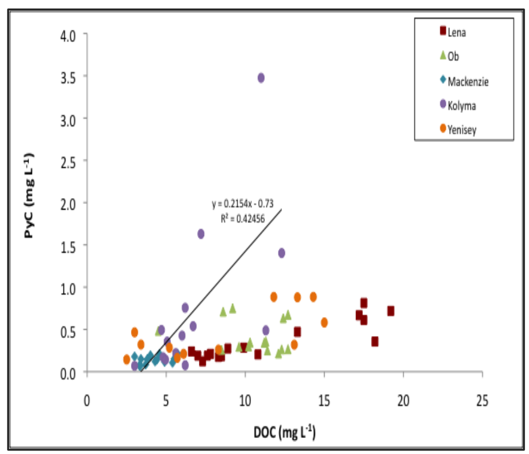
Pyrogenic carbon (dissolved black carbon, DBC) is intrinsic component of Siberian riverine DOC



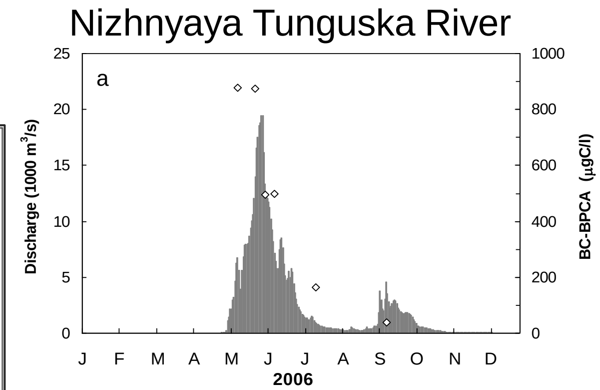
DBC versus DOC concentrations of global rivers.
Jaffé et al 2013, Science

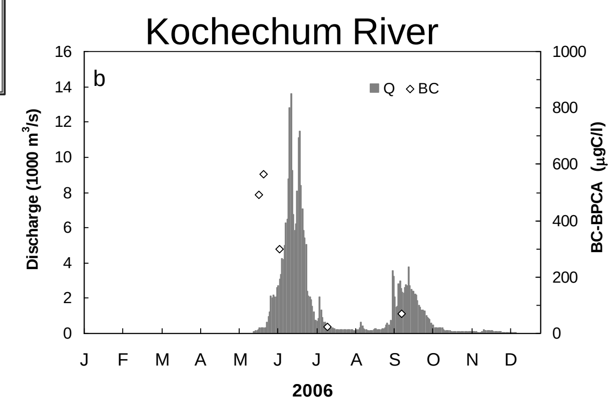






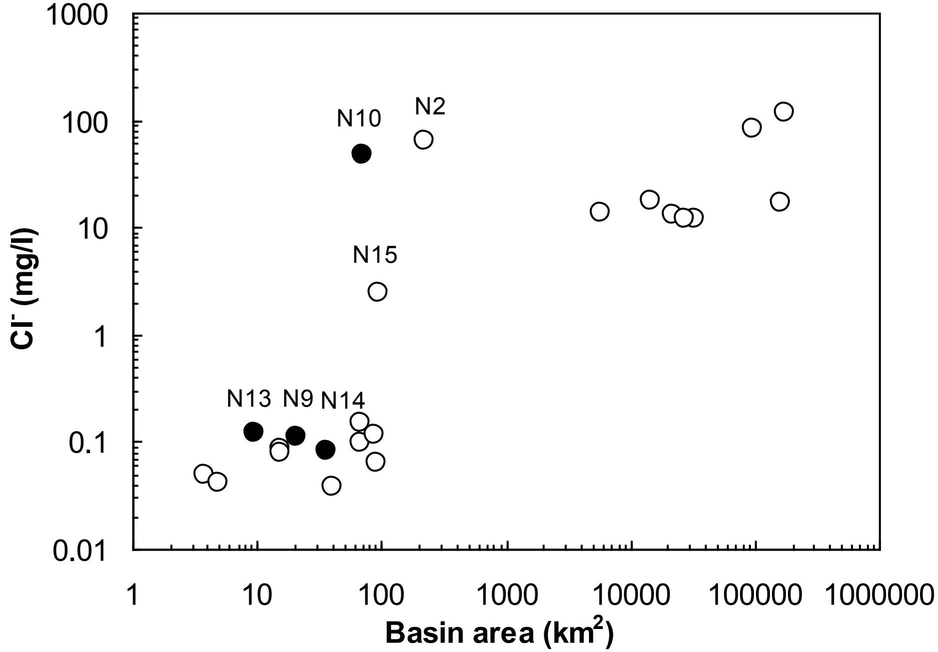
DBC versus DOC concentrations of Siberian rivers.
Myers-Pigg *et al* 2013, ASLO meeting





DBC concentrations in rivers of Central Siberian Plateau.
Prokushkin *et al*, unpublished

Indicators of permafrost degradation



Evaporite signal as NaCl/CaCl2 appeared in river/stream waters through "through taliks" and wildfires may accelerate this process

Parham *et al*, 2013, Biogeochemistry

Wildfire effect

Implication for C export:

- Combustion products of terrestrial OM constitutes up 8% of DOC in Siberian rivers
- Combustion of C source leads to decreased DOC production in terrestrial ecosystems and lower release to rivers
- Deepen active layer leads to higher retention of DOC in soils and lower DOC release, but higher mineralization and weathering rates cause elevated DIC flux
- DOC flux from large Siberian rivers can be potentially larger with no fire scenario

Conclusions

- Rivers draining Siberia demonstrate significant potential to increase the release of terrestrial carbon to the Arctic Ocean. Increased hydrological C losses are projected through:

(i) enhancement of temperature-controlled DOC, DIC, POC and CO_2 production processes within watersheds;

(ii) raised precipitation, thereby increasing C mobilization from organic-rich layers;

(iii) introduction of a new source of C as NEP increases/vegetation shifts northward and

(iv) release of old C from degrading permafrost

Increased DOM (C,N and P) input may significantly change NPP in river, estuarine and ocean ecosystems

Dry scenario of warming in high latitudes undoubtedly leads to decreased terrestrial C export due to:

- inhibition of DOC production in terrestrial ecosystems and less DIC and pCO_2/pCH_4 transport
- shorten fire return interval, removing the source of OC in terrestrial ecosystems

Thank you for attention!

Acknowledgements

Thanks all colleagues from IF SB RAS, GET-CNRS, MPI-BGC, TAMUG, Uni Hannover, FFPRI and others for joint field and laboratory works and constructive discussions.

Themes for working groups

- 1. Compare C concentrations and fluxes by major Siberian rivers: spatial patterns and different estimates...
- 2. Calculate flow-weighted mean annual C concentrations for Siberian rivers.
- 3. Analyze elements bound to DOC
- 4. Calculate seasonal C fluxes