Sediment delivery towards the Lena River delta: quantification and environmental implications

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The Lena River delta: An accumulative environment

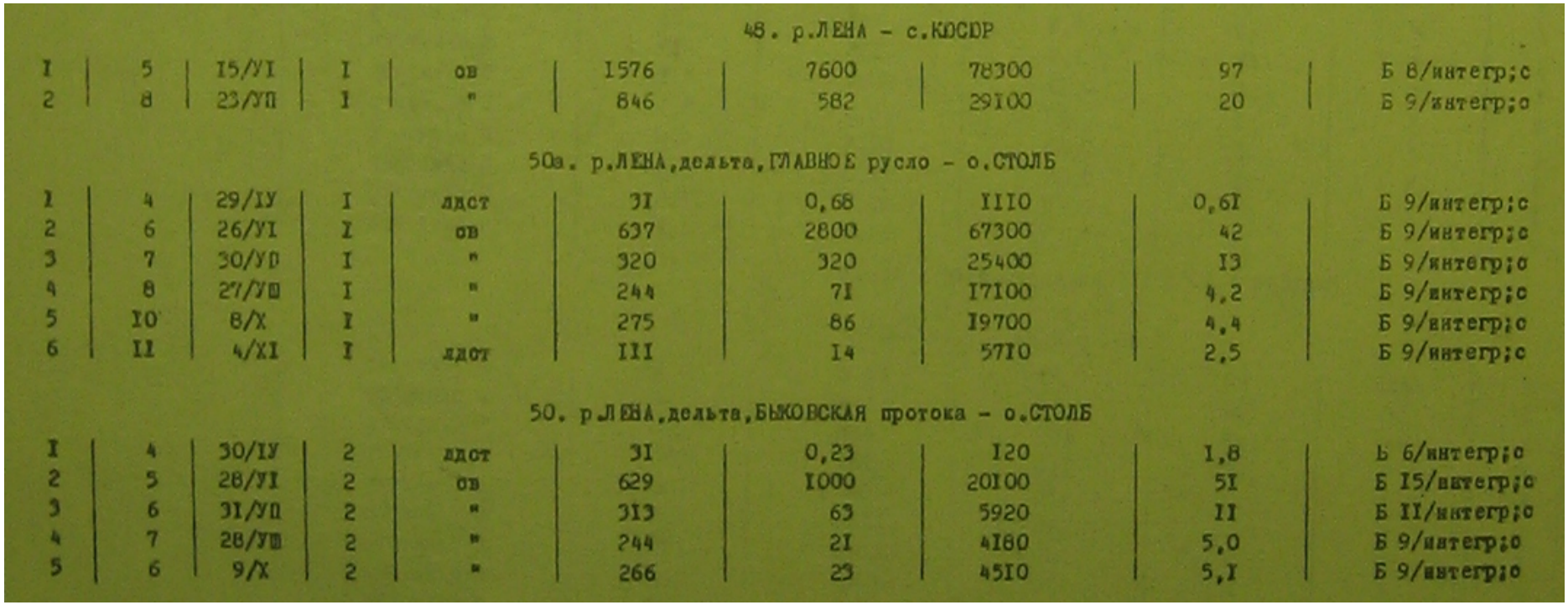
Sediment transfer: “a jerky conveyor belt” [Walling, 1983]

- How we define ‘sediment concentration’?
- How (when, where) we measure sediment concentrations and fluxes?
- How the data are treated?
- How the data are published, stored and retrieved?
- How the data are used in flux calculations?

Suspended sediment data

- Virtually unavailable
- Mostly historical
- Scarce
- Inaccurate
- GS Kyusyur:

17 years, 71 obs.



48. р.ЛЕНА – с.КЮСЮР

I	5	I5/УI	I	ов	I576	7600	78300	97	Б 8/интегр;с
2	8	23/УП	I	"	846	582	29100	20	Б 9/интегр;с

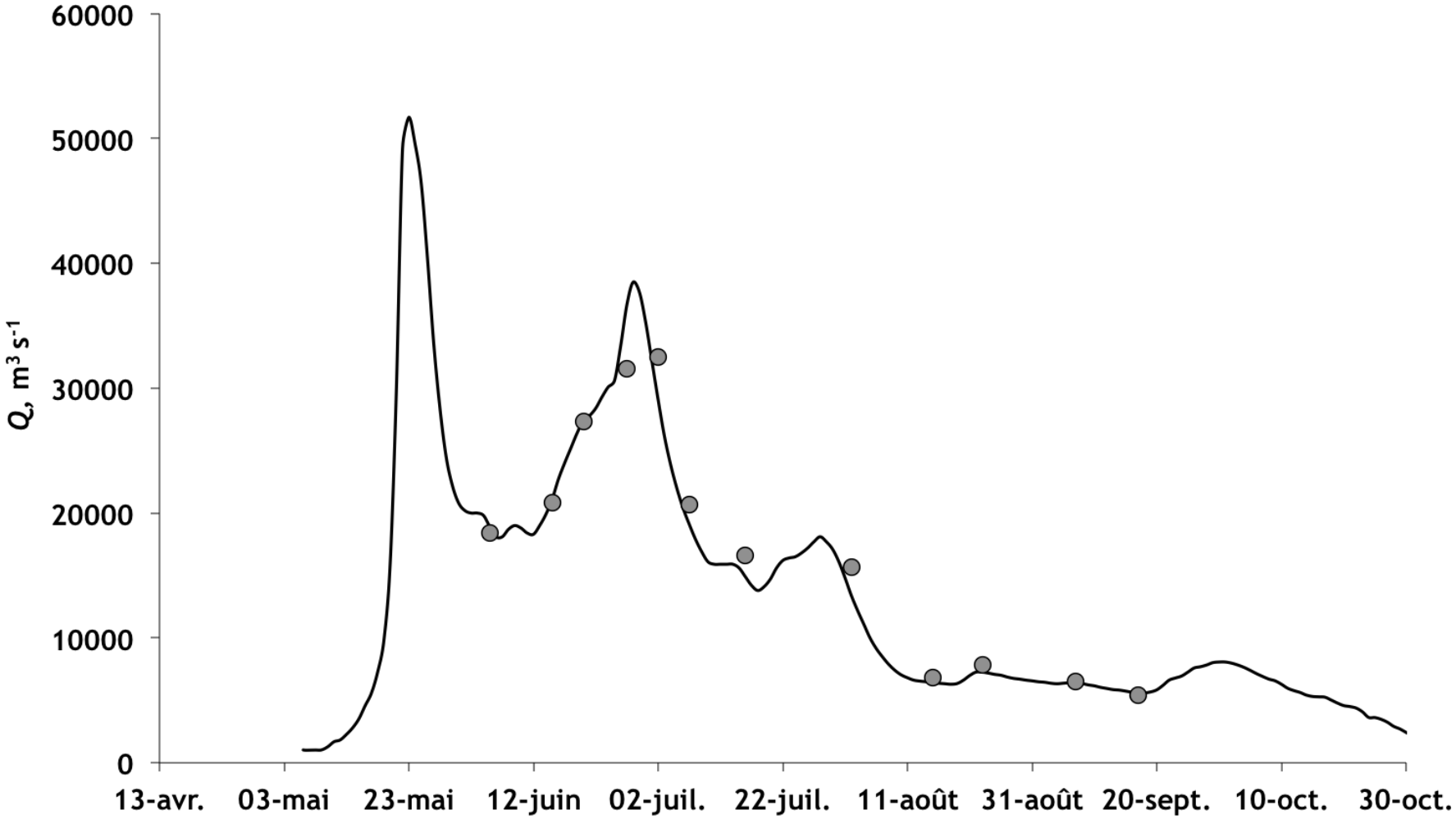
50а. р.ЛЕНА,дельта,ГЛАВНОЕ русло – о.СТОЛБ

I	4	29/IУ	I	адст	3I	0,68	IIIO	0,6I	Б 9/интегр;с
2	6	26/УI	I	ов	637	2800	67300	42	Б 9/интегр;с
3	7	30/УП	I	"	320	320	25400	I3	Б 9/интегр;с
4	8	27/УШ	I	"	244	7I	I7100	4,2	Б 9/интегр;с
5	I0	8/Х	I	"	275	86	I9700	4,4	Б 9/интегр;с
6	II	4/XI	I	адст	III	I4	57I0	2,5	Б 9/интегр;с

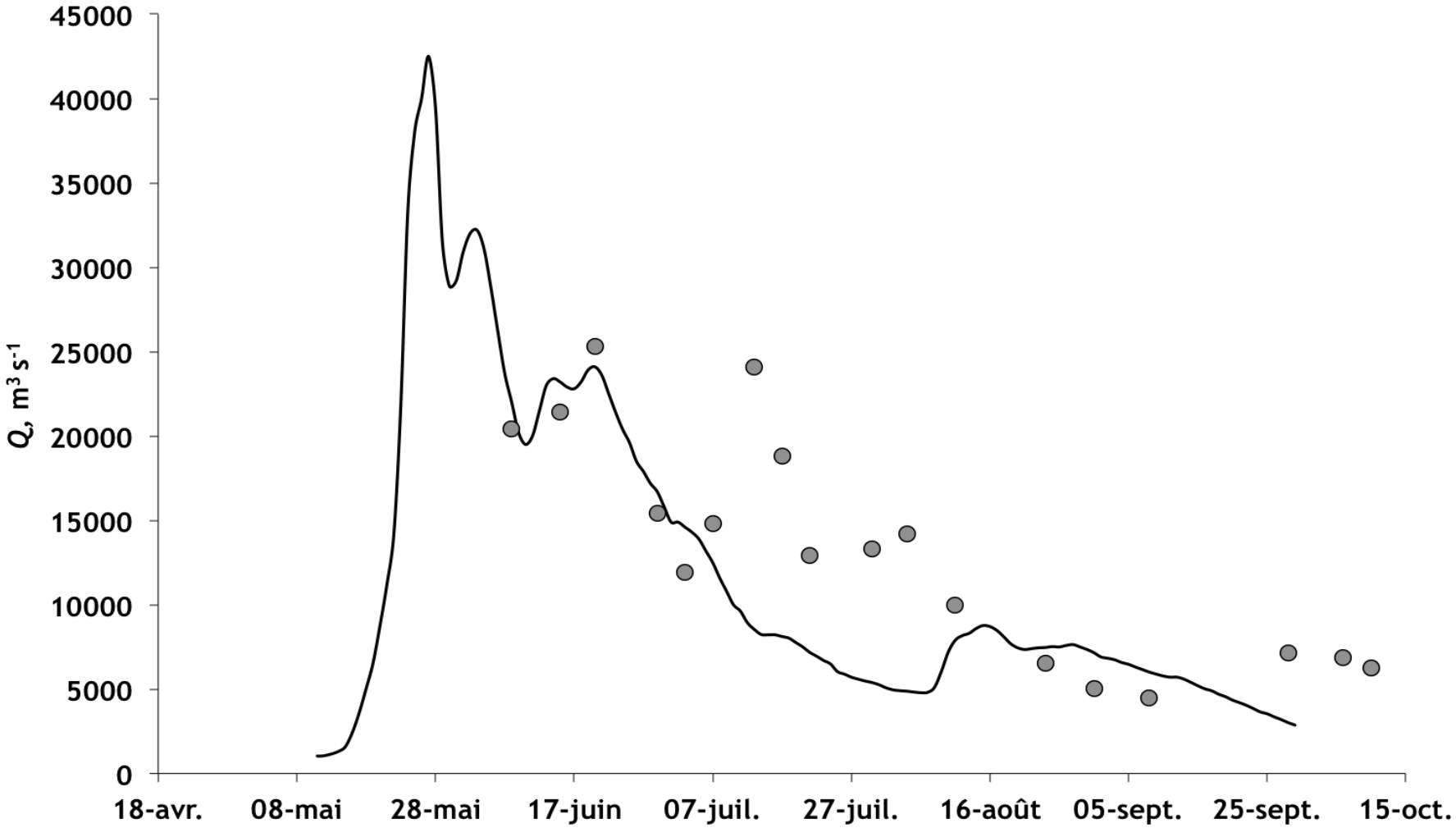
50. р.ЛЕНА,дельта,БЫКОВСКАЯ протока – о.СТОЛБ

I	4	30/IУ	2	адст	3I	0,23	I20	1,8	Ь 6/интегр;с
2	5	28/УI	2	ов	629	I000	20I00	5I	Б I5/интегр;с
3	6	3I/УП	2	"	3I3	63	5920	II	Б II/интегр;с
4	7	28/УШ	2	"	244	2I	4I80	5,0	Б 9/интегр;с
5	6	9/Х	2	"	266	23	45I0	5,I	Б 9/интегр;с

Suspended sediment data: Lena at Tabaga, 1966



Suspended sediment data: Lena at Tabaga, 1964



Sediment Rating Curve

1. A concept

A belief that one variable has the capacity to describe the totality of processes affecting the sediment transport:

$$\text{SSC},\ Y_S \sim Q,\ Y_Q$$

Based on $Q,\ Y_Q \sim i$ and $Y_S \sim i$, where i – runoff formation intensity, and stream power equation.

2. A model

A physically-based distributed model of sediment detachment, routing, storage and deposition is yet to be developed.

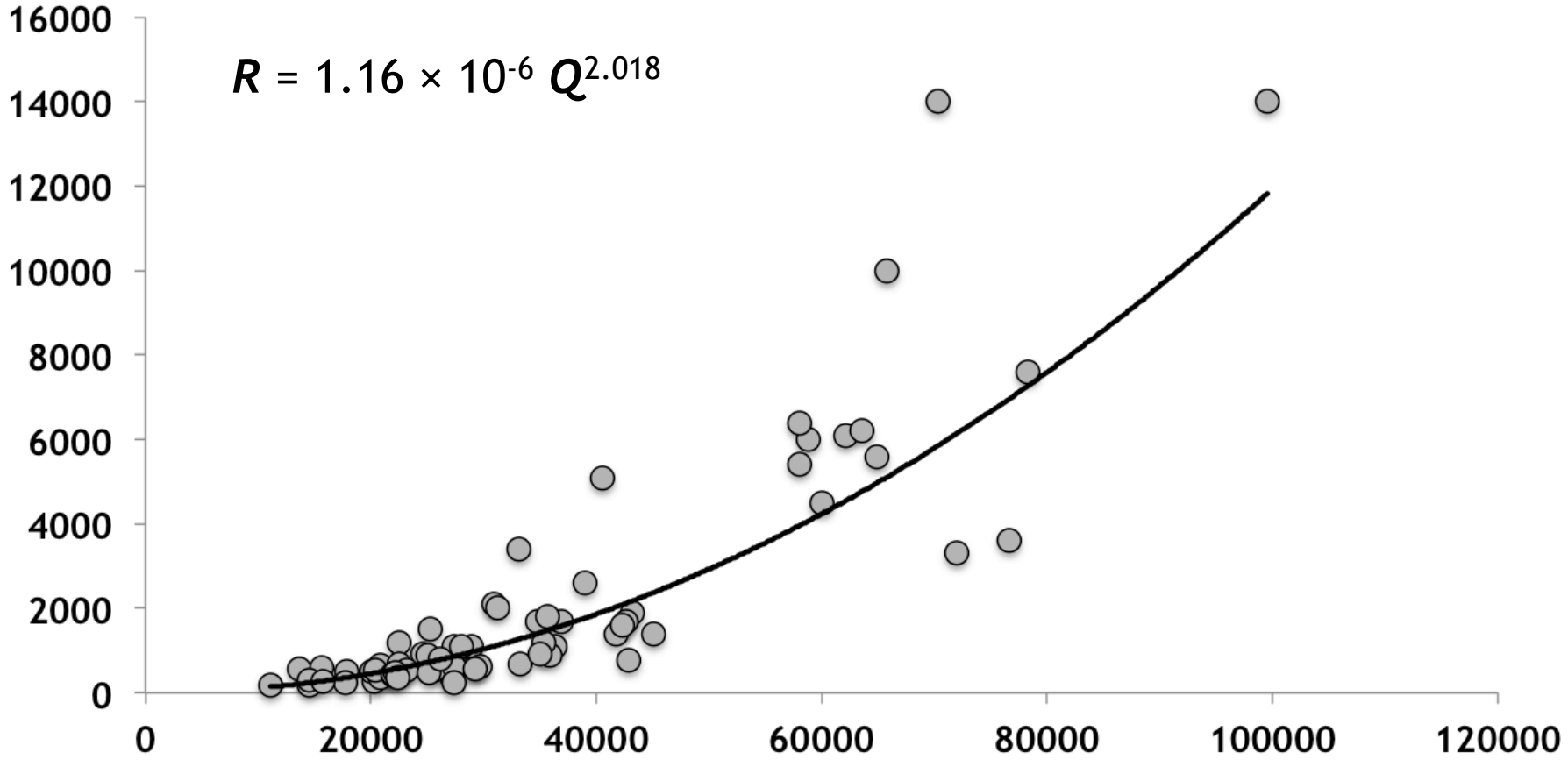
$$\text{SSC} = aQ^b$$

'Coloured box' regression model and, as such, an optimization problem (best fit).

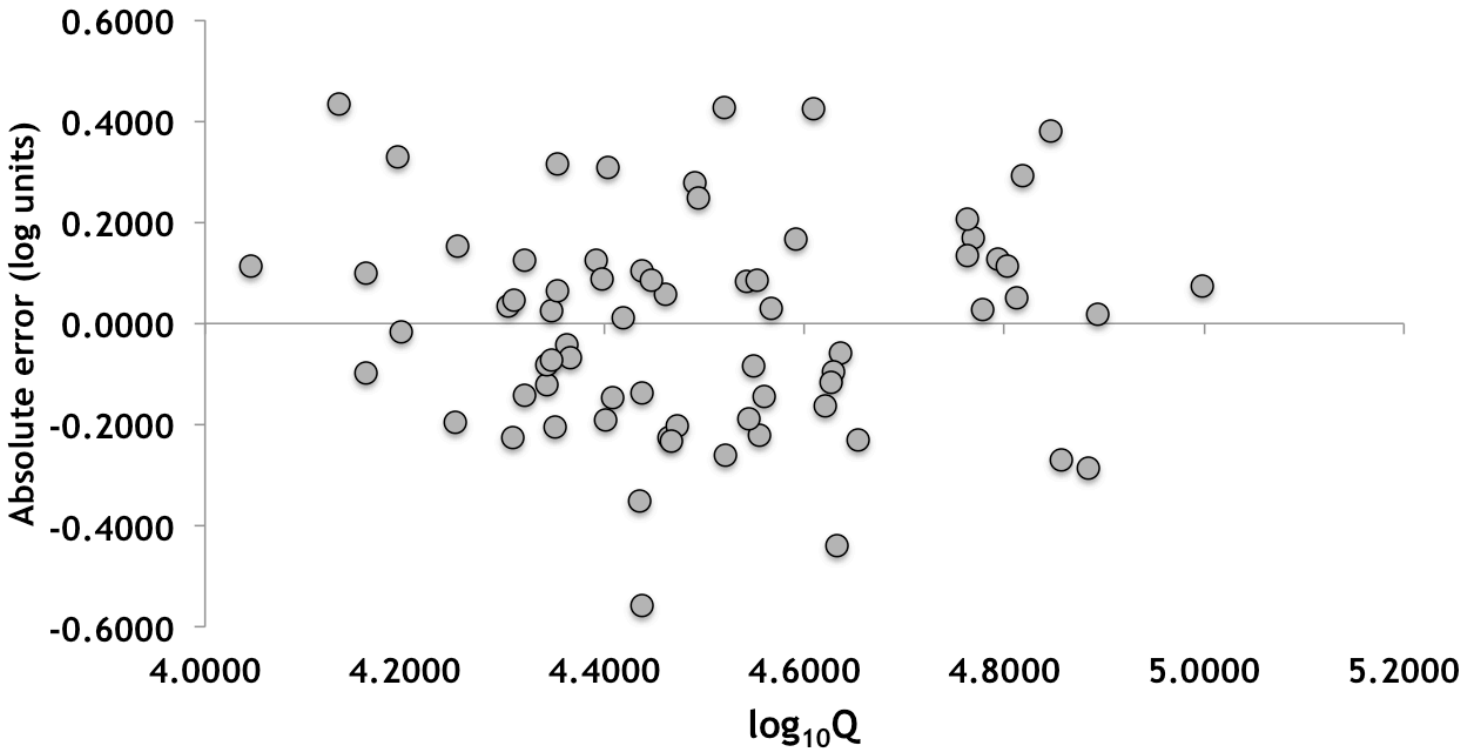
3. A tool

Sediment rating curves are extensively used in daily (monthly, …) sediment load calculations, forecasts and river management planning.

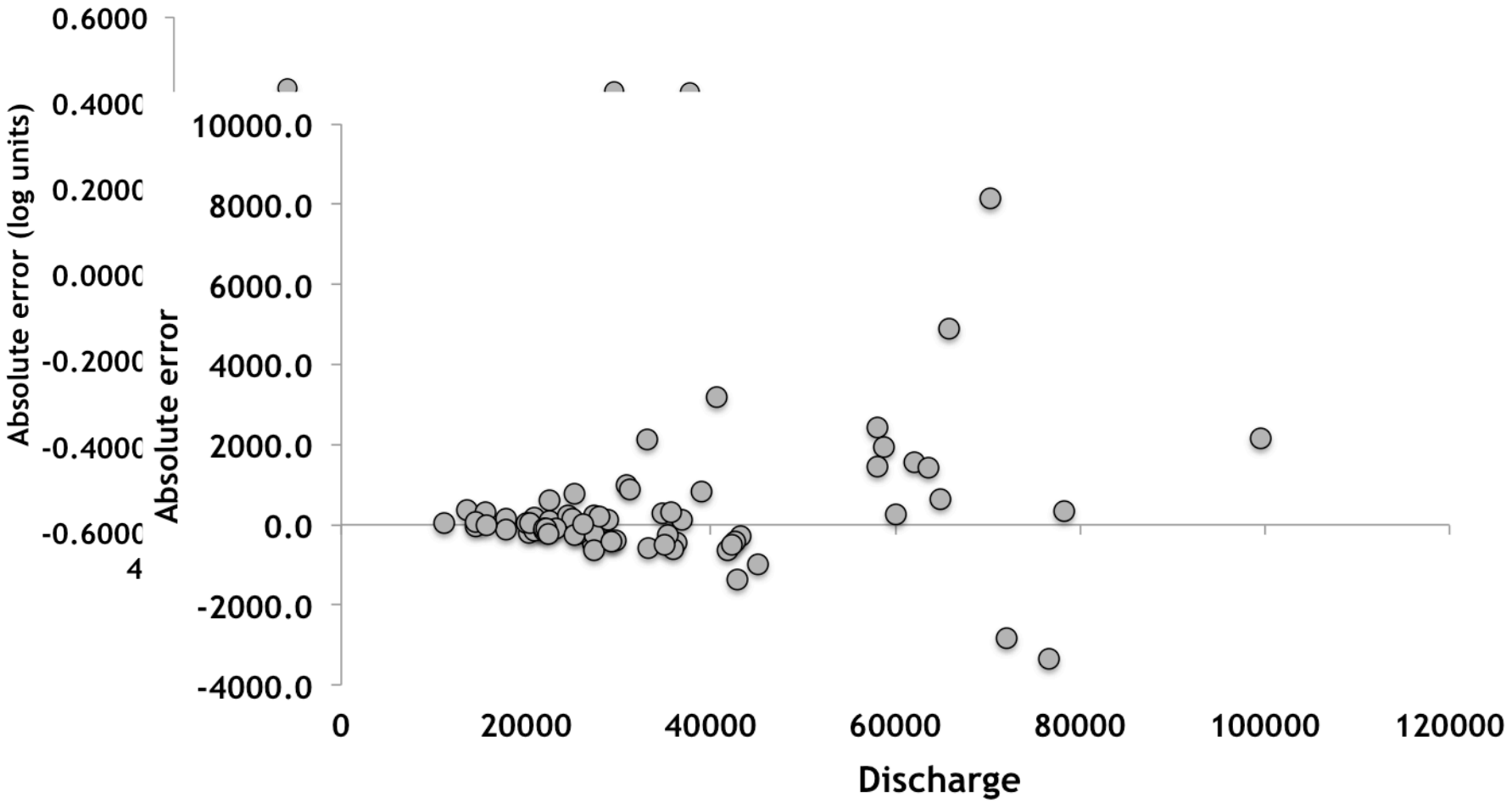
Sediment Rating Curve: Lena at Kyusyur (1961-1977)



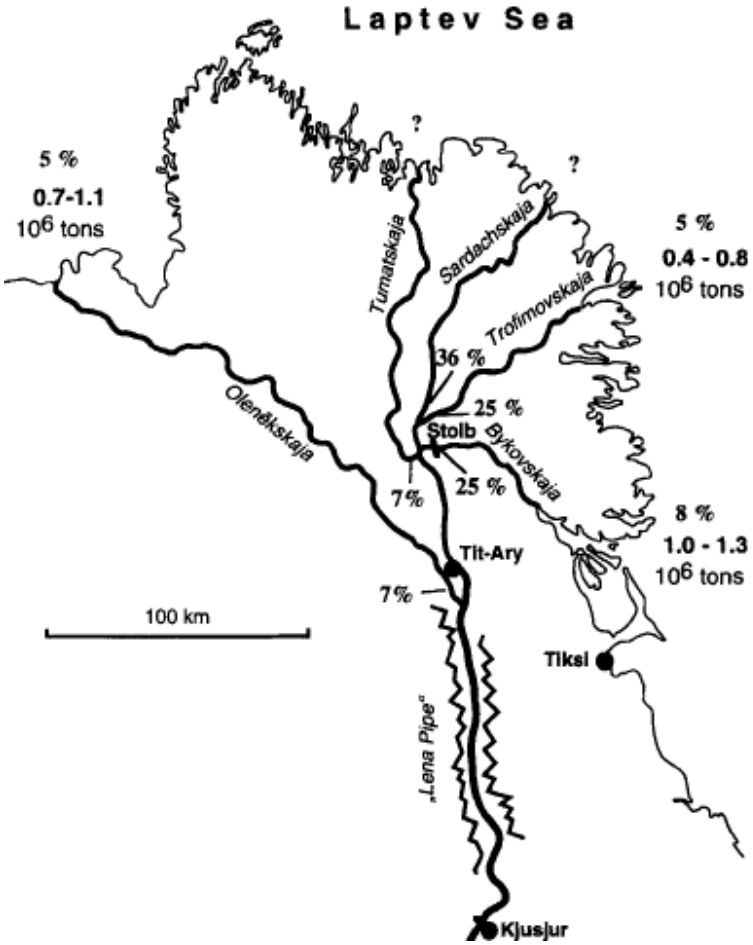
Model errors



Model errors



Suspended load estimates

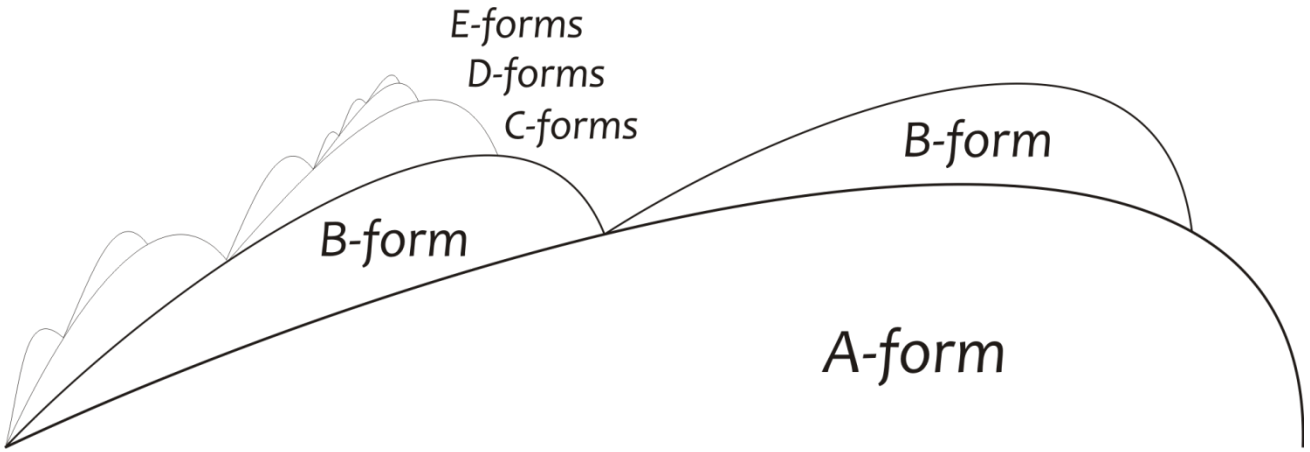


Consentient suspended sediment flux:
20.7 ± 0.3 Mt

Strongly seasonal flux (June):
ca. 60% (12.4 Mt)

Supply to the delta margin:
10 to 17% [Rachold et al., 1996]

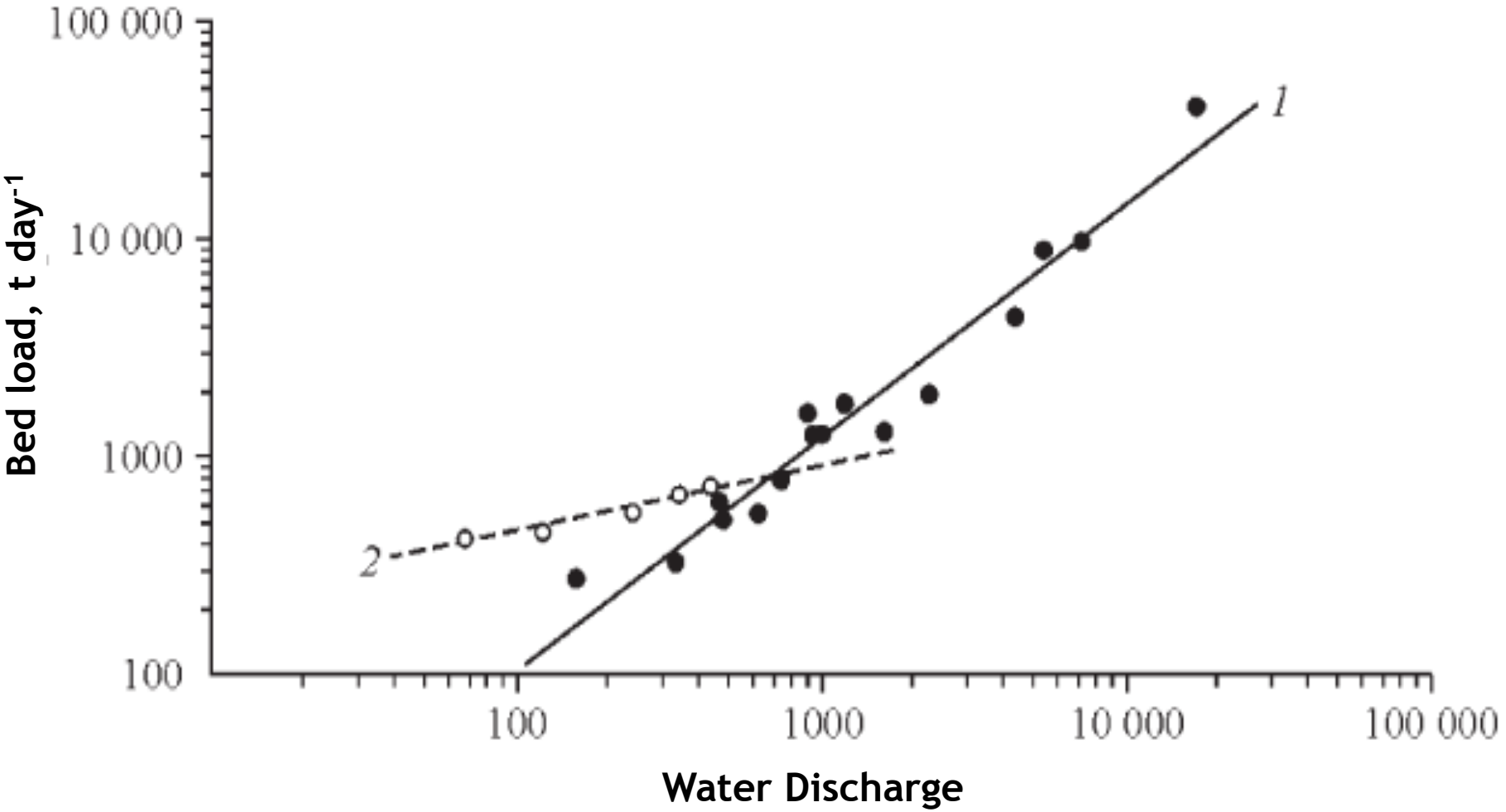
Bed load calculations [Alekssevskiy, 2004]



$$g_г = k \cdot \sigma^* \cdot h_г \cdot C_г,$$

Here k stands for dimensionless bedform coefficient, σ^* - sediment density, $h_г$ – bedform height, $C_г$ – bedform movement rate. Computations are carried out for each hydrological season separately (from [Alexeevsky, 1998]).

Bed load estimations [Tananaev, Anisimova, 2013]

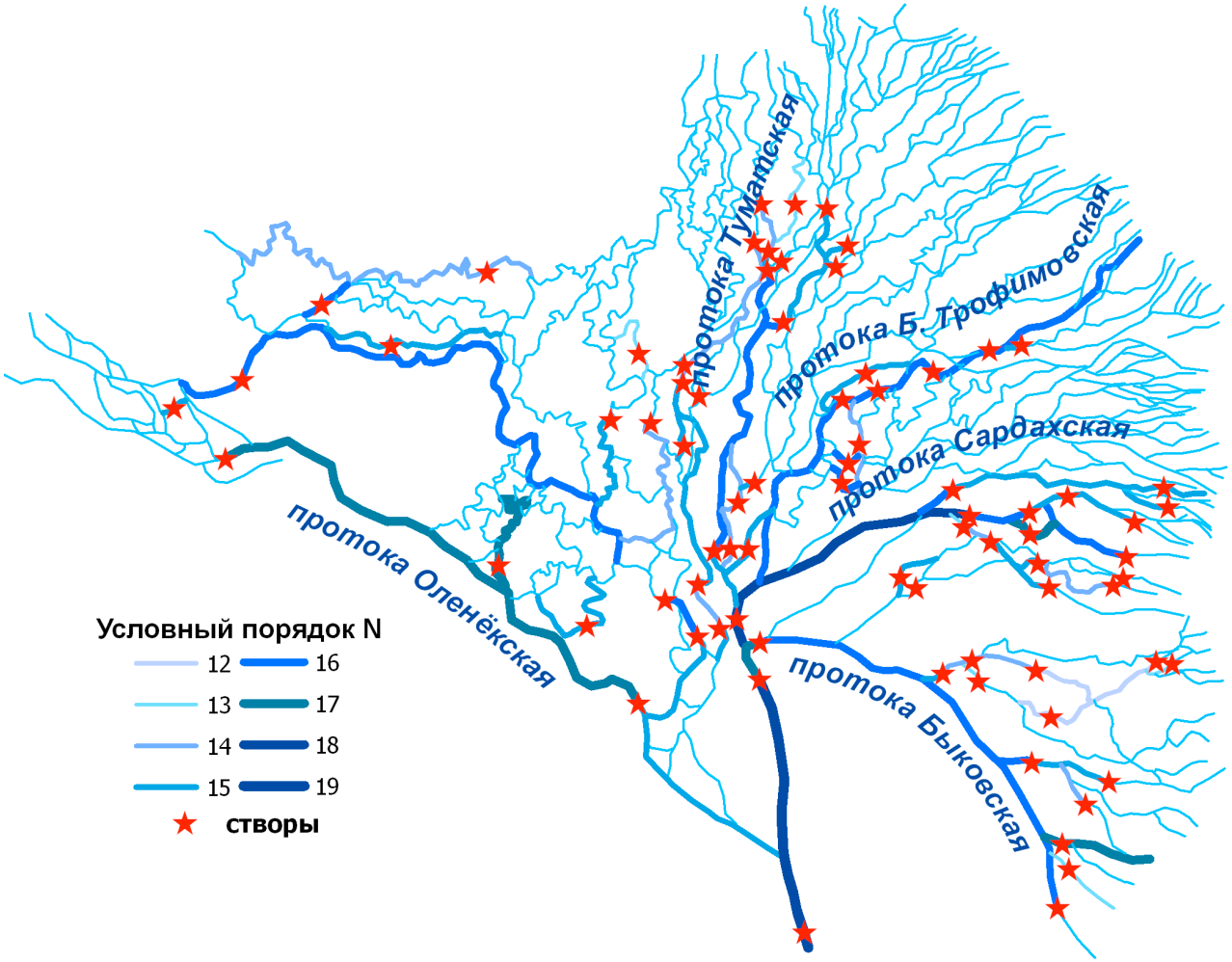


Sediment delivery to the Lena River delta region

Total sediment delivery: **36 Mt**

- 21 Mt as suspended material
- 15 Mt as bed load
- 2-4 Mt reach the delta margin
- Surge events [Rivera et al., 2006] ~ 17 events during the last 2000 yr;

Water redistribution in the delta region: conditional stream order [Alekseevsky et al., 2013]



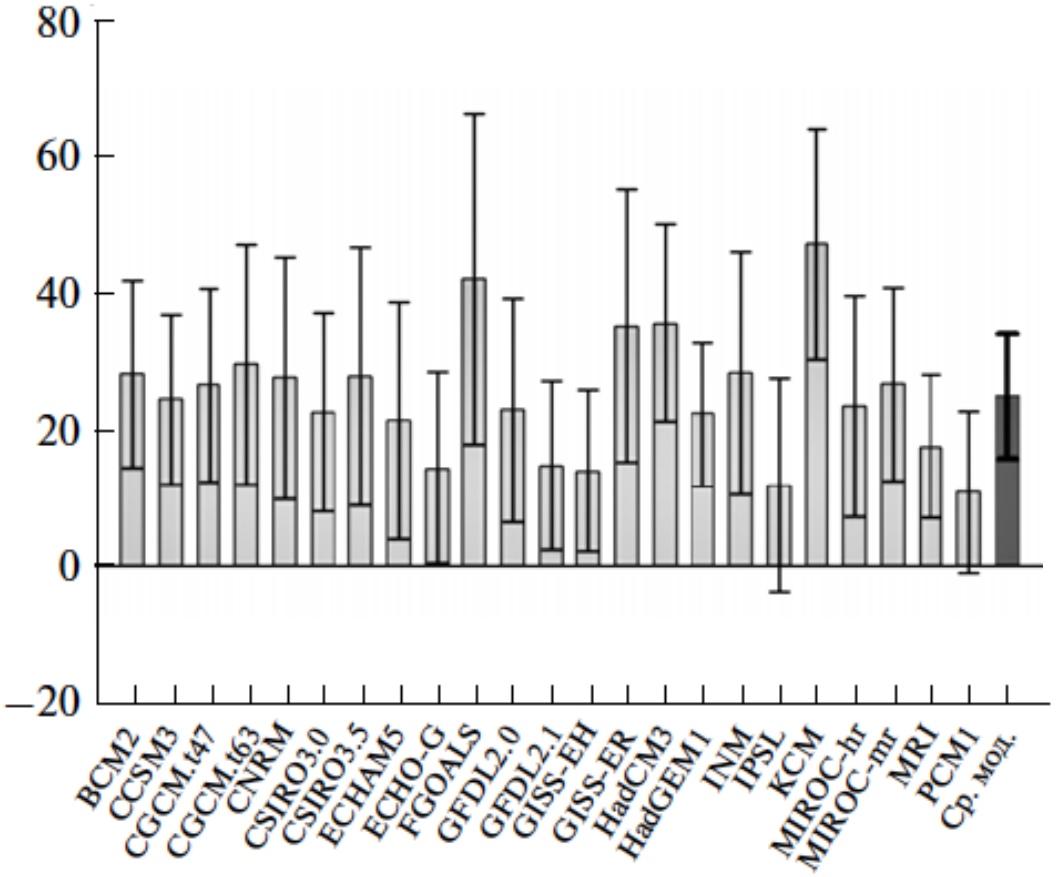
$N = 1 + \log_2 P(1)$
[Scheidegger, 1966]

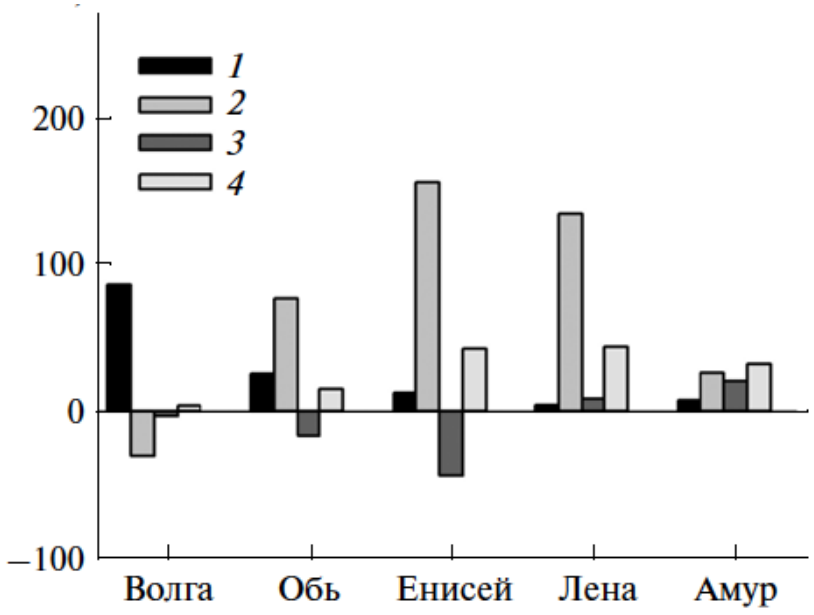
$N \sim Q$

$P_i/P(1) = Q_i/Q$

$N_i = 1 + \log_2 P_i$

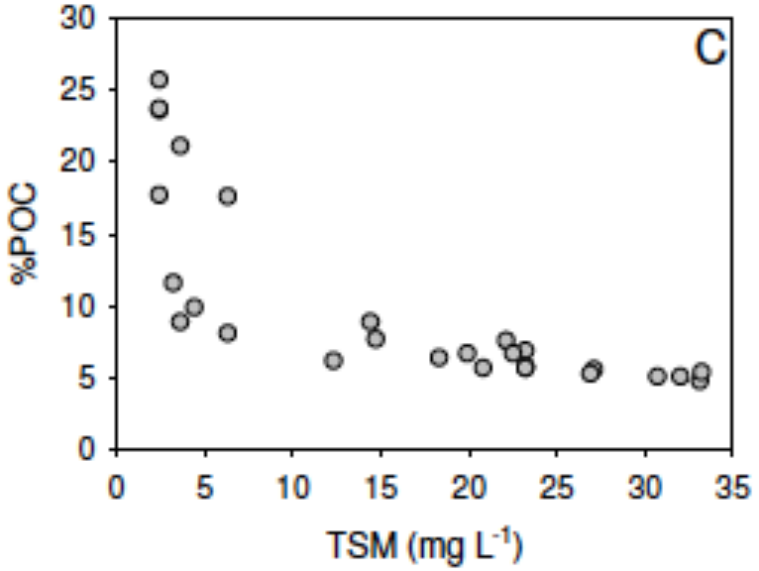
Environmental Implications: (1) Discharge increase



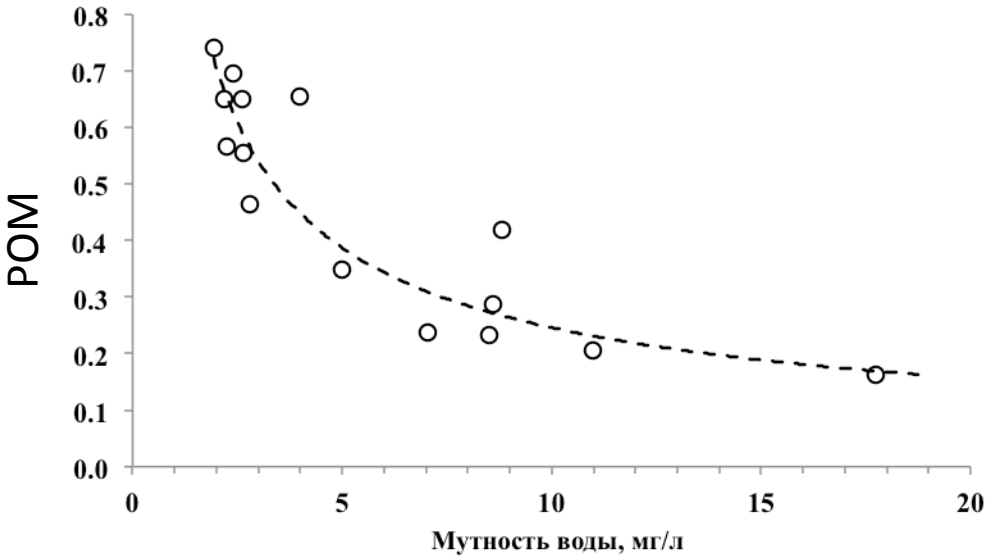


+22% Ensemble-averaged
+130 mm Spring runoff
+ 13 Mt Suspended load
+ 2 Mt Bed load

Environmental Implications: (2) Organic matter supply



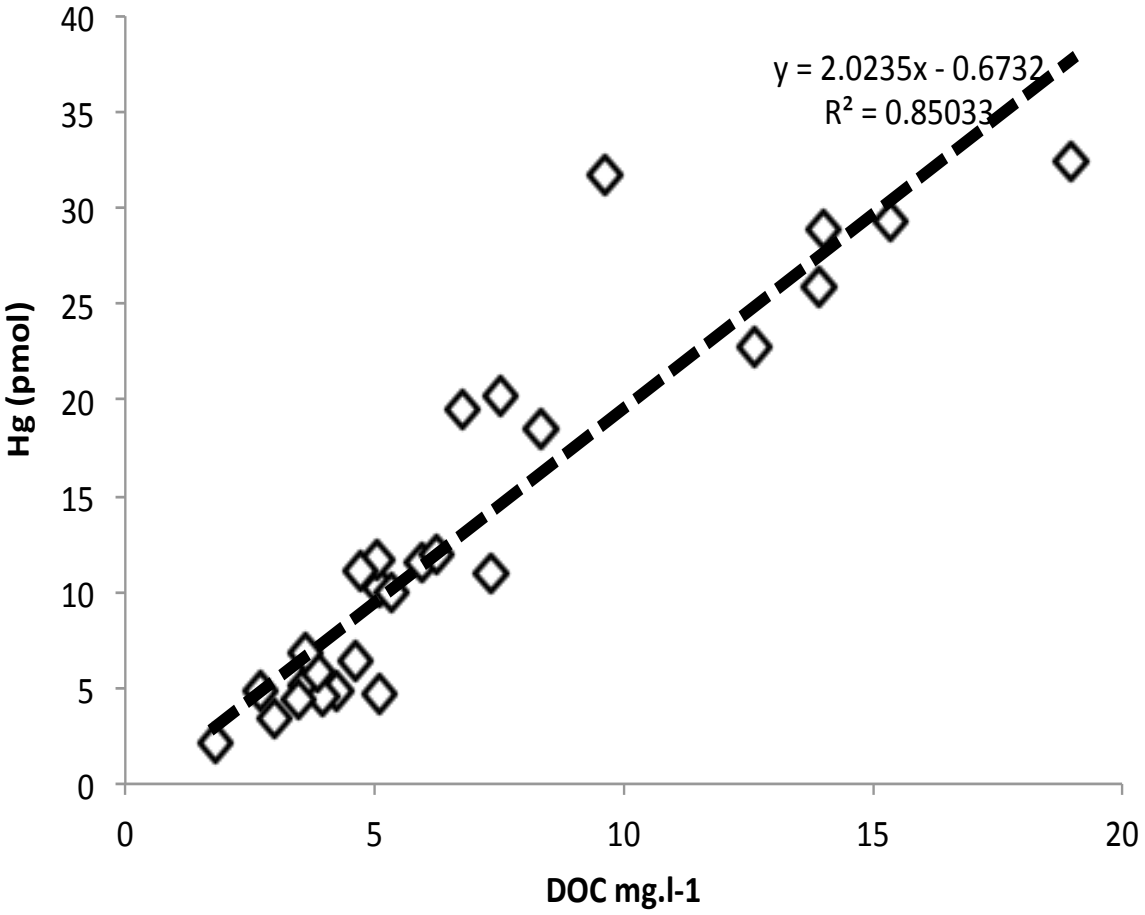
Oubangui R. [Bouillion et al., 2012]

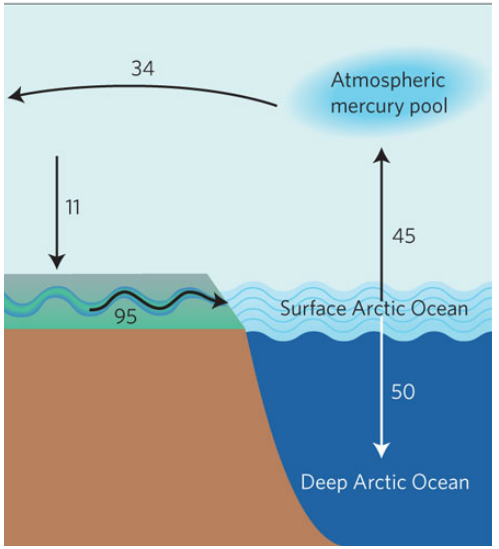


Graviyka R. [Tananaev, in press]

Organic carbon content in suspended matter varies regionally.
Assume 20% of suspended load is actually POM: **4 Mt**, POC: **1.8 Mt**
DOC flux [Amon et al., 2012]: **6.47 Mt**

Environmental Implications: (3) Hg fluxes





10/10/2013 Russia signs Minamata Convention on Mercury

FIGURE: SONKE, J. & HEIMBURGER, L.-E., *NATURE GEOSCI.* **5,** 447-448 (2012)

Conclusions

- Sediment fluxes are hardly quantifiable given the quality and quantity of the data used;

Further research directions:

- Heat fluxes associated with sediment accumulation within the floodplain and alluvial bars;
- Quality, age and fate of the particulate organic matter entering the delta region [Guo et al., 2007; Hahn-Schofl et al., 2011; Gustaffson et al., 2011]
- Chemical composition of the particulate matter; heavy metals, rare earth metals [Rachold et al., 1996]

Thanks for your attention!