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Estimation of the peak outflow from natural lakes within the Neva River basin

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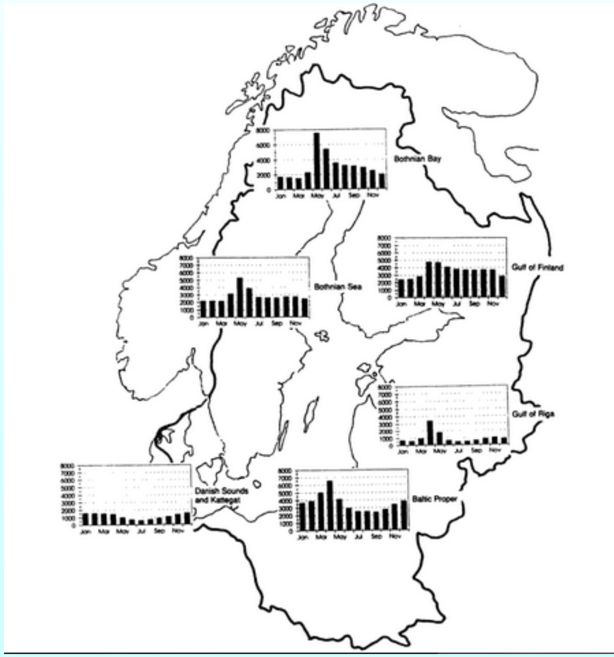
Background

Swamps (13%)



(S. Bergström et al, 2001)

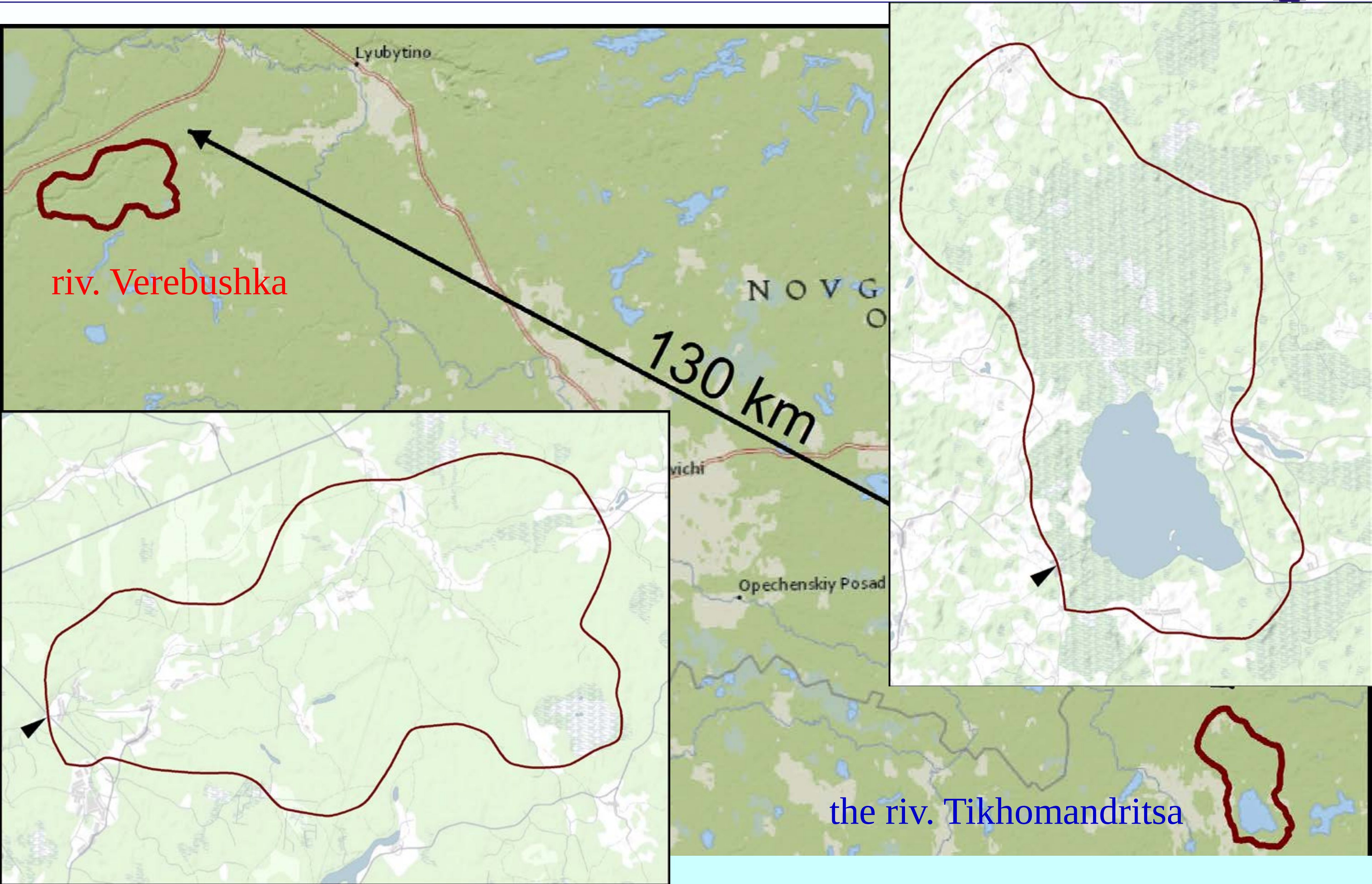
Lakes & water storages (12%)

Urban areas (1,5%)

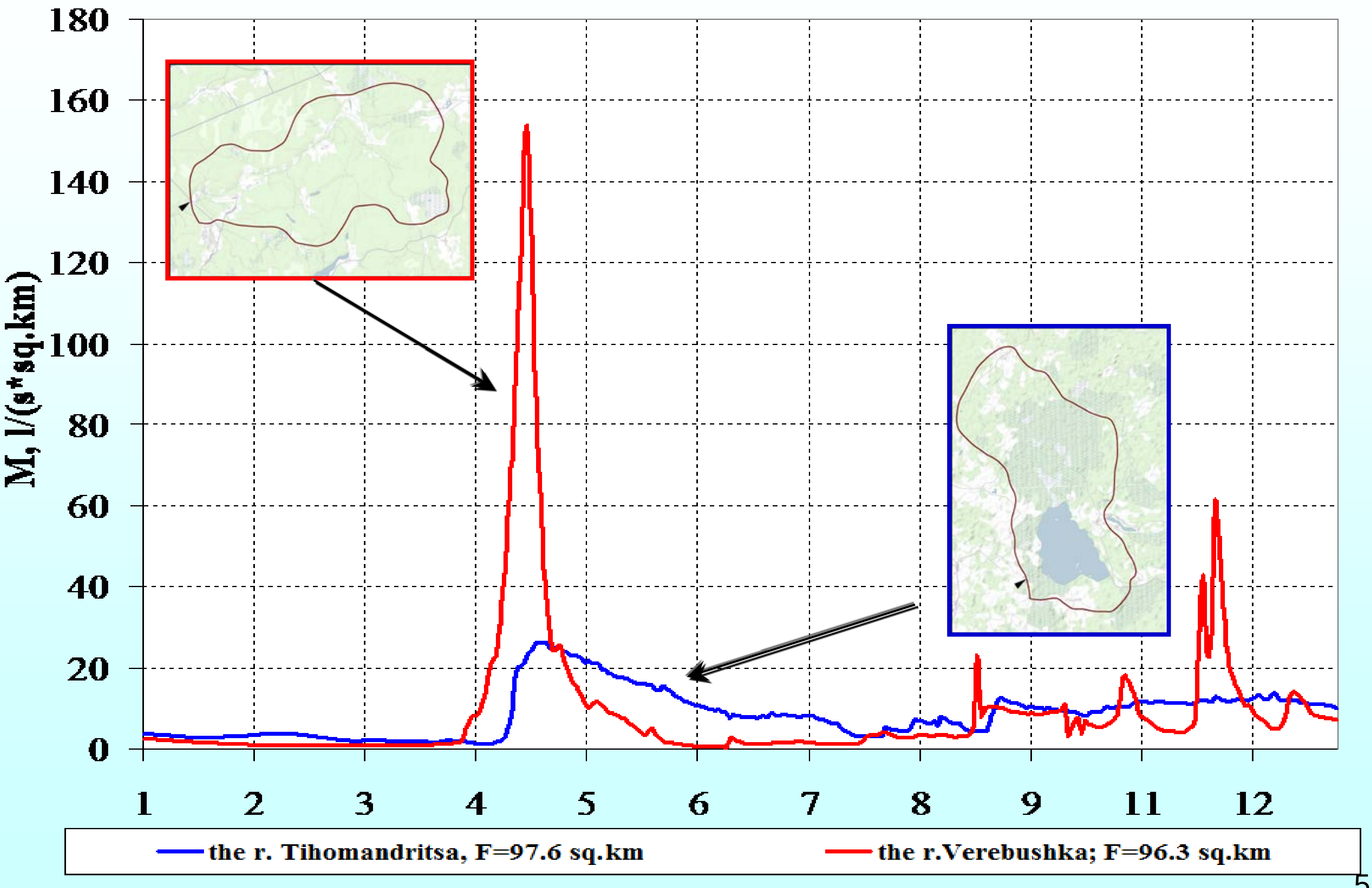
Objectives

- to analyze the process of the lake flood control
- to assess the general outline of the lake stage-outflow relationships
- to offer an approach & tools for modeling the lake flood control process
- to simulate lake’s inflow & outflow in the case of lacking hydrological data
- to estimate the peak outflow changing due to the lake flood control

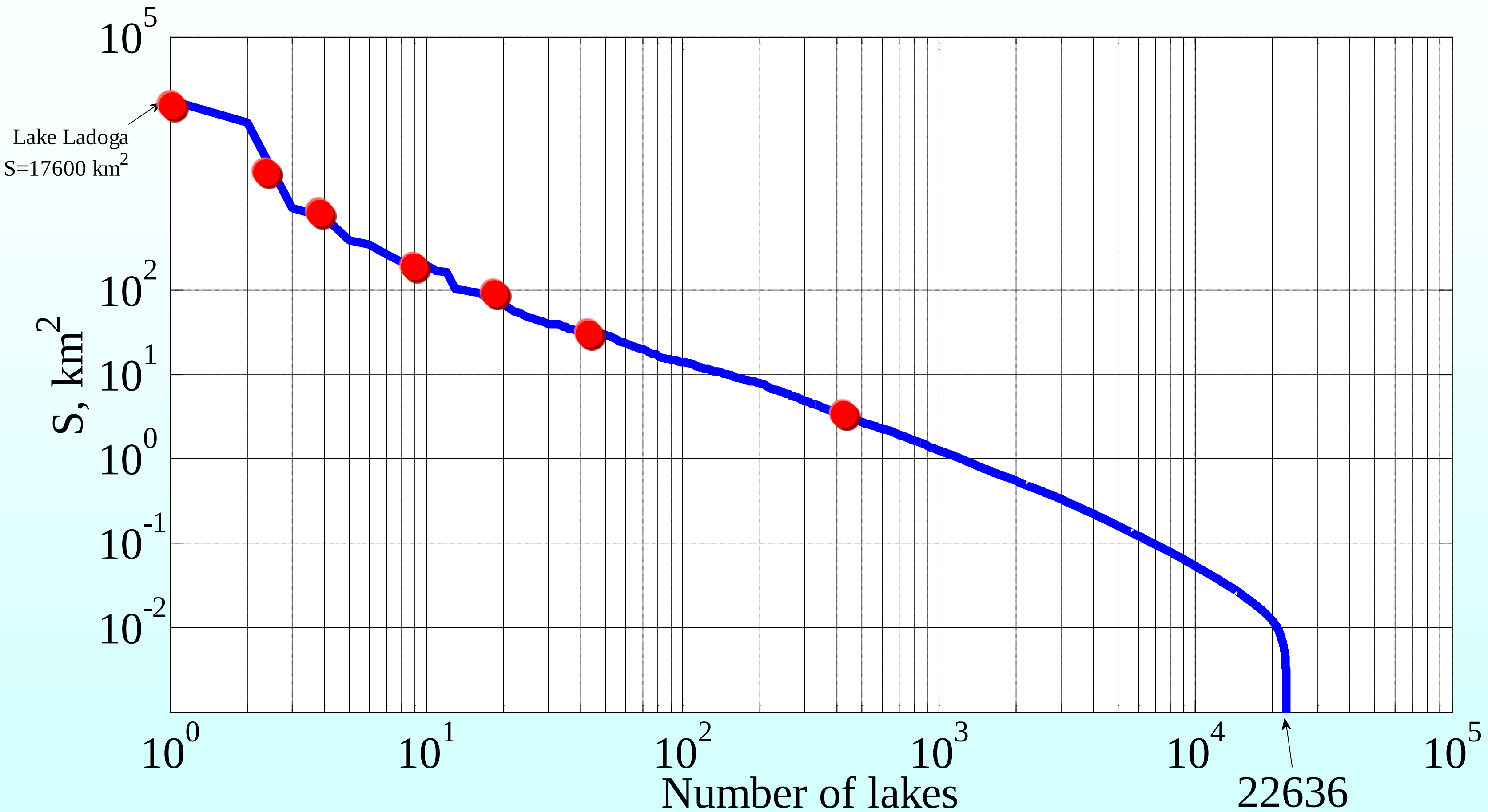
The lake flood control: an example



The process of the lake flood control



Lake distribution within the Neva river basin

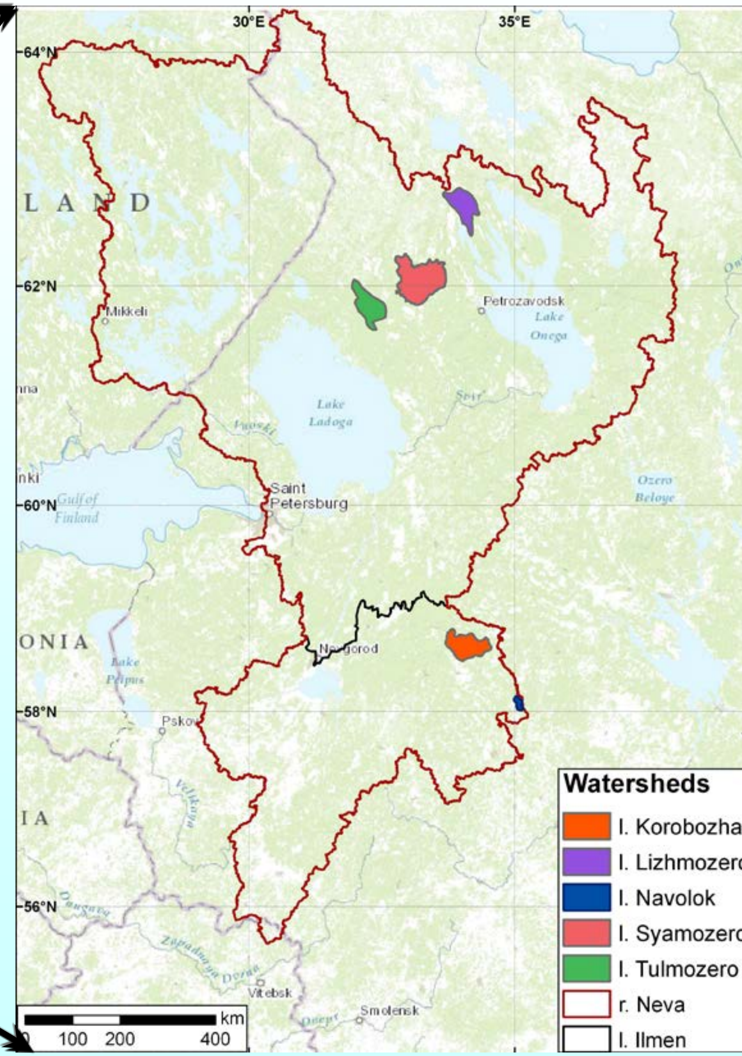


The total account of lakes – about 22500*

The total water surface area – 39505 sq.km*

*Russian part, the source of the data – topographic maps, 1:200 000

Study area



The riv. Neva basin
F=281000 sq. km

The lake routing algorithm

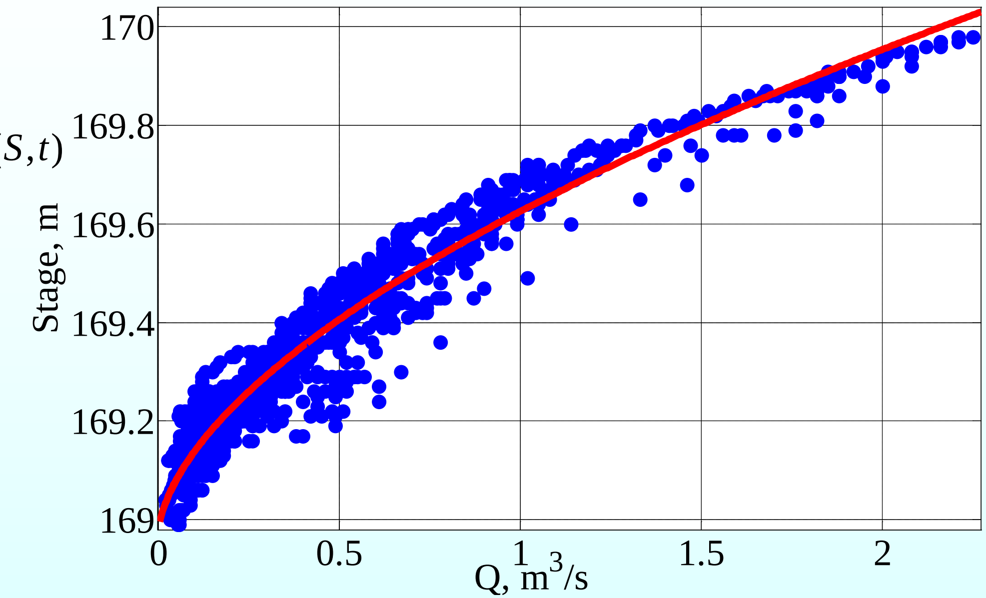
$$\frac{dW}{dt} = Q_{\text{in}} - Q_{\text{out}} - E + P + (Q_{\text{grw.in}} - Q_{\text{grw.out}})$$

$$\frac{dW}{dt} = \frac{Q_{\text{in.},t} + Q_{\text{in.},t+\Delta t}}{2} - \frac{Q_{\text{out.},t} + Q_{\text{out.},t+\Delta t}}{2} - E(S,t) + P(S,t)$$

$$Q_{\text{out},t} = \sqrt[n]{\frac{H_t - H_0}{a}} \quad \text{(Glushkov's equation)}$$

$$S = f(W) = f\left(\frac{H_t + H_{t+\Delta t}}{2}\right);$$

Rating curve

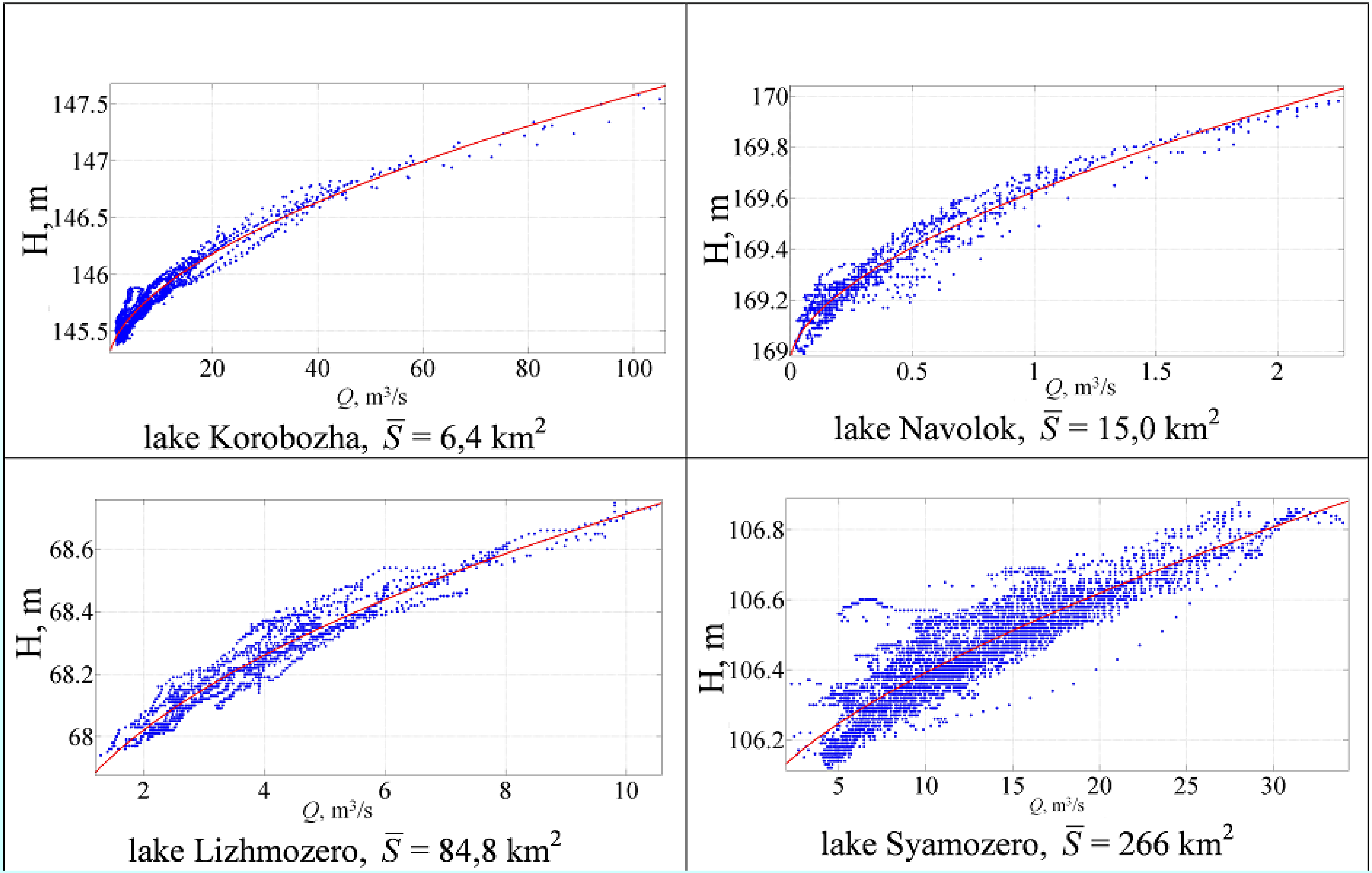


Assumptions:

$$Q_{\text{grw.in}} = Q_{\text{grw.out}}$$

no ice phenomena, wind tide & seiches

The rating curve approximation



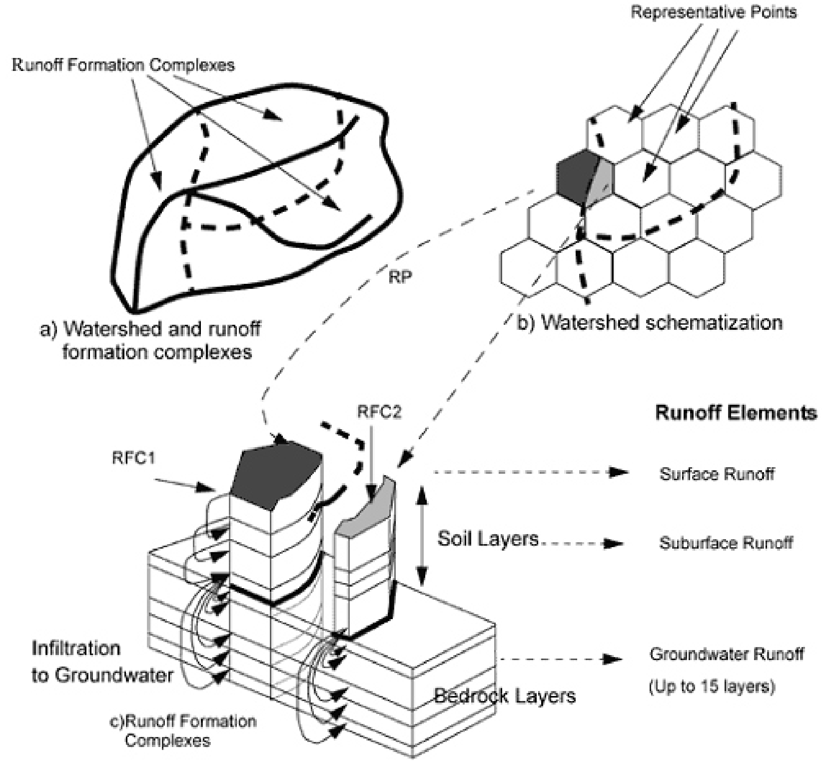
Hydrograph Model

- distributed model of runoff formation processes

- looking for the simplest solutions

Modeling periods
1971-1991
1991-2011

- Input data:
  - precipitation
  - air temperature
  - air deficit



(Vinogradov, Semenova, Vinogradova, 2011)

- Output results: river runoff, soil and snowpack characteristics, full water balance

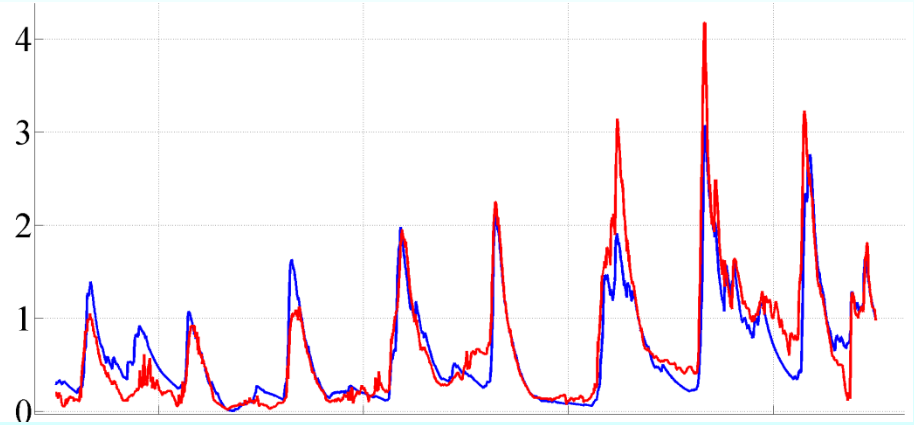
www.hydrograph-model.ru

Modeling & verification

simulated
observed

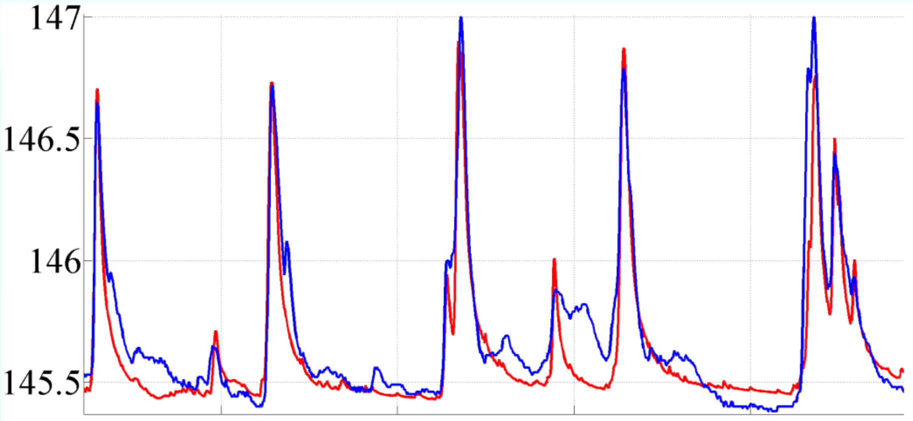
Model verification

Outflow hydrographs



the riv. Tikhomandritsa

Water level fluctuations of the lakes



Lake Korobozha water levels

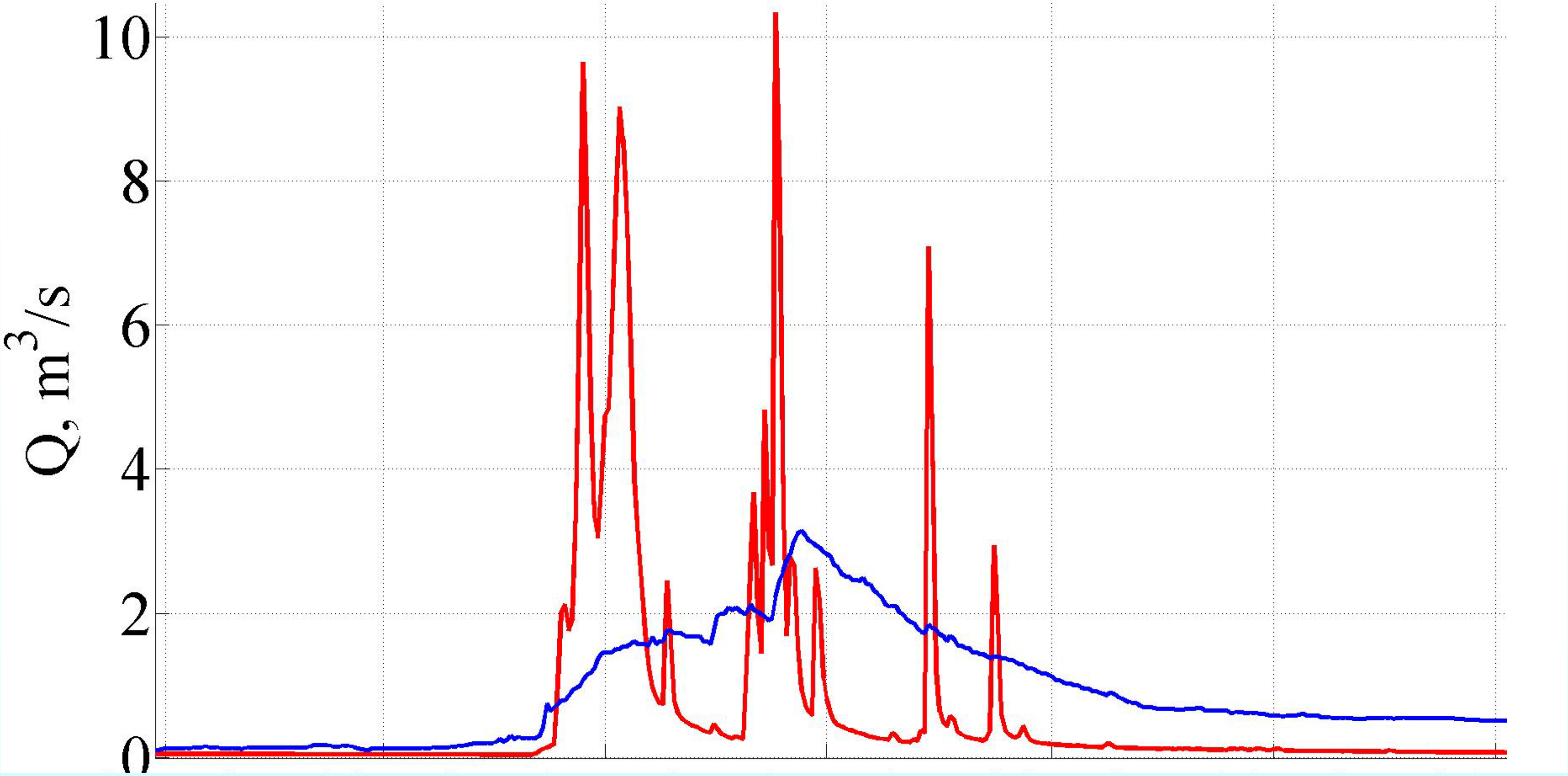
$$Ef_Q = 1 - \frac{\sum_{i=1}^{n} (Q^i_{sim} - Q^i_{obs})^2}{\sum_{i=1}^{n} (Q^i_{obs} - \overline{Q_{obs}})^2} \qquad \overline{Ef_Q} = 0{,}79$$

$$Ef_H = 1 - \frac{\sum_{i=1}^{n} (H^i_{sim} - H^i_{obs})^2}{\sum_{i=1}^{n} (H^i_{obs} - \overline{H_{obs}})^2} \qquad \overline{Ef_H} = 0{,}73$$

More subbasin lakes, less *Ef*

Inflow & outflow results

Inflow → Outflow

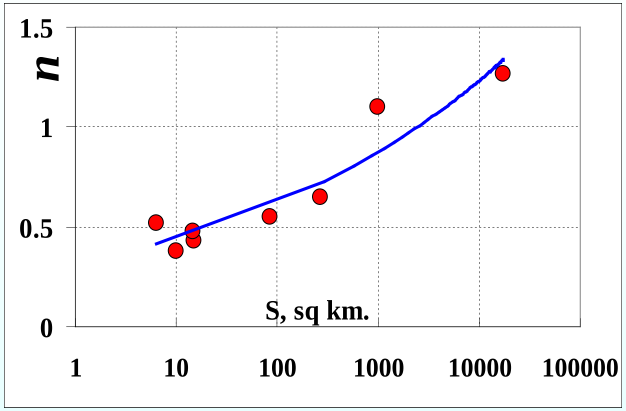


Lake Navolok → the riv. Tihomandritsa

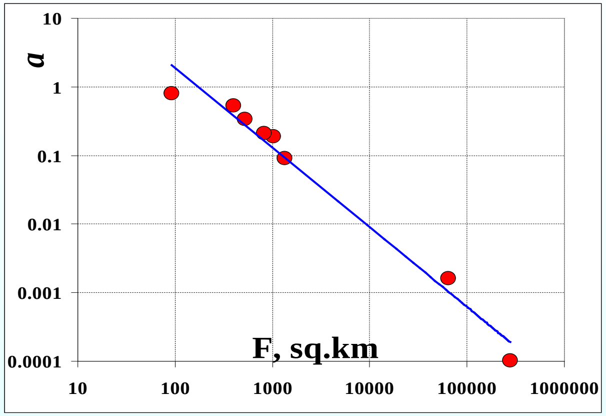
S=15 sq.km

Parameter generalization

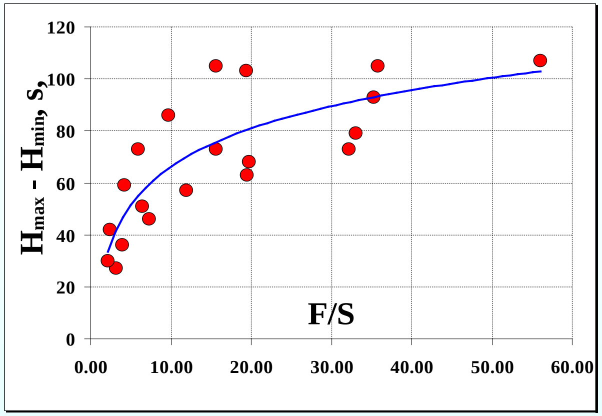
$n = f(S)$

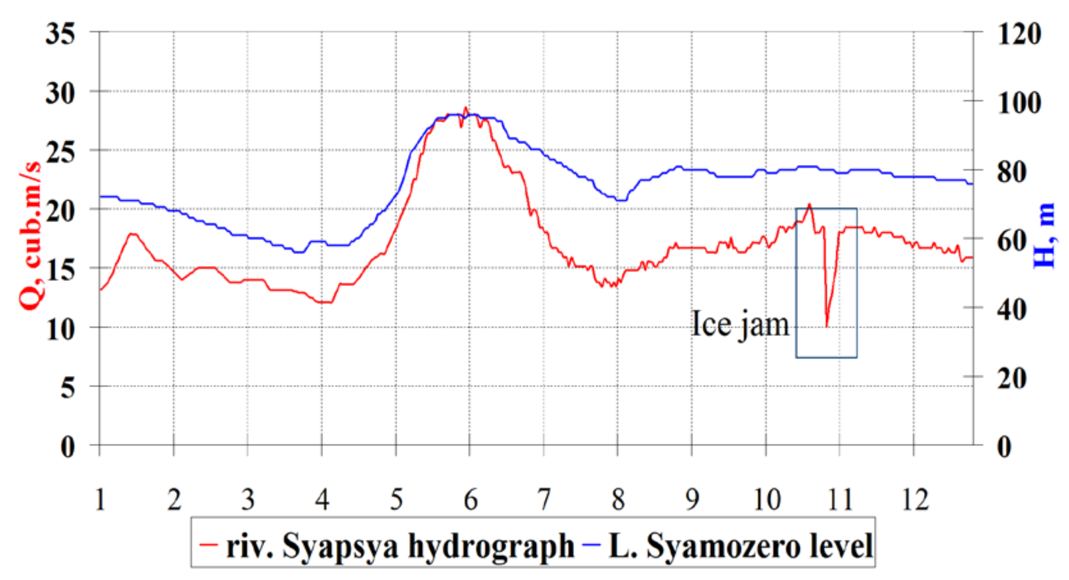


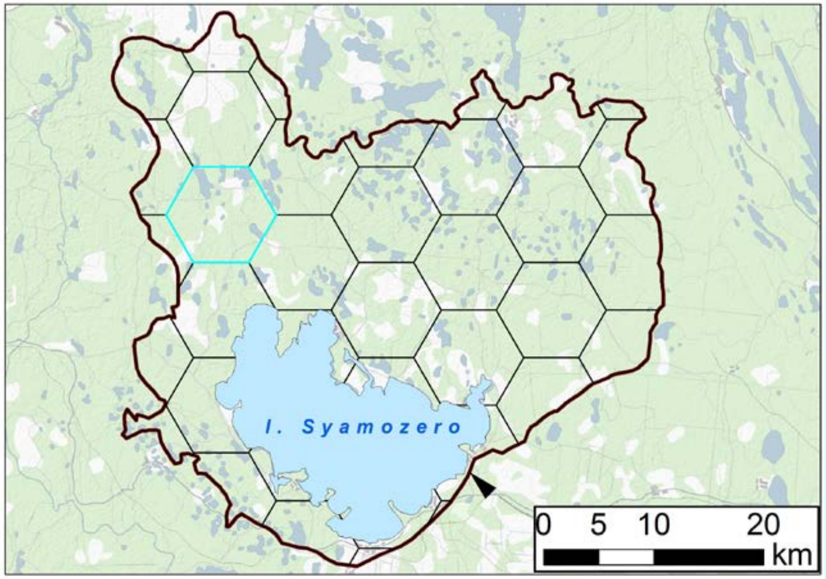
$a = f(F)$



$H - H_0 = \frac{H_{max} - H_{min}}{2} = f(F/S)$

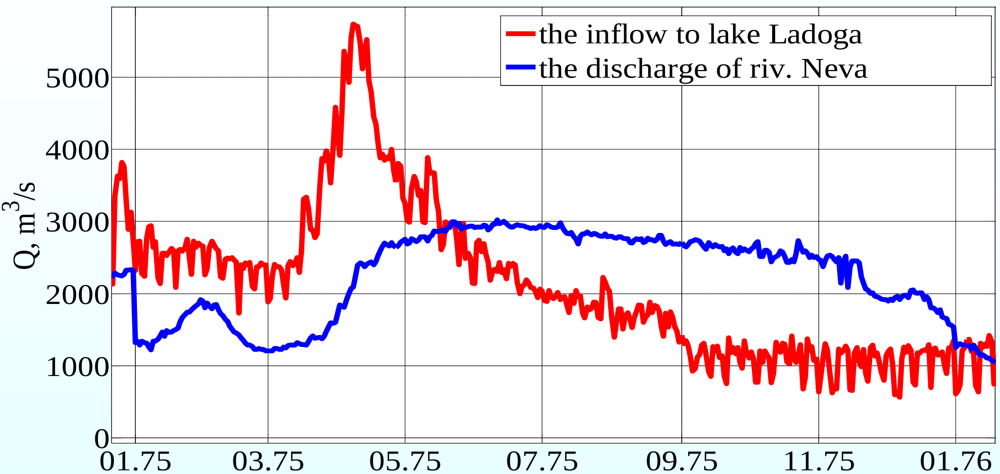


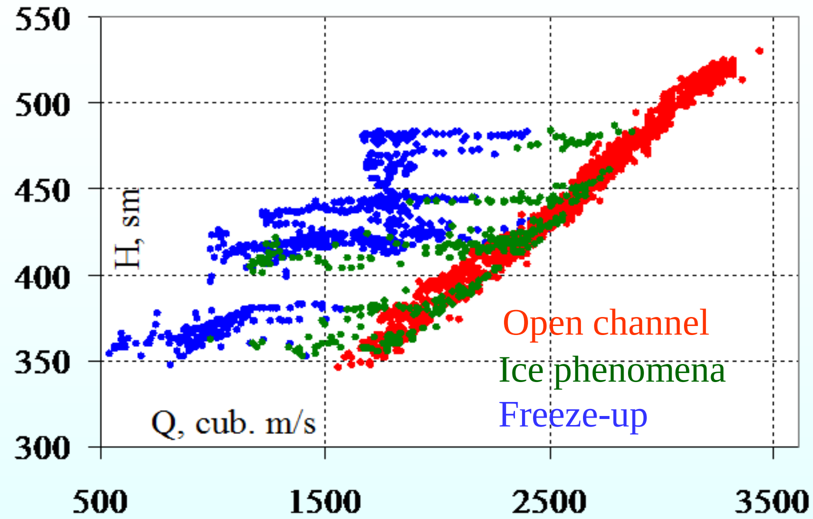


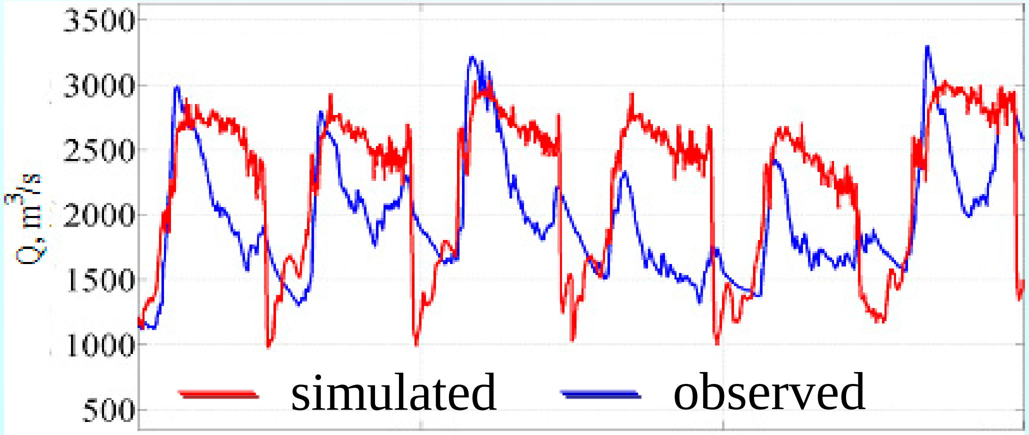


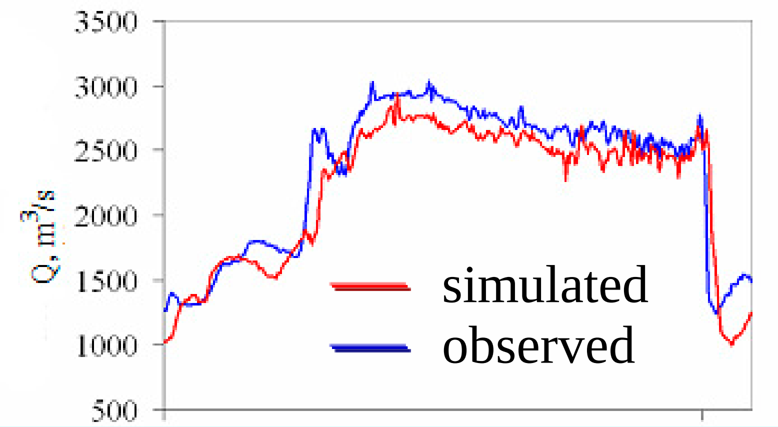
$NSE_{fin} = 0.39 \rightarrow 0.76$

Large systems – the riv. Neva









Single rating curve

Rating curves for the certain periods

Mean peak reducing – 2.2 (5500 → 2500 cub.m/s)

Mean lagging – 50 days [from 20 to 76]

Summary

- the present work characterizes the changes of the peak flow due to the lake flood control process
- the influence of the lakes on the river runoff within the Neva basin is extremely strong. Lake Ladoga halves the peak inflow and “slows” it for 48 days on an average
- it’s suggested to generalize RC parameters for the lakes & basins with the lack of the data
- the accuracy of the approach is inversely as the lake’s water surface area & the rate of the dynamical & ice phenomena

Thank you for your attention