Numerical simulation of the Lena River estuary dynamics in the summer season

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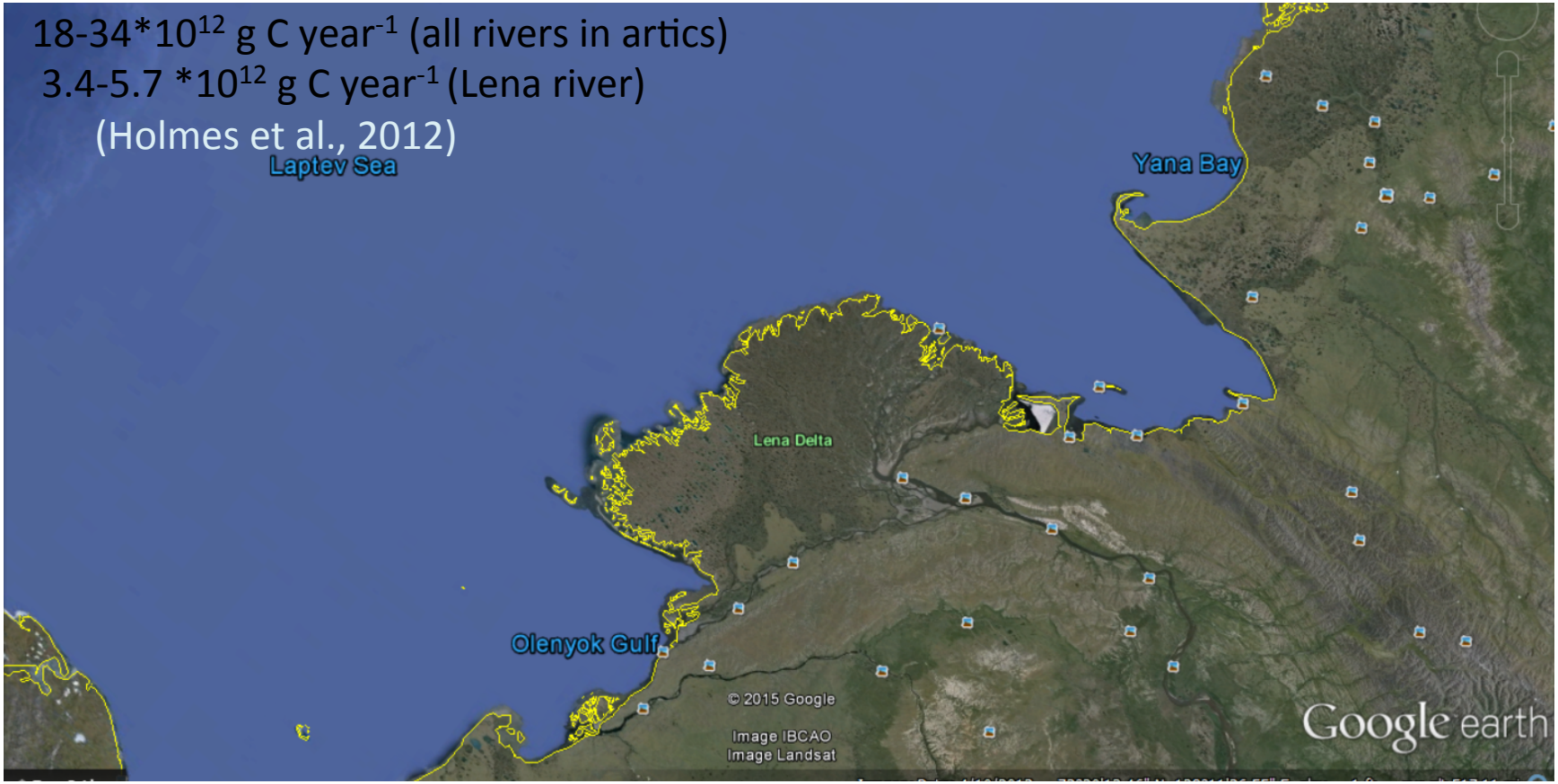
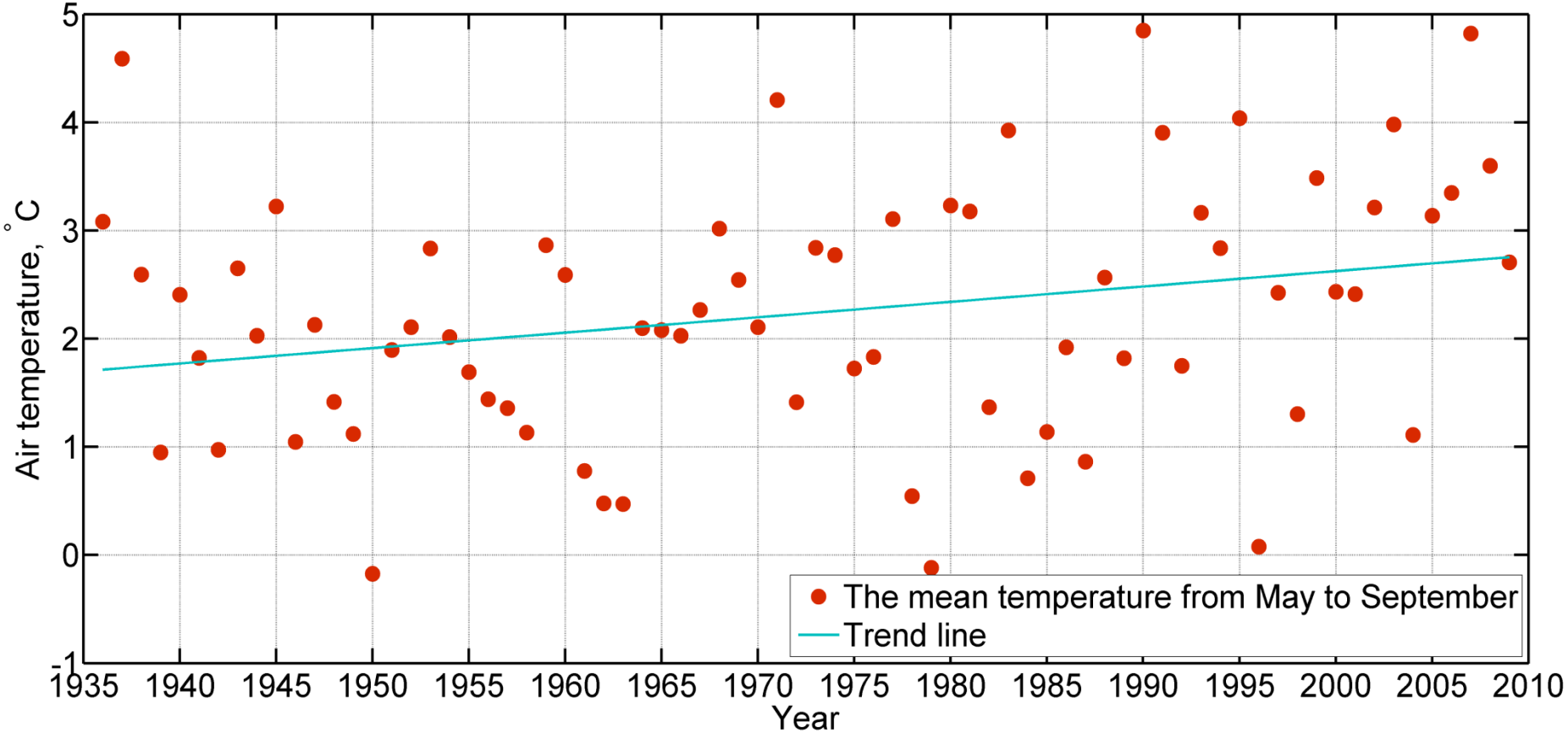
Why are we interested in simulation of dynamics in the Lena Delta region?

- 18-34*10^{12} g C $year^{-1}$ (all rivers in artics)
- 3.4-5.7 *10^{12} g C $year^{-1}$ (Lena river)
  (Holmes et al., 2012)

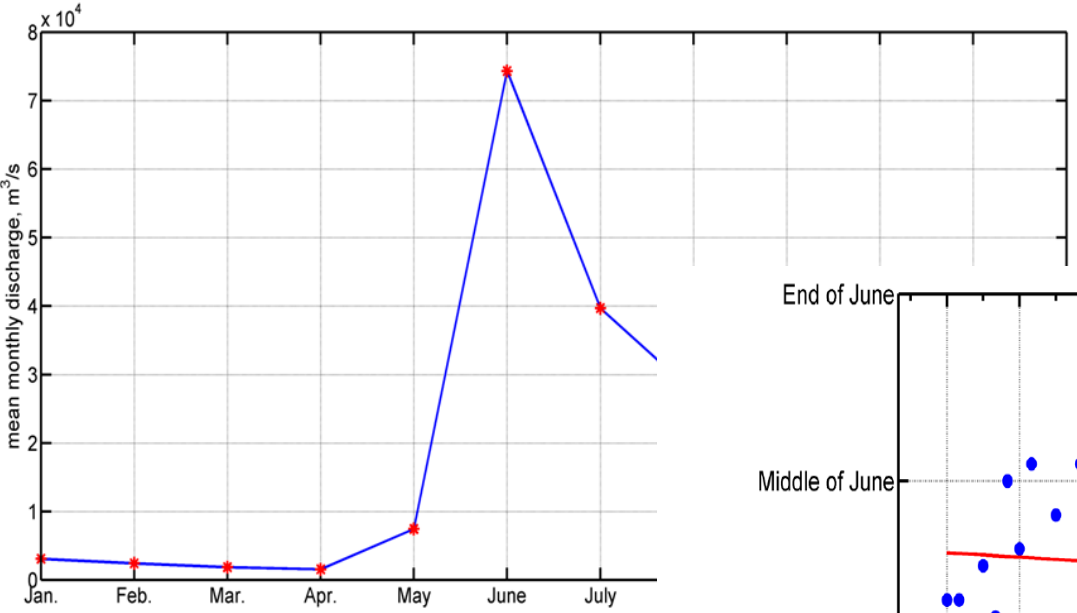


Why are we interest in simulation of Lena Delta River???

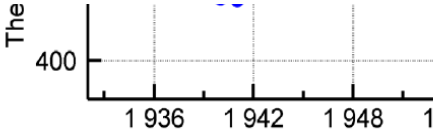


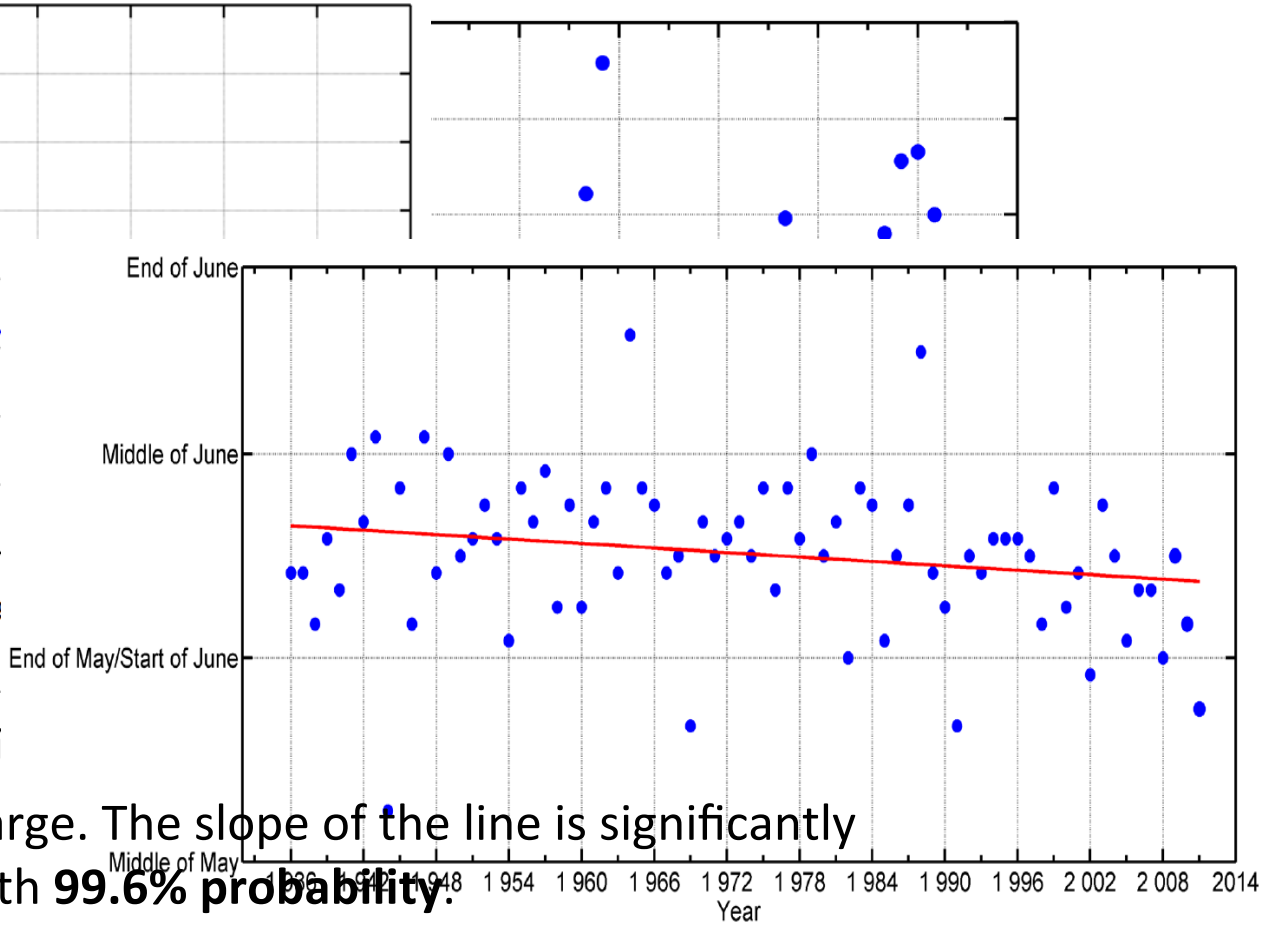
Mean surface air temperature from 1936 to 2009, Tiksi Bay. The theoretical slope of the line is significantly different from 0 with **98% probability**.

Why are we interest in simulation of the Lena Delta River???



The mean monthly discharge for the period from 1





Total annual discharge. The slope of the line is significantly different from 0 with **99.6% probability**.

The time of the year when the daily flow reached a maximum. The theoretical slope of the line is significantly different from 0 with 94.1% probability

Why are we interest in simulation of Lena Delta River???

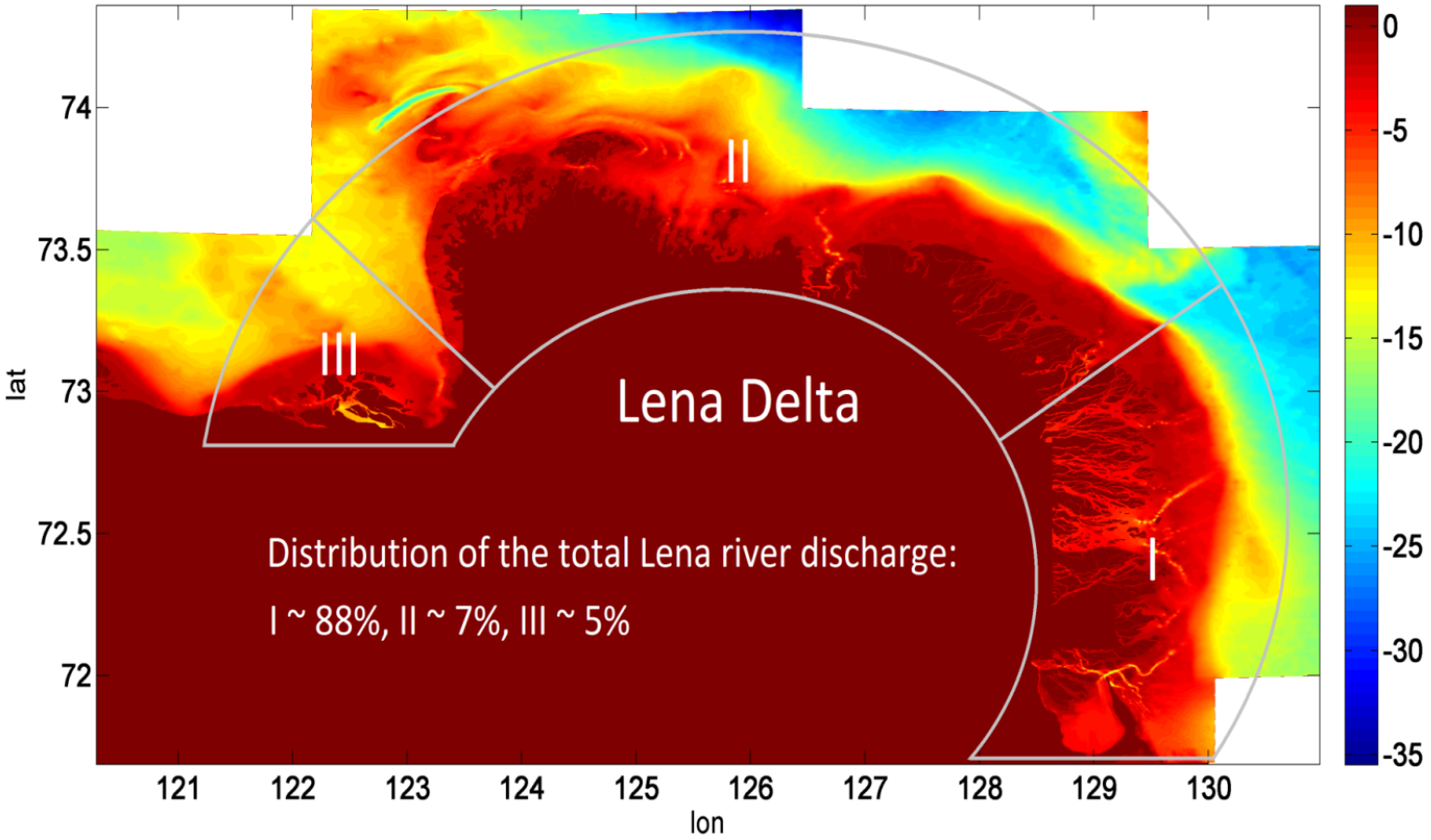


Figure showing detailed seabed topography (0m – terrestrial area). This map visualizes the locations of main channels where local extrema of freshwater discharge are located.

Vera Fofonova

BUT…

Why are we interest in simulation of Lena Delta River???

- ✓ Direct measurements are by far insufficient.
- ✓ All models, which include the Laptev Sea shelf zone, do not resolve the Lena Delta; modeling efforts of the Lena Delta are virtually absent.

So modeling approach is necessary

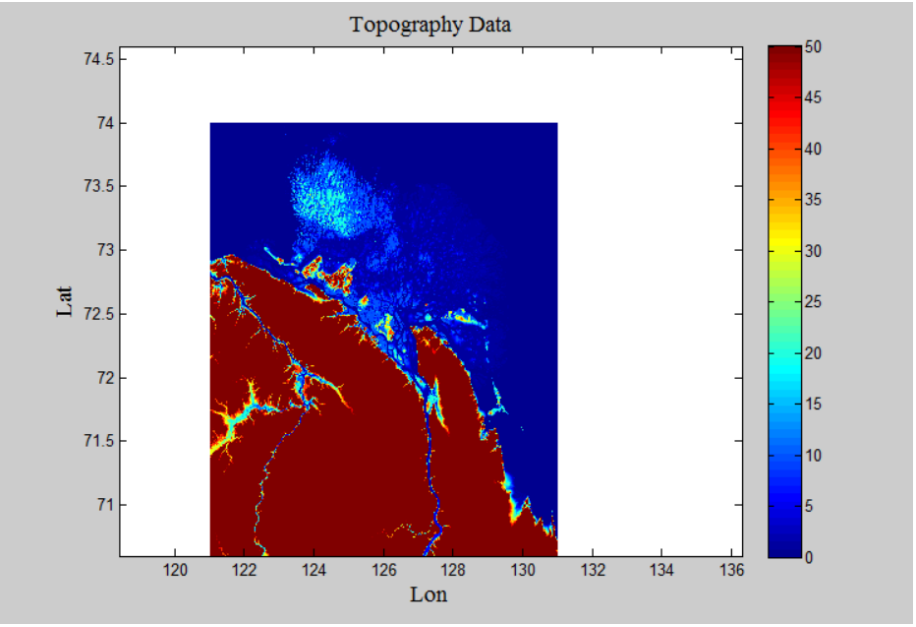
Main objectives

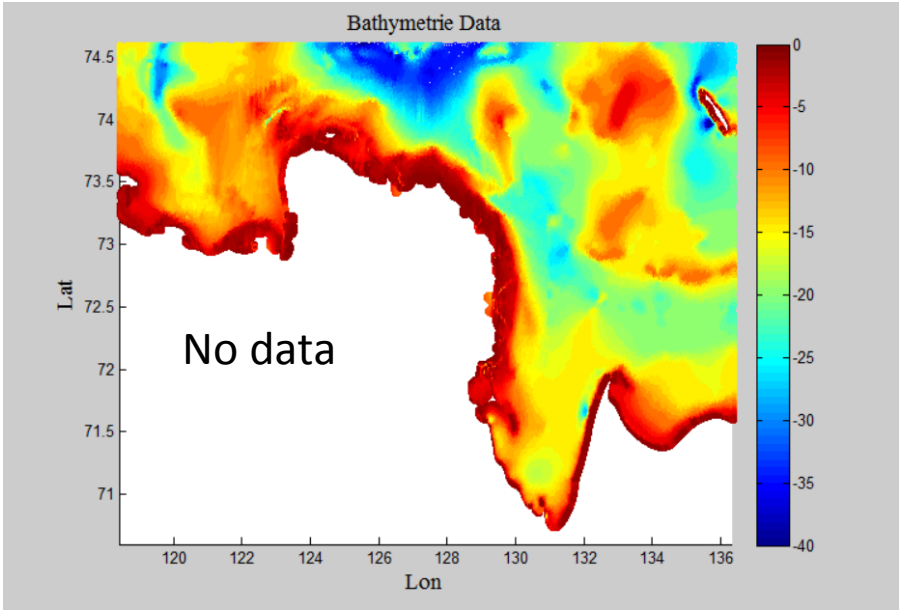
- ✓ **Set up a hydrodynamic module for the Lena Delta river.**

- ✓ **Analysis based on numerical simulations of:**

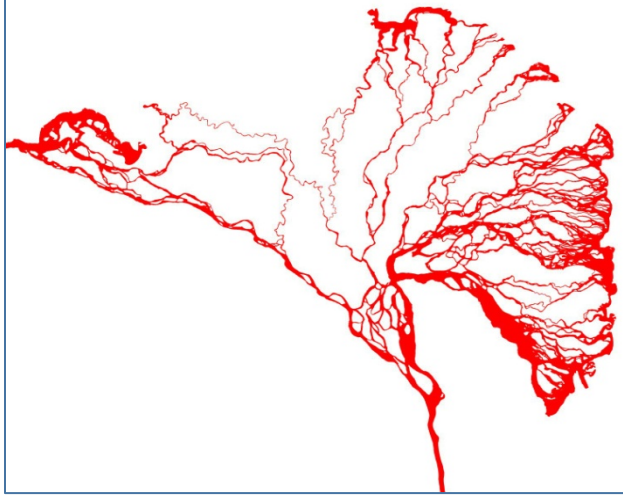
  - ➢ velocity regimes in the different freshwater channels depends of the discharge conditions and flood area (resolve)
  - ➢ salt water penetration to the Delta
  - ➢ tidal wave transformation.

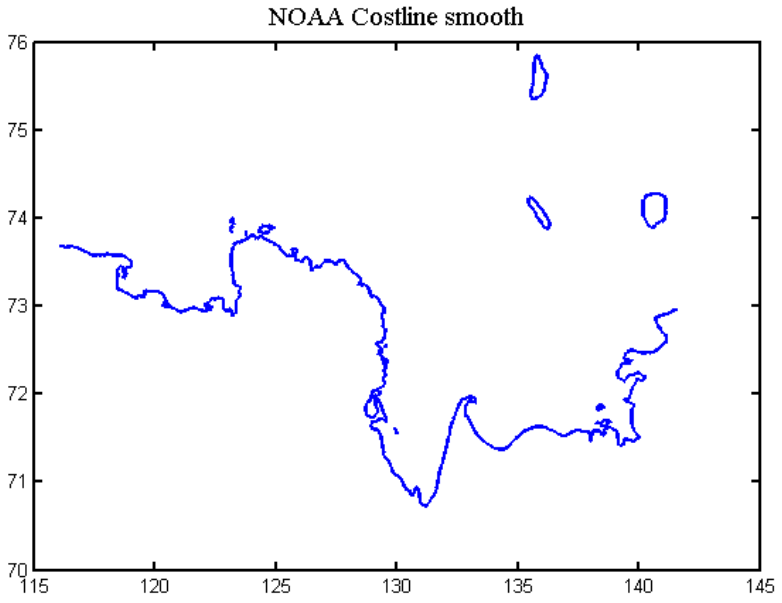
Data



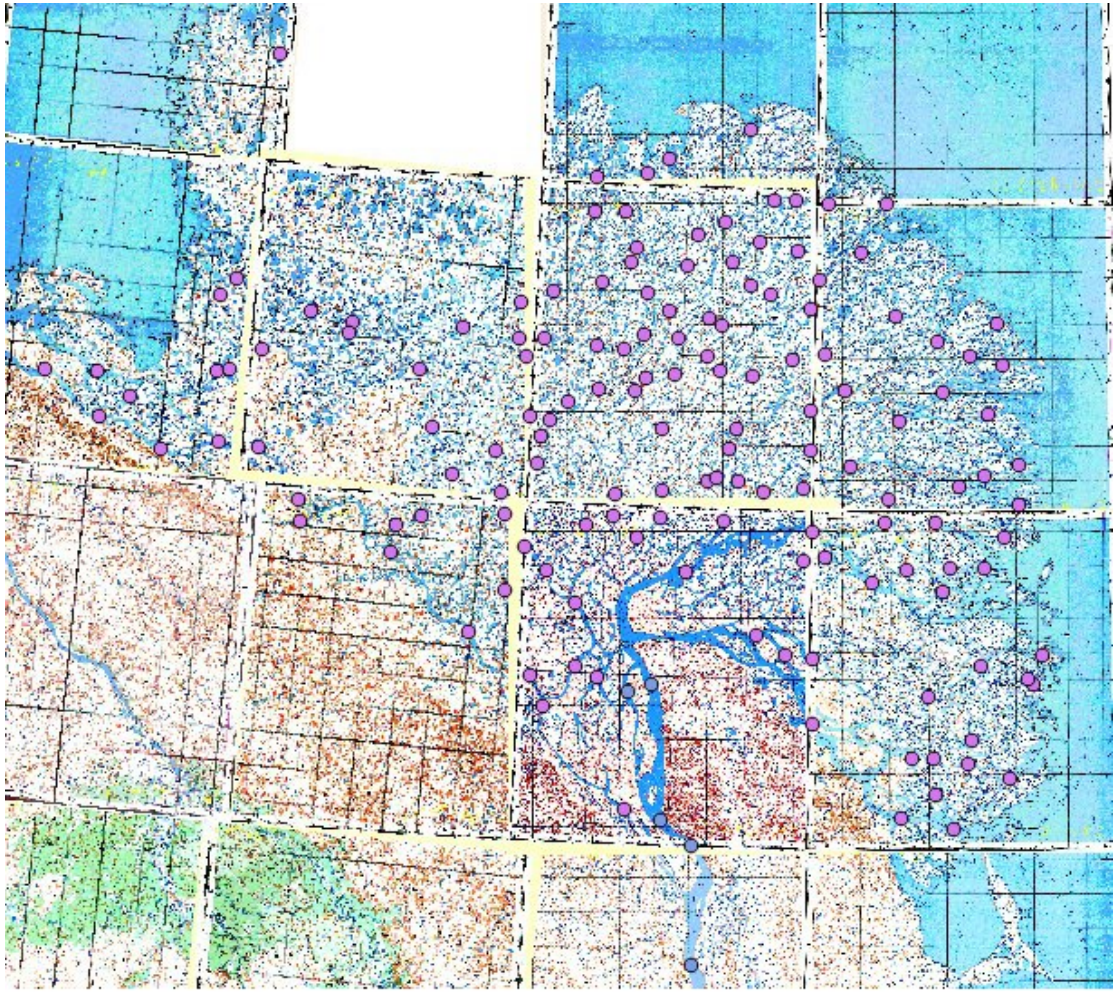


The area covered by water during the low water season





Data



Each point contains information:

1. Longitude, Latitude
2. Velocity
3. Width of channel
4. Water level

Soviet maps with a resolution of 2 km

How to proceed?

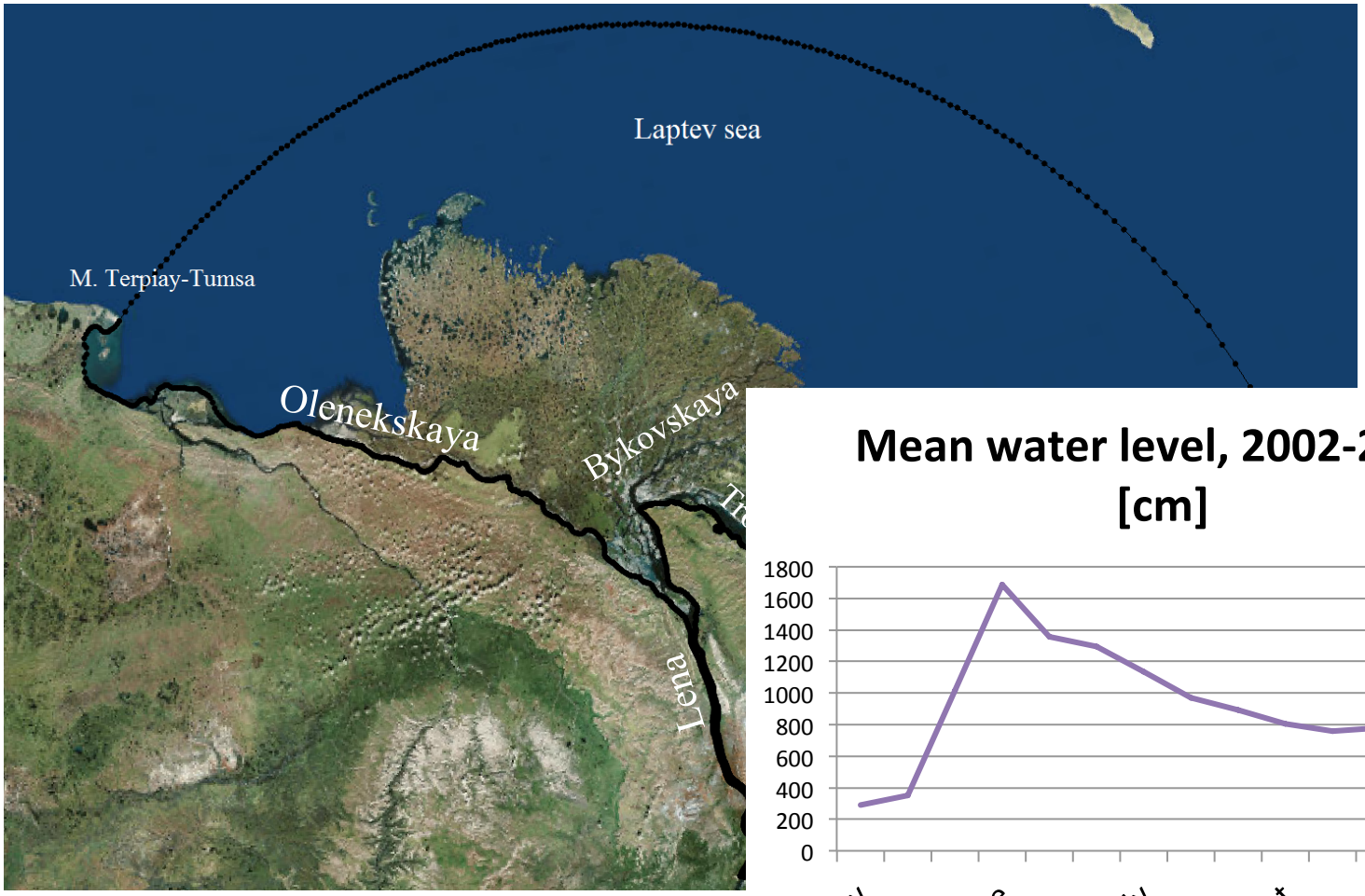
Main question

How to setup the model to provide a good base for the simulation?

- Selection of computational domain
- Construction of solid boundaries
- Mesh generating in the selected area
- Construction of relief matrix, where it is missing

Model setup

Computational Domain

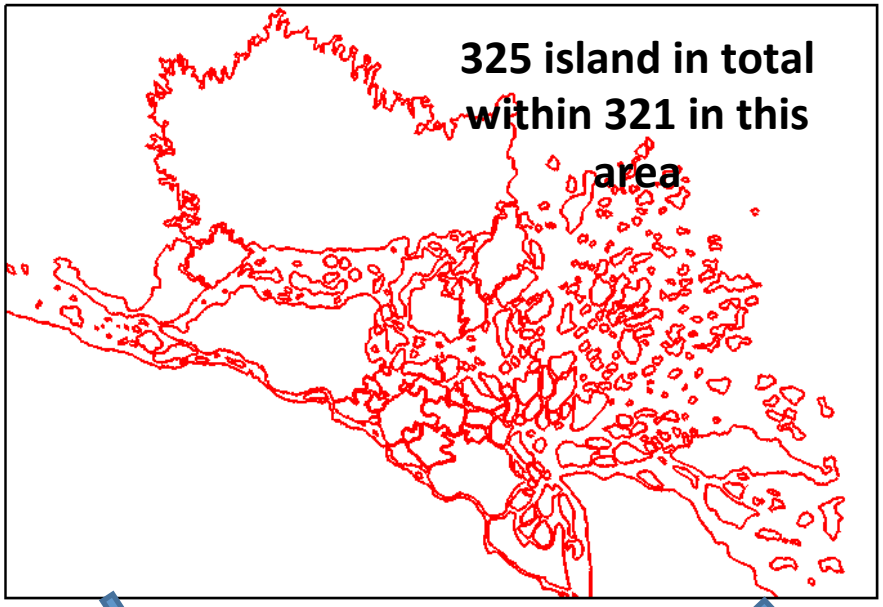


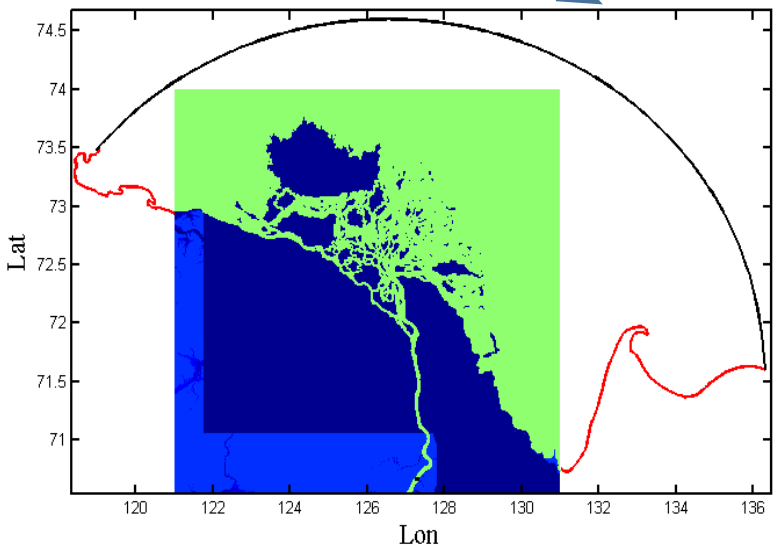
Mean water level, 2002-2010, [cm]

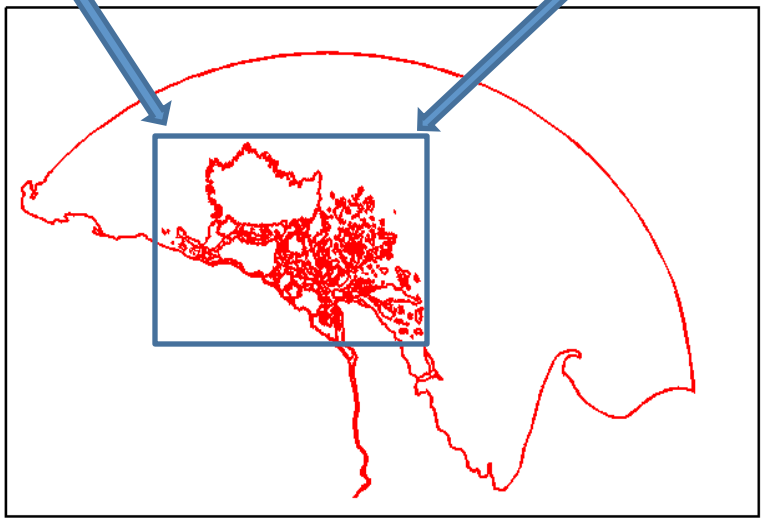
Model setup

Construction of s

Topograph
+
NOAA coastl
+
Information abou
level at different p
during the high w







Model setup

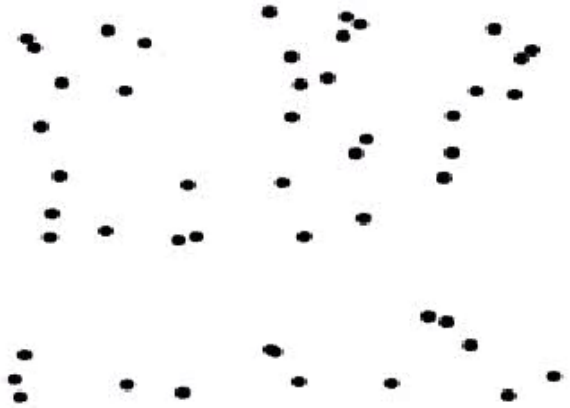
Unstructured mesh generating

Algorithm used: distmesh2d (PER-OLOF PERSSON)

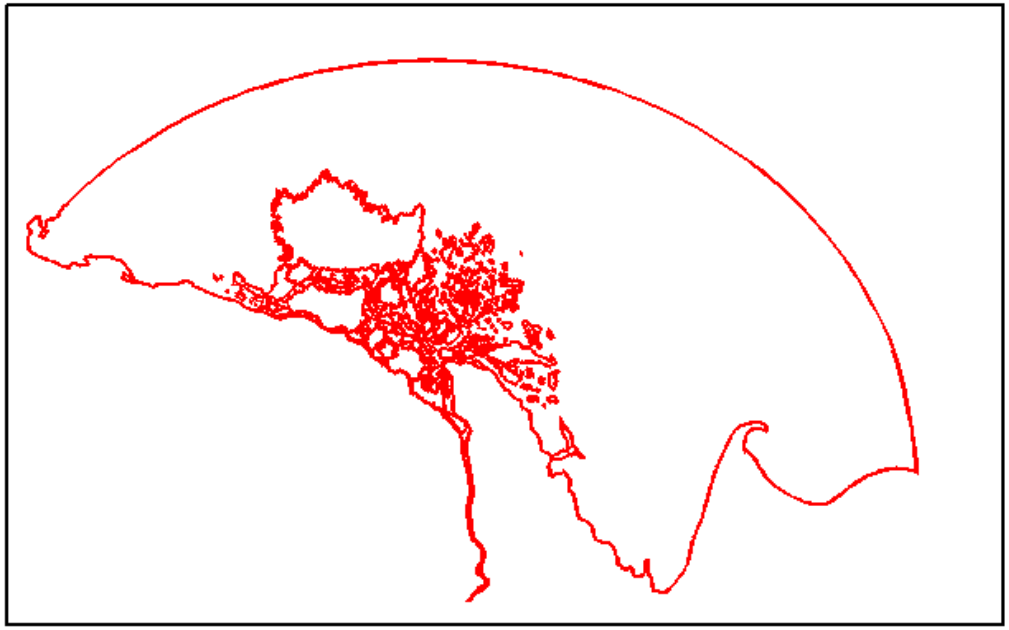
based on mechanical analogy between a triangle mesh and 2-D truss structure

- Node location is found by solving for equilibrium in a truss structure

- The topology is reset by Delaunay algorithm

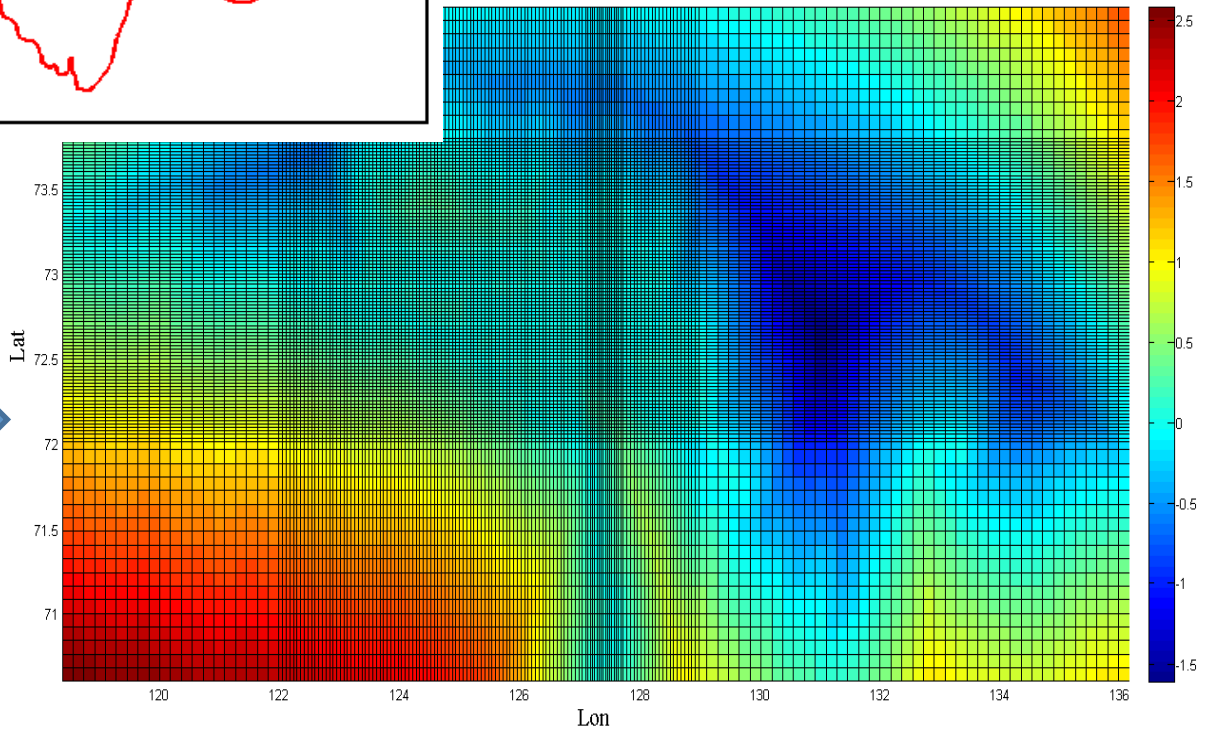


Distance matrix



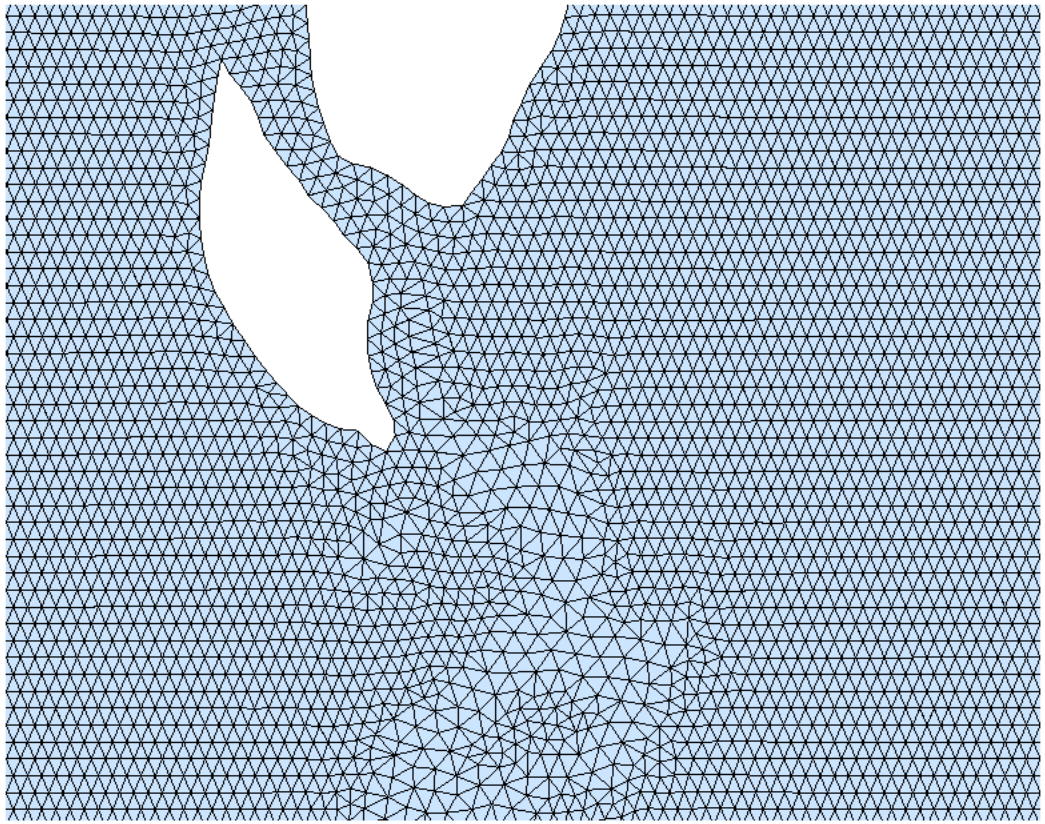
boundaries (solid boundaries+ open boundaries

Distance matrix



Model setup

Unstructured mesh generating (837405 nodes)



Model setup

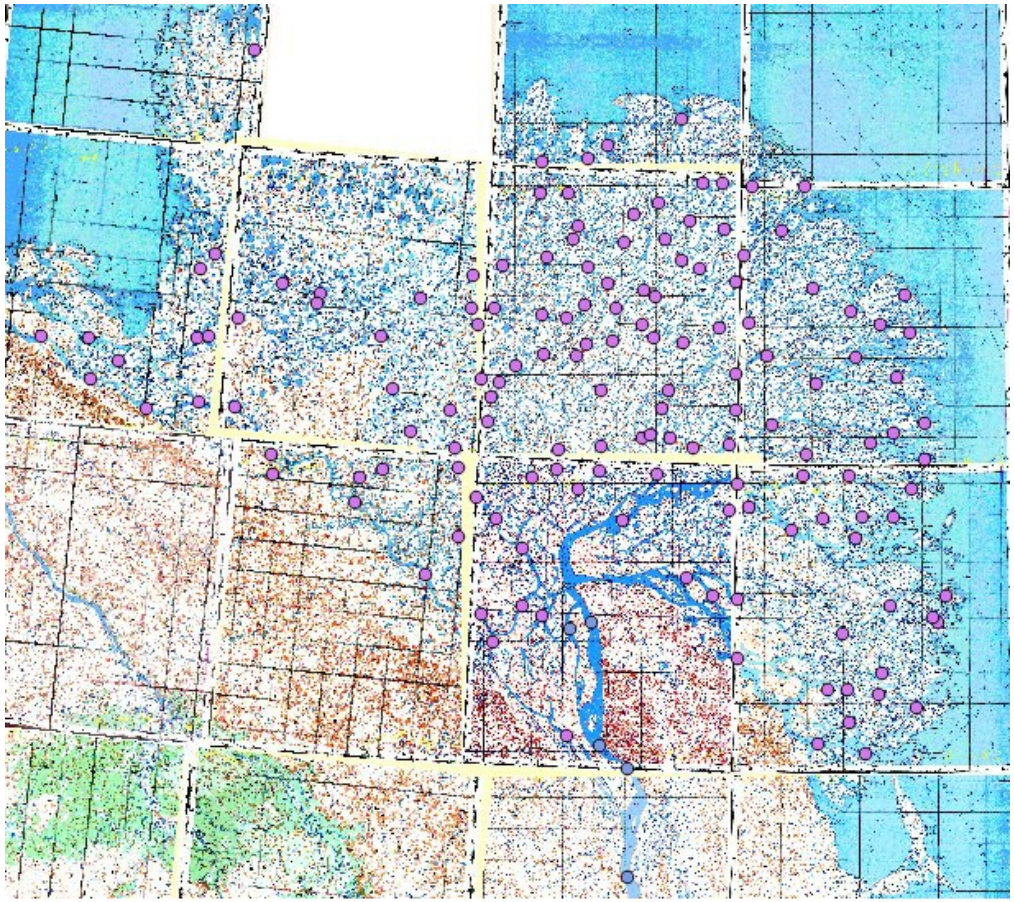
Reconstruction of bathymetry data in the channel

Cross sections of the main stream at different location of the main stream, including:

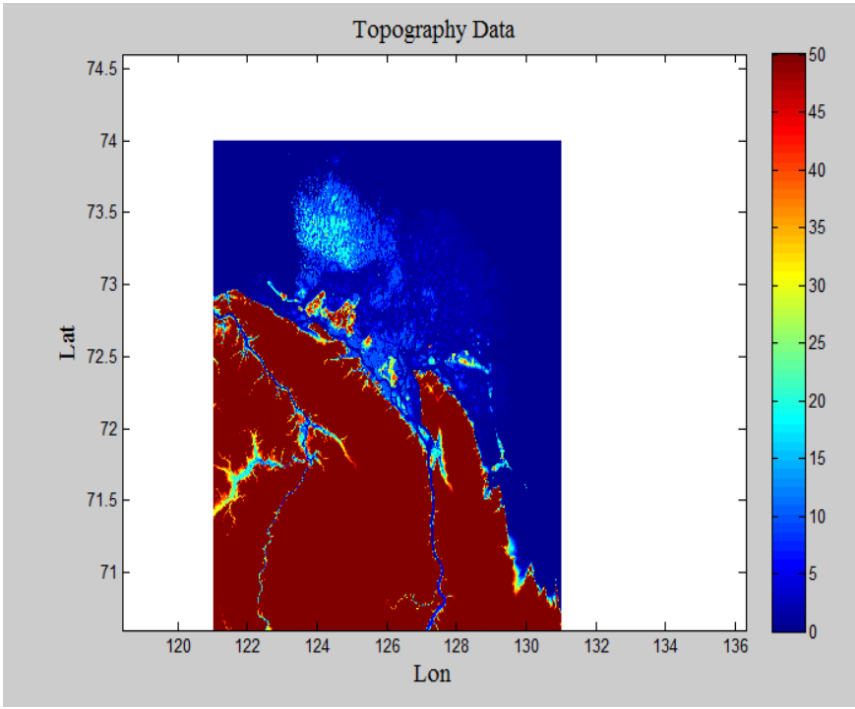
- Cross section area
- Width of the section on free surface
- Maximum depth along the section
- Mean depth along the section
- Absolute elevation at the two end points of the section
- coordinates where the cross section is taken

Model setup

Reconstruction of bathymetry data in the channel



Processing Soviet maps with a resolution of 2 km



Topography data

Model setup

Reconstruction of bathymetry data in the channel

$$Q = B \cdot h^{\frac{5}{3}} J^{\frac{1}{2}} n^{-1};$$

$$v = c\sqrt{RJ};$$

$$R = \frac{w}{B};$$

$$c = \frac{14{,}8}{J^{\frac{1}{6}}} - 26.$$

Q – discharge;

B – stream width;

h – stream depth;

J – slope of the water surface;

n – roughness coefficient;

w – cross-sectional area;

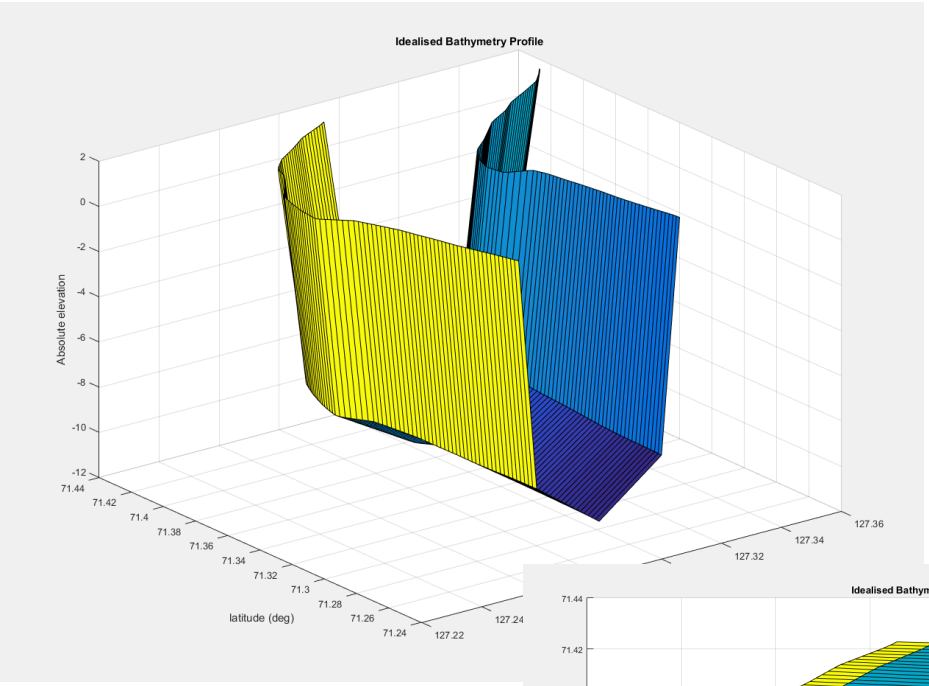
c – Chezy coefficient;

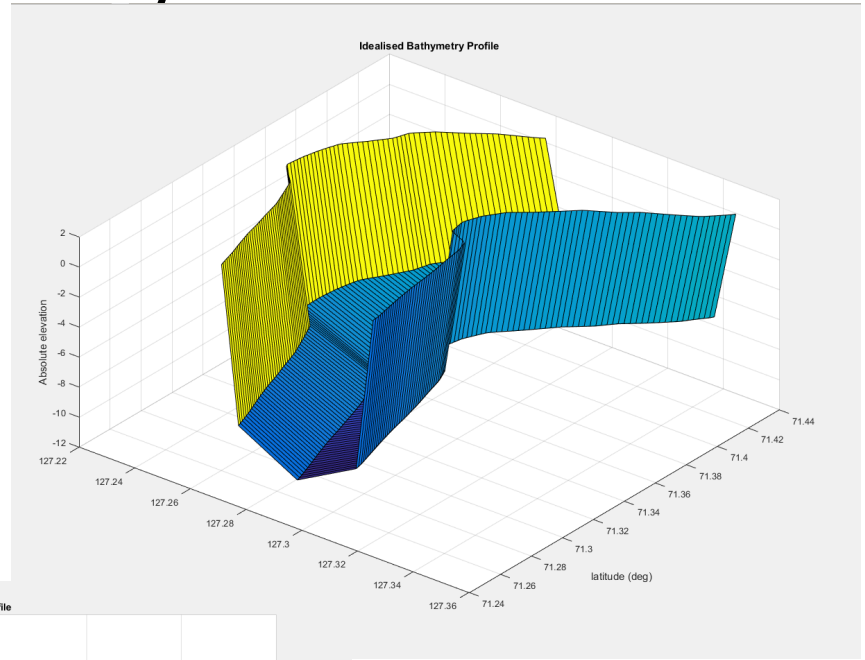
R – hydraulic radius;

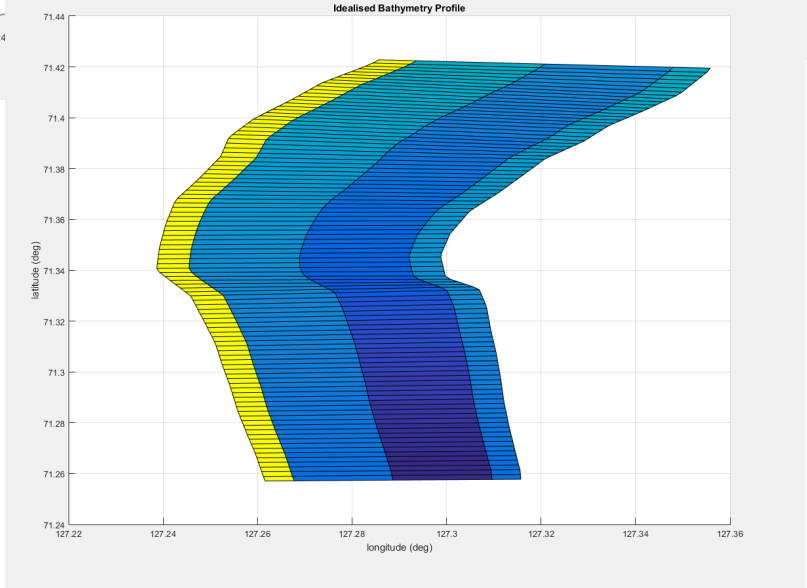
v – stream velocity;

Model setup

Reconstruction of bathymetry data in the channel







Next step

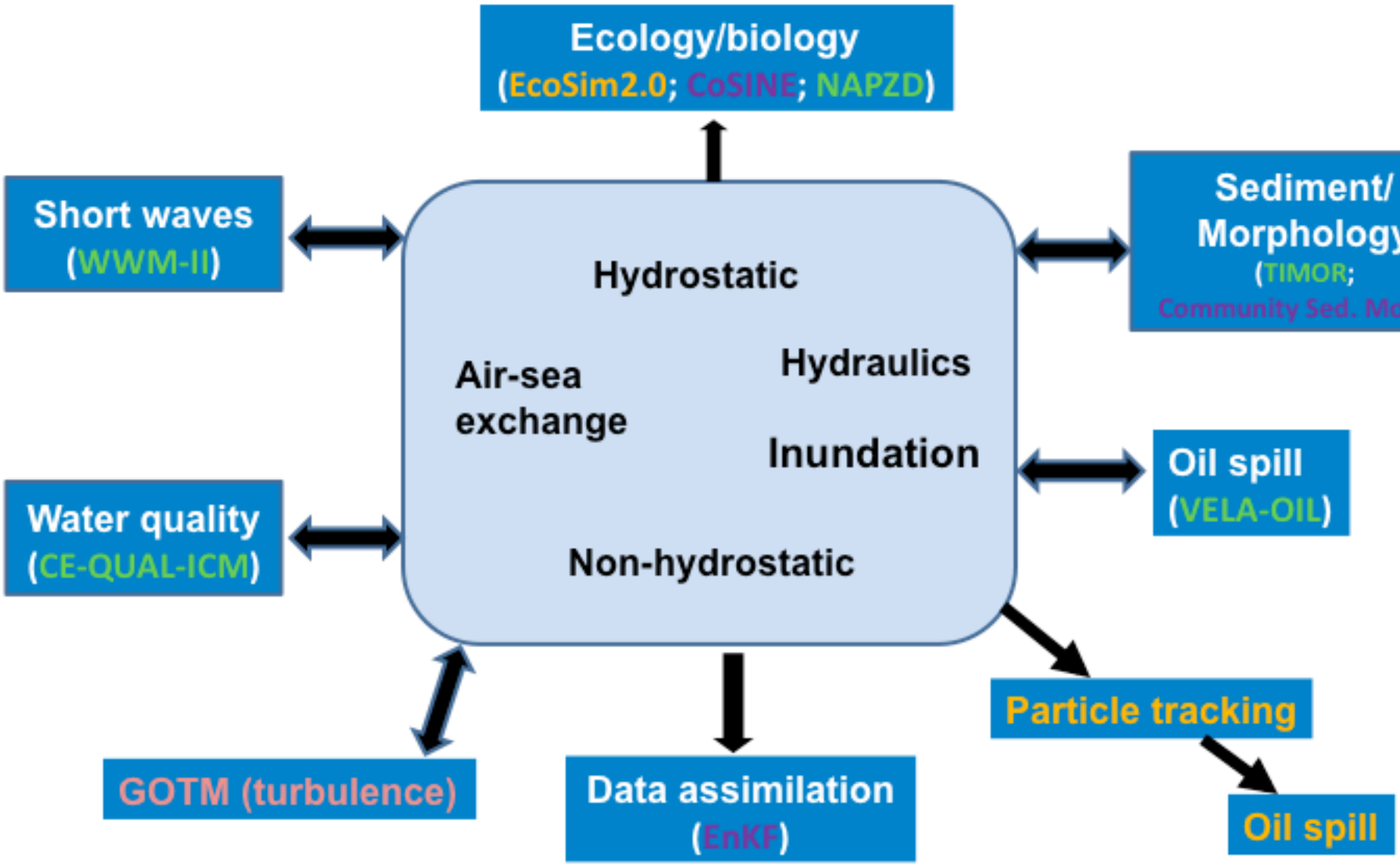
Running the model

We have to approach for that:

- Discontinuous Galerkin method (DGM)
- SELFE (Circulation Model for Oceans and Estuaries)

SELFE uses a semi-implicit finite-element/ volume Eulerian-Lagrangian algorithm to solve the Navier-Stokes equations (in either hydrostatic and non-hydrostatic form).

SELFE modeling system



Color code: Open-released Soon-to-be-released In-development Free-from-web

What has been already done

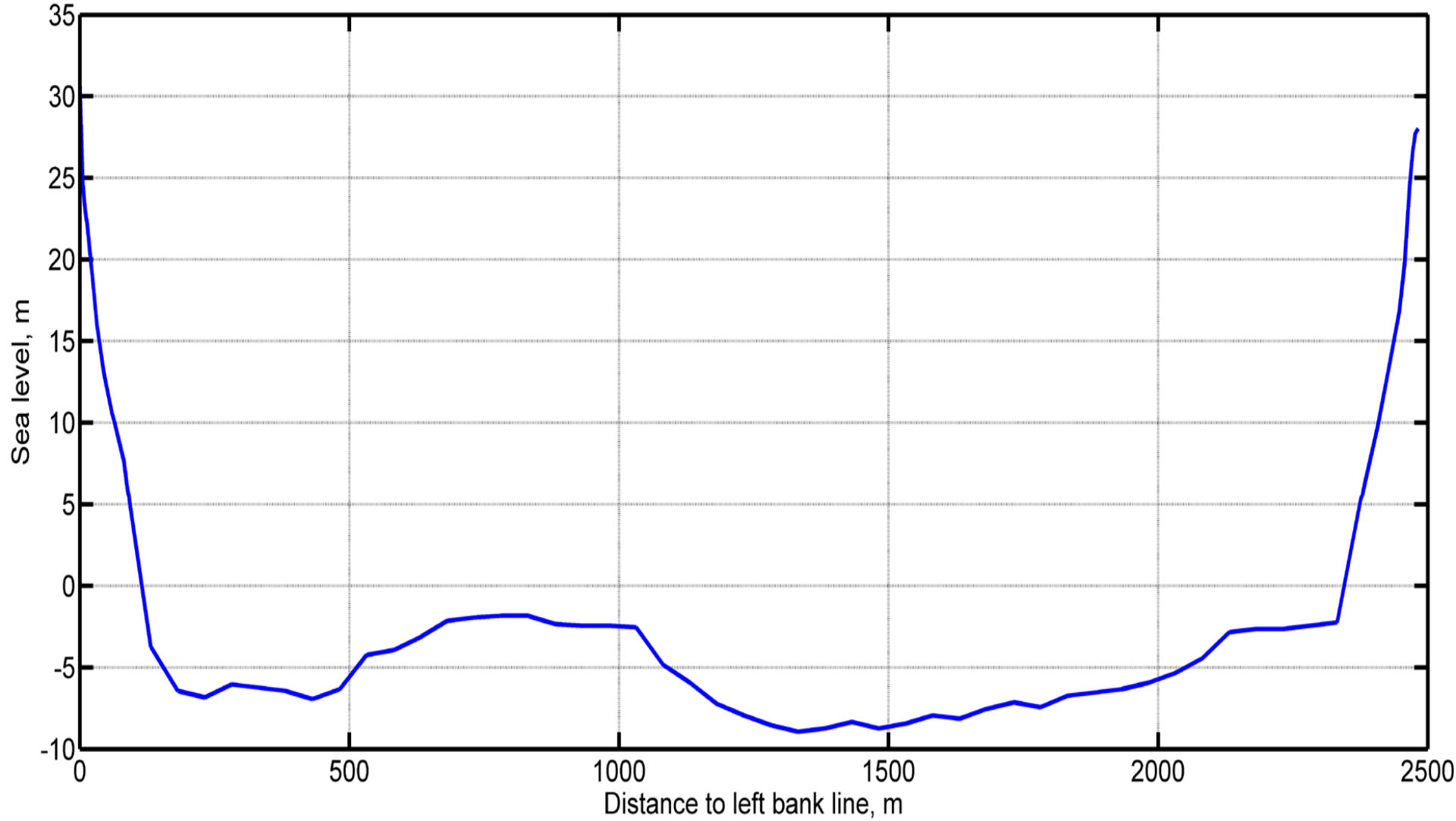
- Computational domain which is selected such tha
- Construction of solid and open boundaries
- Generation of good grid which should able to resolve a complex dynamics in this area
- Construction of relief matrix where it is missing
- Setup the model to provide a good base for the future simulations
- We have already partly analyzed the velocity regime and tide transformation

Outlook

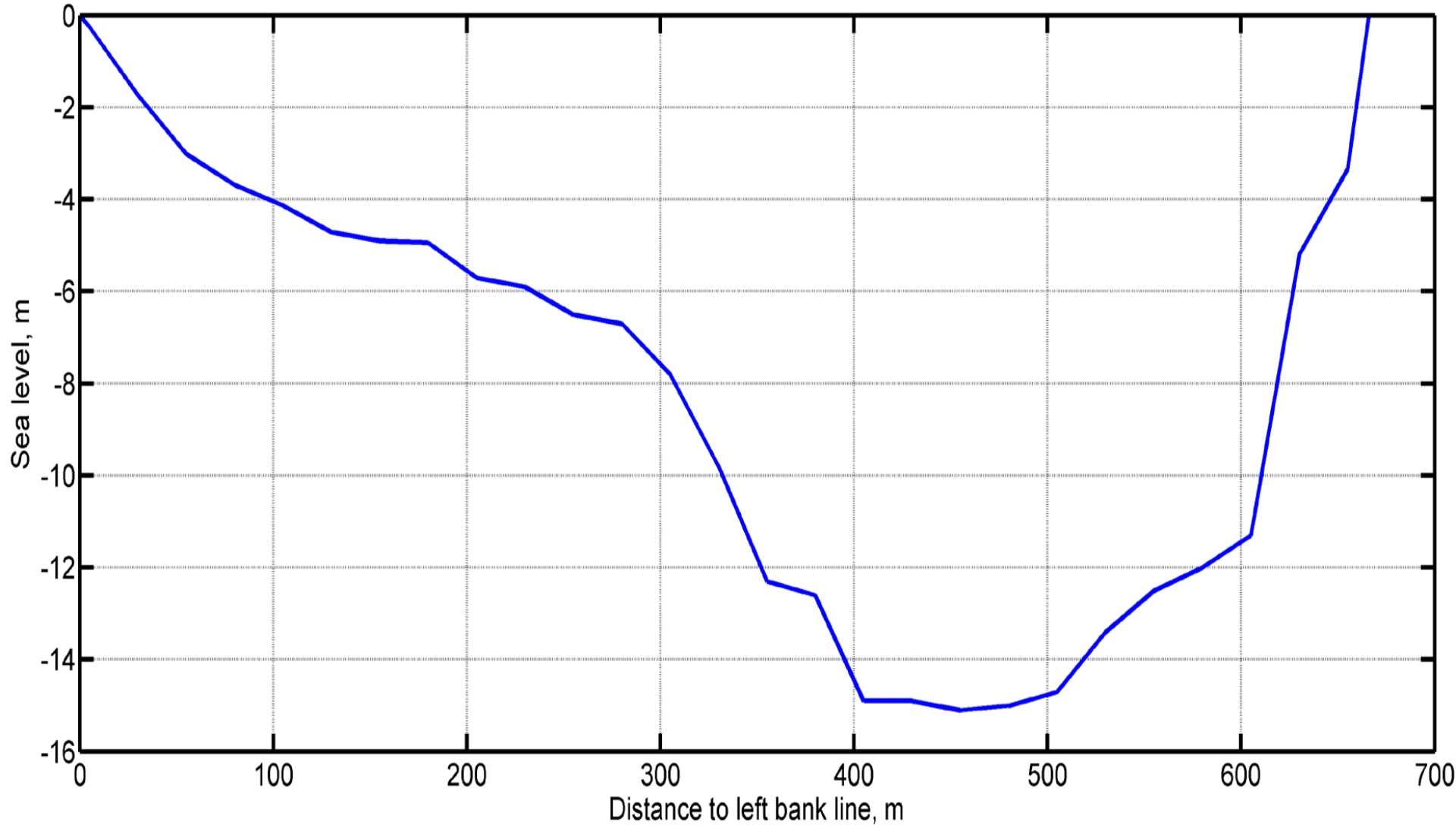
- velocity regimes in the different freshwater channels
- salt water penetration to the Delta
- tidal wave transformation

THANK YOU FOR YOUR ATTENTION

Спасибо!!!

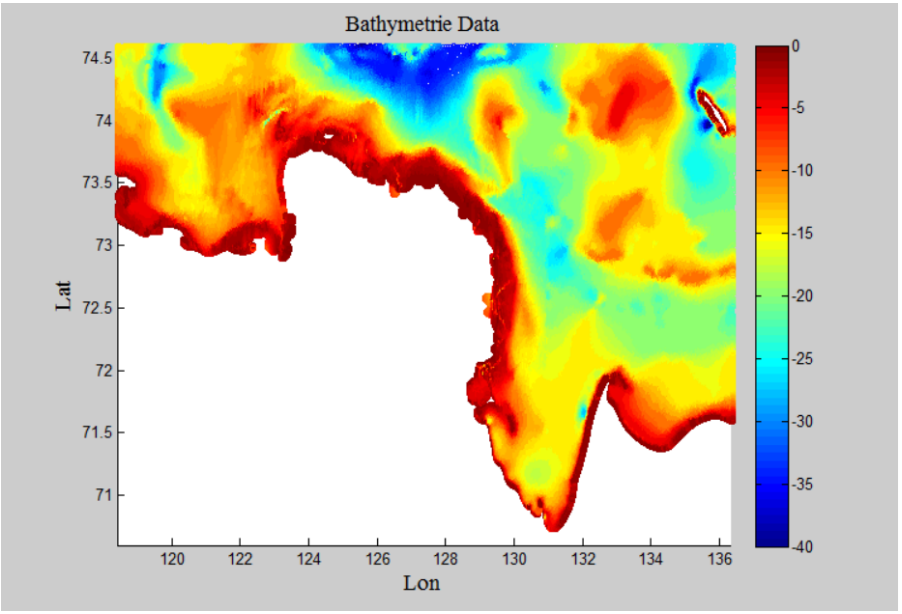


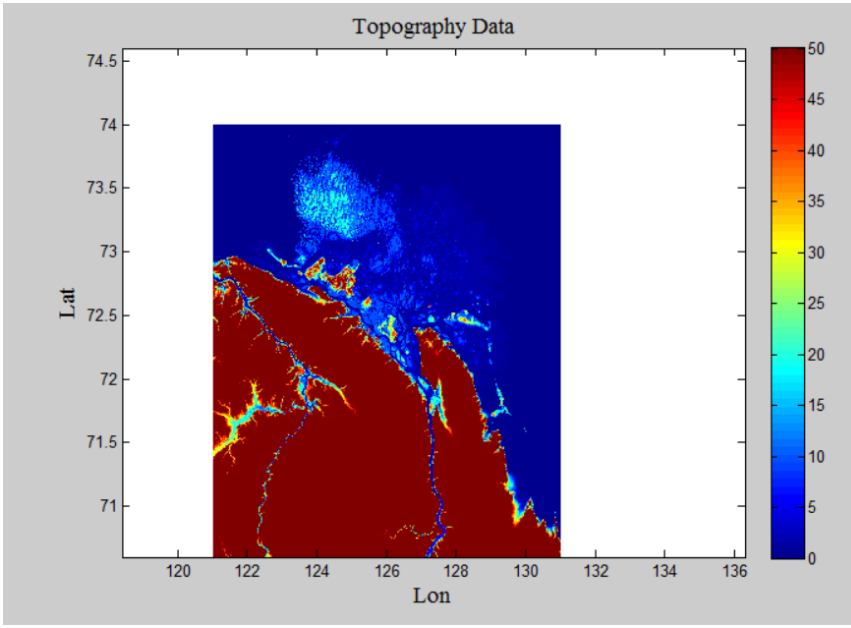
The transverse profile of the riverbed in the area of GS Kusur based on observations in 2012, first decade of June, [m].



The transverse profile of the riverbed in the area of GS Habarova based on observations in 1991, last decade of November, [m].

How to construct these parameters mainly fd and fh???



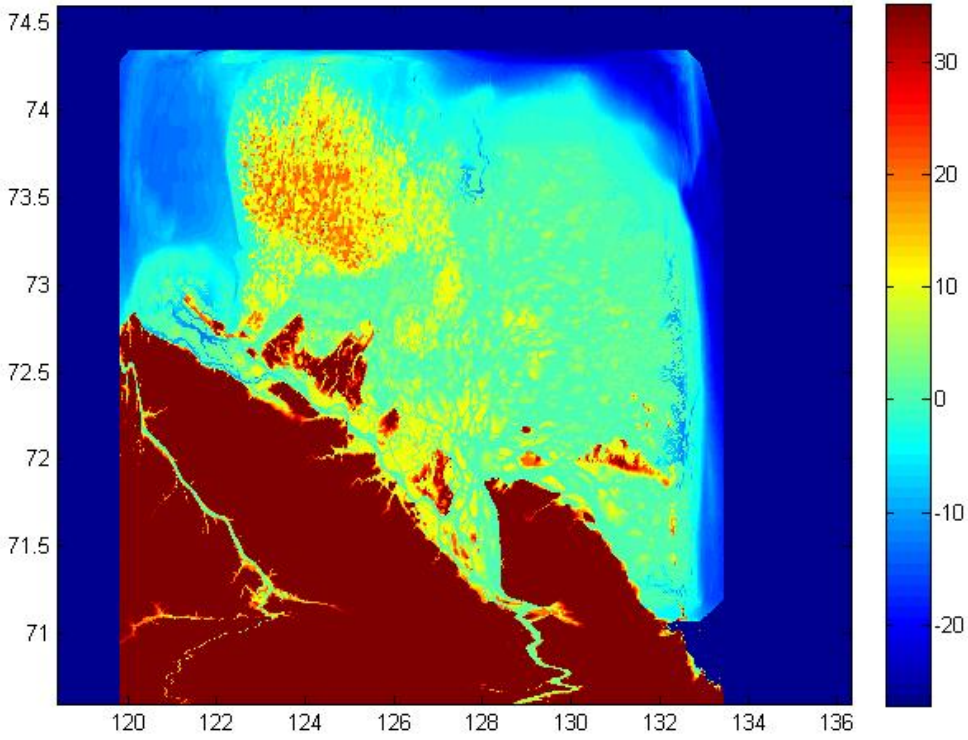


Dist matrix fig

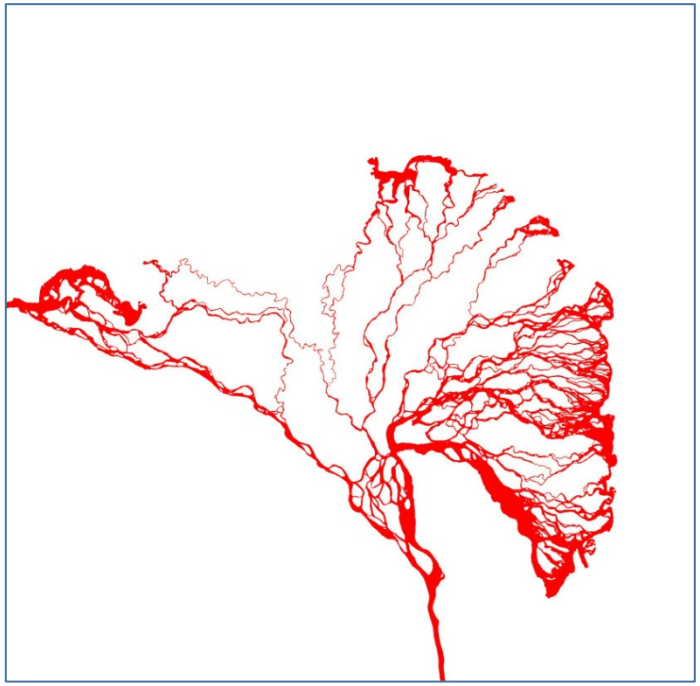
Scale factor fig

Model setup

Reconstruction of bathymetry data in the channel



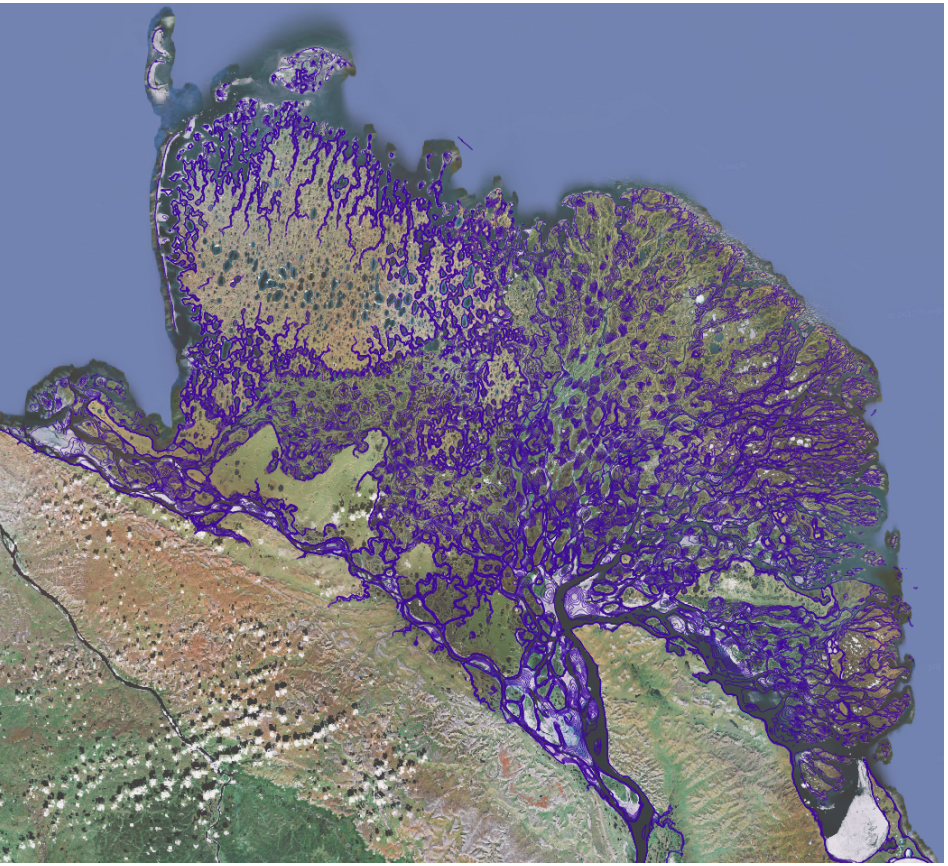
Topography and bathymetry data

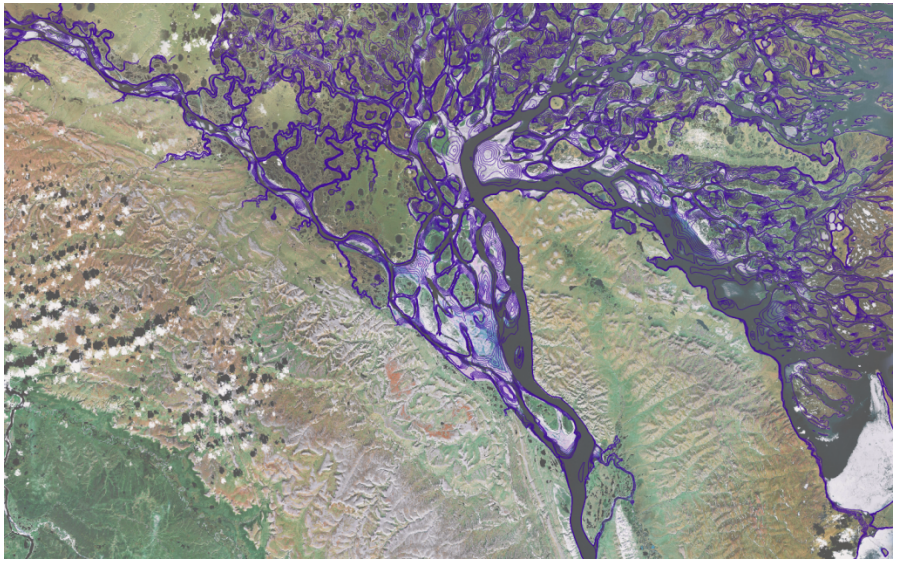


The area covered by water during the low water season

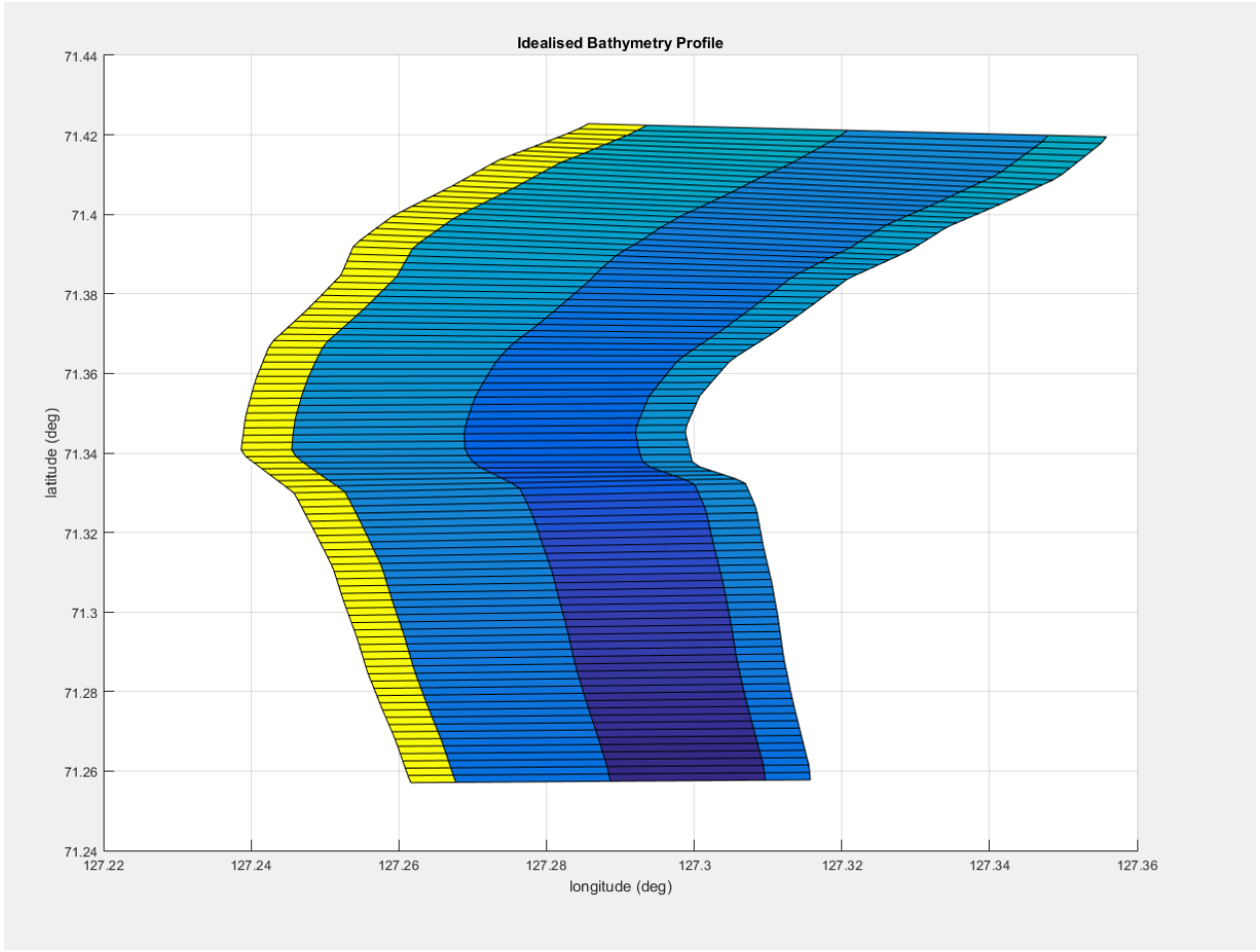
Model setup

Reconstruction of bathymetry data in the channel





contour elevation > 8m not shown


Idealised Bathymetry Profile
71.44
71.42
71.4
71.38
71.36
71.34
71.32
71.3
71.28
71.26
71.24
latitude (deg)
127.22
127.24
127.26
127.28
127.3
127.32
127.34
127.36
longitude (deg)