Storm surges in the easternmost Gulf of Finland during operation of the Flood Protection Barrier of St. Petersburg

V.Ryabchenko[1], *P.Andreev*[2], *A.Averkiev*[3], *A.Dvornikov*[1], *K.Klevanny*[4] , *V.Tsepelev*[2]

[1]St.Petersburg Branch, P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences
[2]North West Administration on Hydrometeorology and Environmental Monitoring, St. Petersburg
[3]Russian State Hydrometeorological University, St.Petersburg
[4]Ltd"CARDINAL Soft", St.Petersburg

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Outline of presentation

- Models of storm surges operating in SPb
- An idealized model of the atmospheric pressure field
- Features of storm surges when the FPB is operating
- Concluding remarks

Two models used to study storm surges in the easternmost GoF

- The system CARDINAL (Coastal ARea Dynamic INvestigation ALgorithm) is a program to simulate the long-wave dynamics and dispersion of pollutants in any basin. It was used to develop a two-dimensional Baltic Sea model to calculate the water level changes using the shallow water equations (http://cardinal-hydrosoft.com). The model (versions from BSM3 to BSM6) has been working in the St. Petersburg Center for Hydrometeorology and Environmental Monitoring since December 1999 in automatic mode for the prediction of water level in St. Petersburg.
- A high-resolution 3-d hydrodynamic model NEVAM coupled with the advanced sea-ice model HELMI for the eastern part of the GoF (Ryabchenko, Dvornikov , Haapala, Myrberg, 2010)

Spatial resolution :

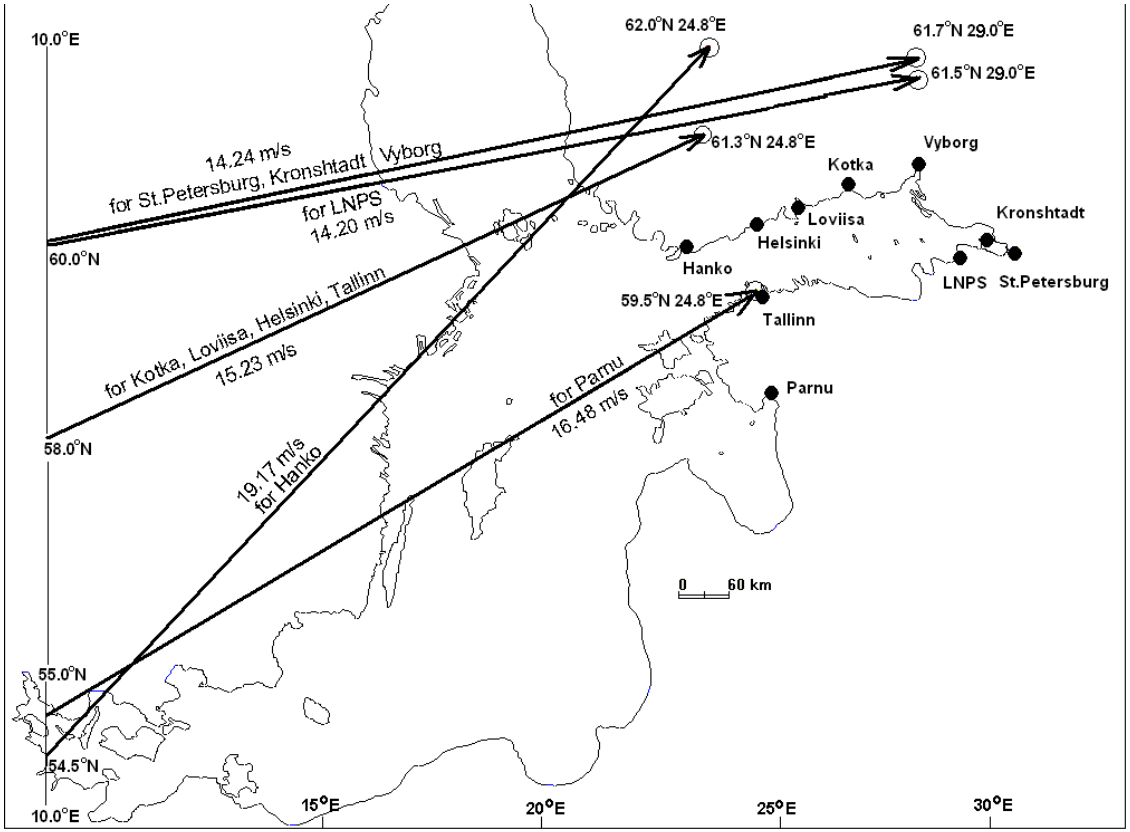
	MIN	MAX
X coordinate	47 m	369m
Y coordinate	39 m	557m

7 sigma-levels

Water depth	0.2 m	34 m

New developments: the specified description of the Flood Protection Barrier (Dvornikov et al., 2013)

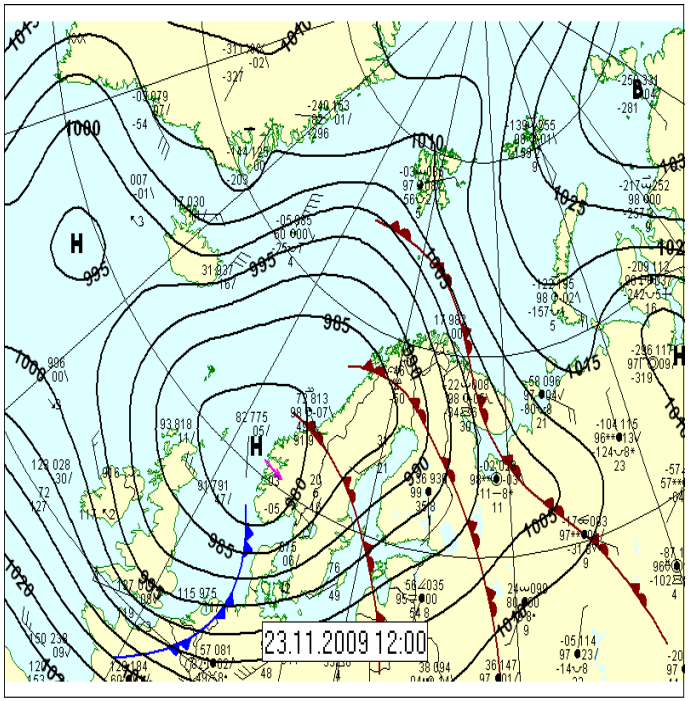
Cyclone trajectories



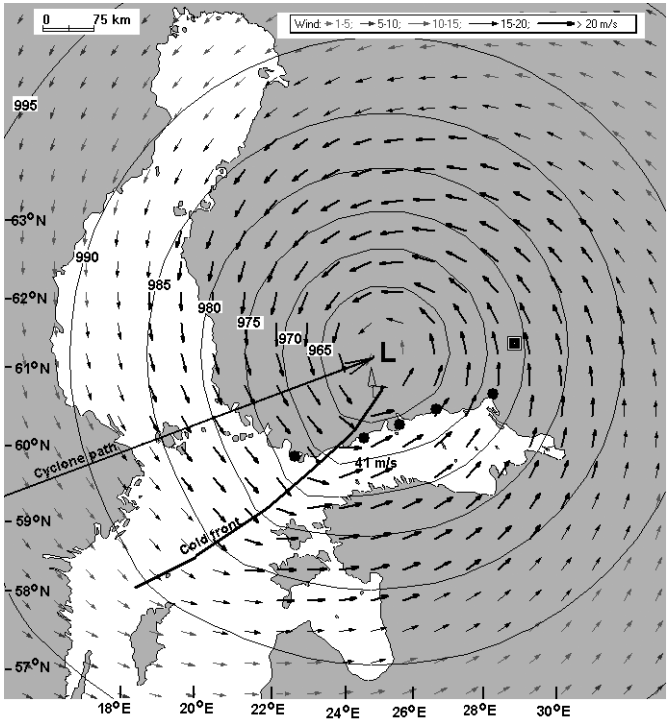
The most dangerous cyclone trajectories, velocities and positions of cyclone centres at the moments of their maximal deepness for different points in the Gulf of Finland and Pärnu (Gulf of Riga).

Klevannyy K.A., Averkiev A.S. Simulation of extreme events in the level in the Gulf of Finland with allowance for the influence of Flood Protection Barrier of St. Petersburg. 2011. *In:* Basic concepts of the modern usage of the coast. V. 3, 10-24.

A synoptic real map with cyclone isobars which are close to concentric.

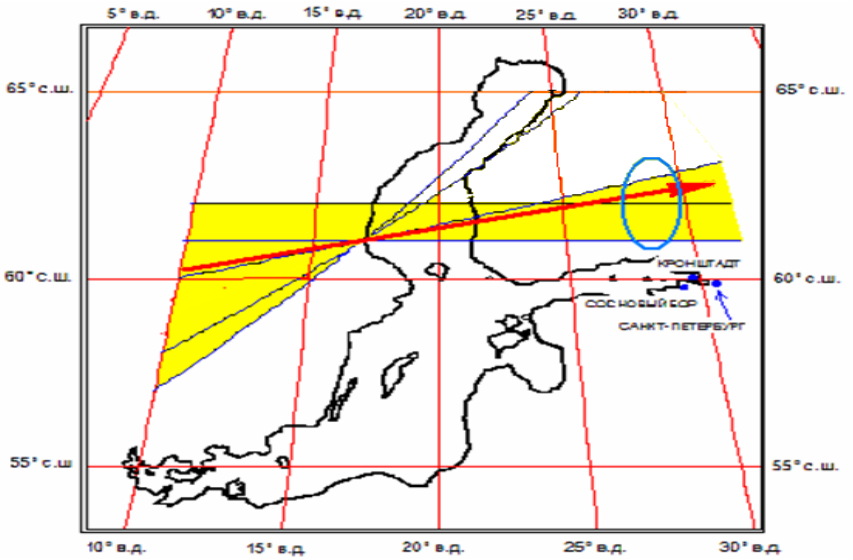


Model cyclone with concentric isobars and extreme parameters.



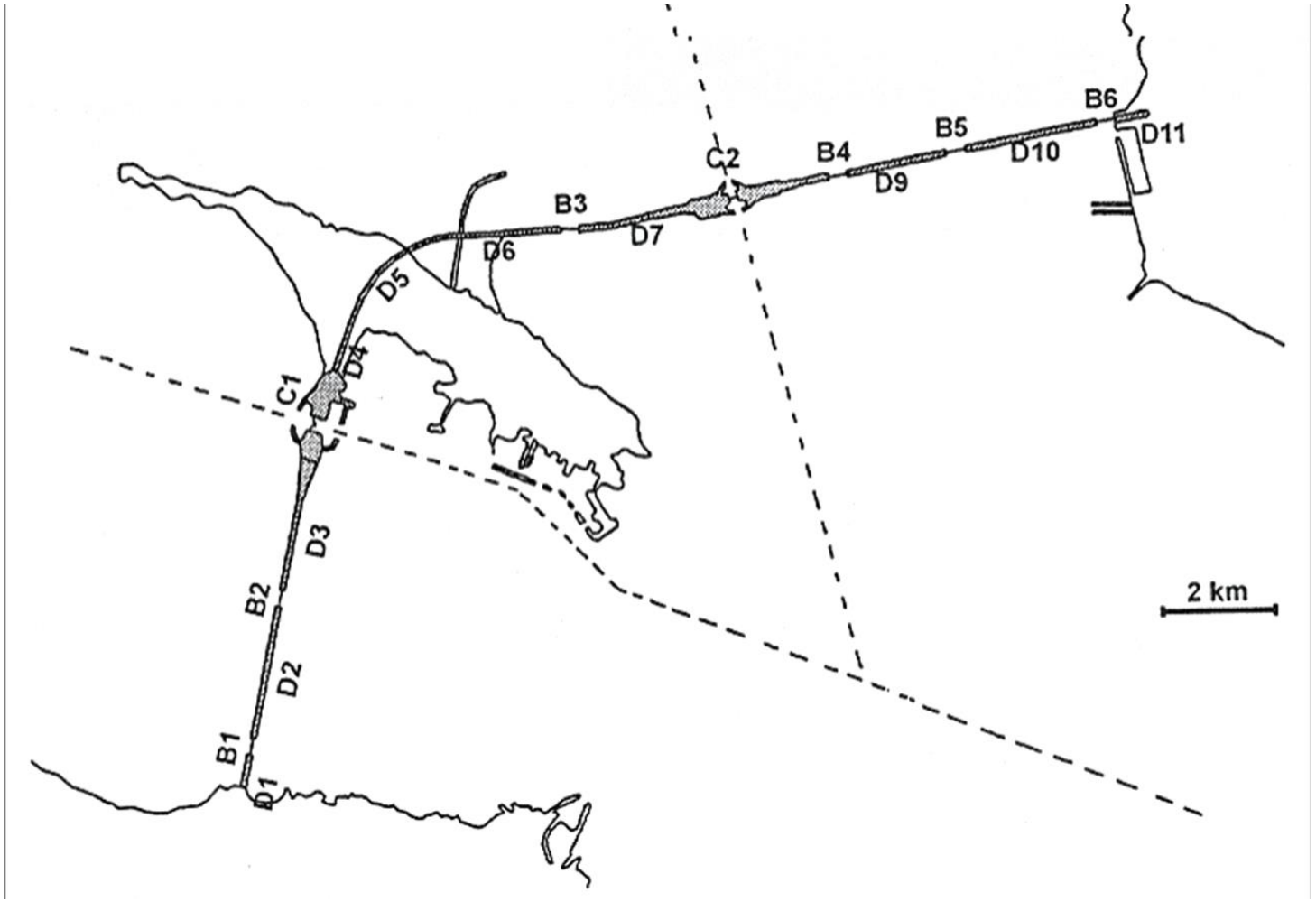
Greatest level rises in the eastern Gulf cause cyclones moving at

V_c=50 km/h
to the east or east-northeast
along 61.5 º N
(according to CARDINAL results)



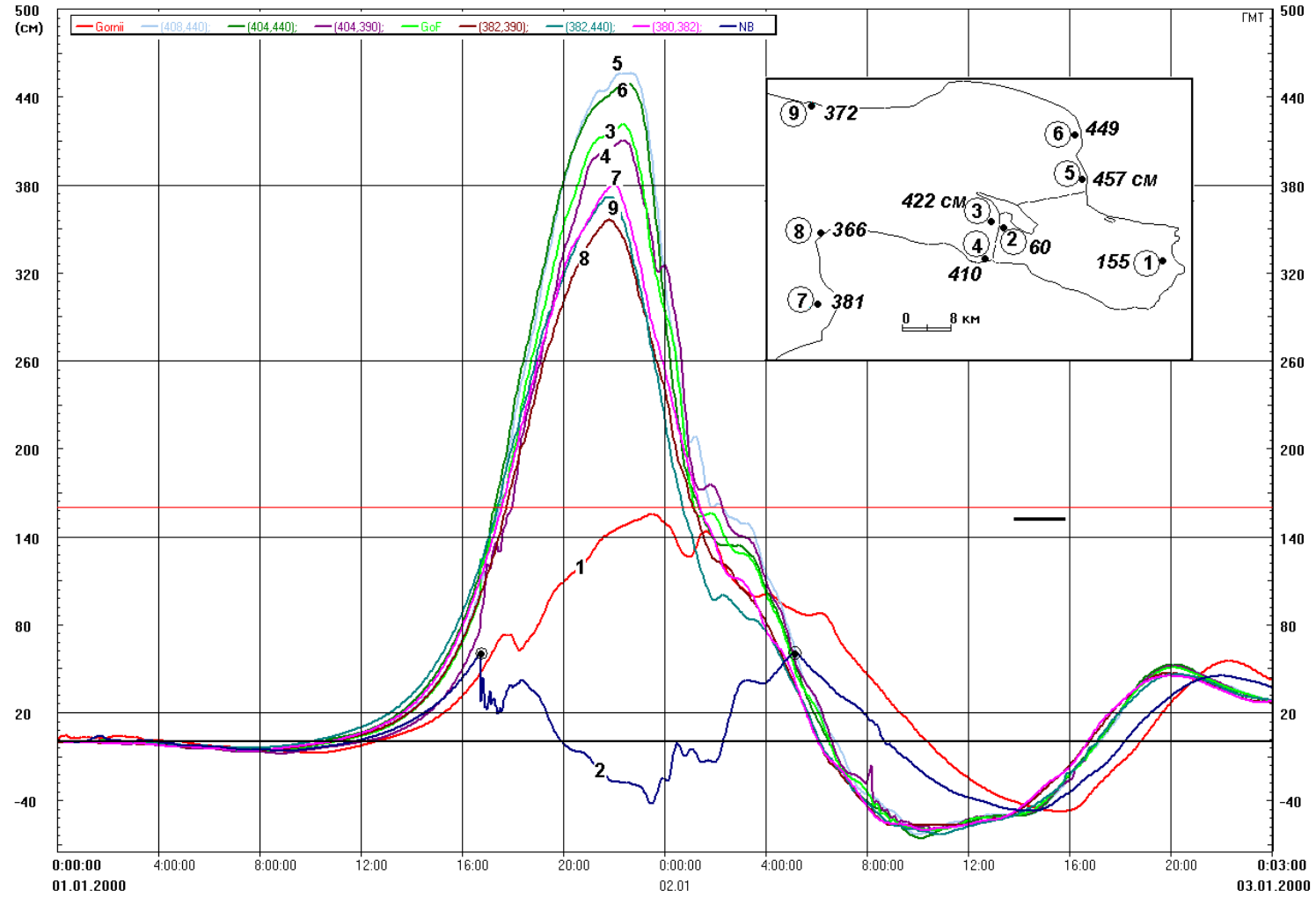
The sector of most dangerous cyclone trajectories. In oval isolated area, pressure in the center of the cyclone has a minimum value.

Scheme of the Flood Protection Barrier (FPB) of St. Petersburg



B1, B2, B3, B4, B5, B6 - waterway gates,
C1 and C2 - navigation passes; D1 - D11 - parts of the dam.
The FPB was open on 12th August 2011

A model situation of passing an extreme cyclone in the case of closed FPB gates



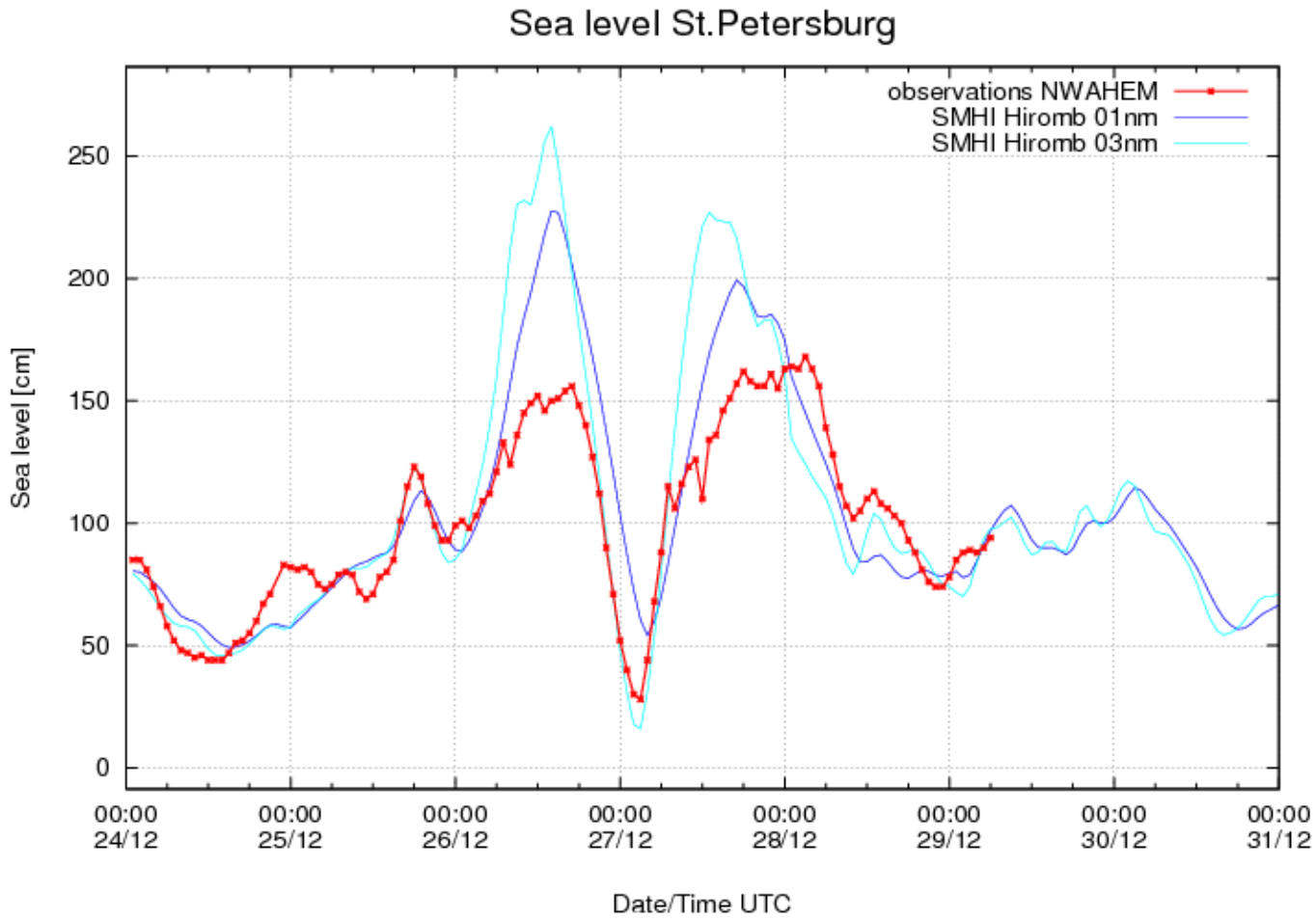
West of the FPB
$\Delta\zeta \leq$ 20-30 cm

In Neva Bay

$$\frac{\Delta\zeta}{\Delta x} = \frac{1.5m}{25km}$$

The time evolution of the water level at various points of the eastern GoF during the passage of the extreme cyclone in the case of closed gates of FPB. Dark points are the moments of opening and closing of the gates of FPB

The tilt of level is about of 1.5 m between the FPB and the Neva mouth, i.e. at a distance of 25 km (Cf. curves 1 and 2).



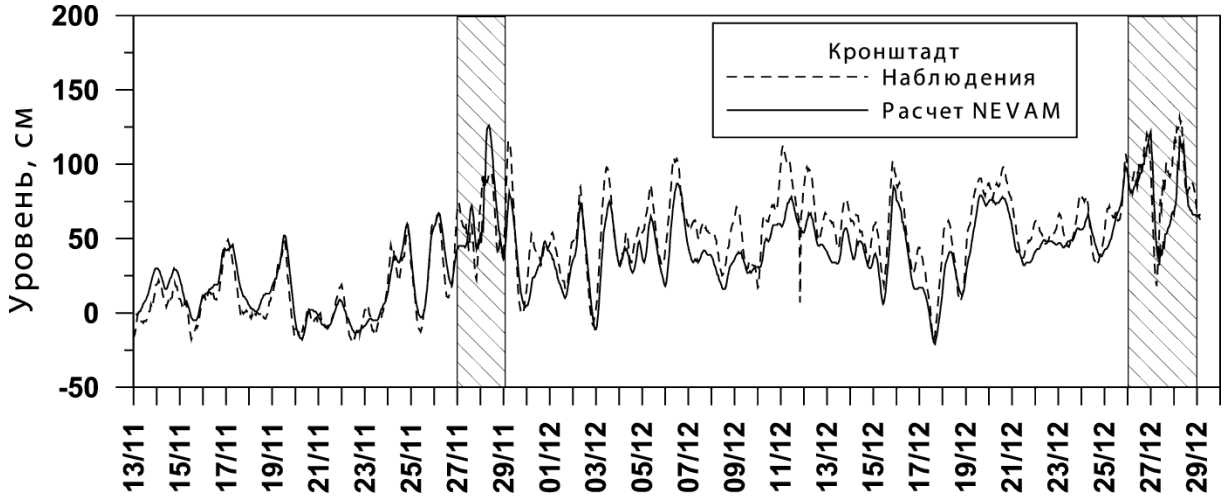
Observed (data of North-West Hydrometeorological Service) and predicted (model HIROMB) water level in St. Petersburg (at the point ” Mining Institute”) during the flood of December 26-27, 2011

1-st closing: 7 h 26 Dec to 1 h 27 Dec ; 2-d closing: 9 h 27 Dec to 6 h 28 Dec

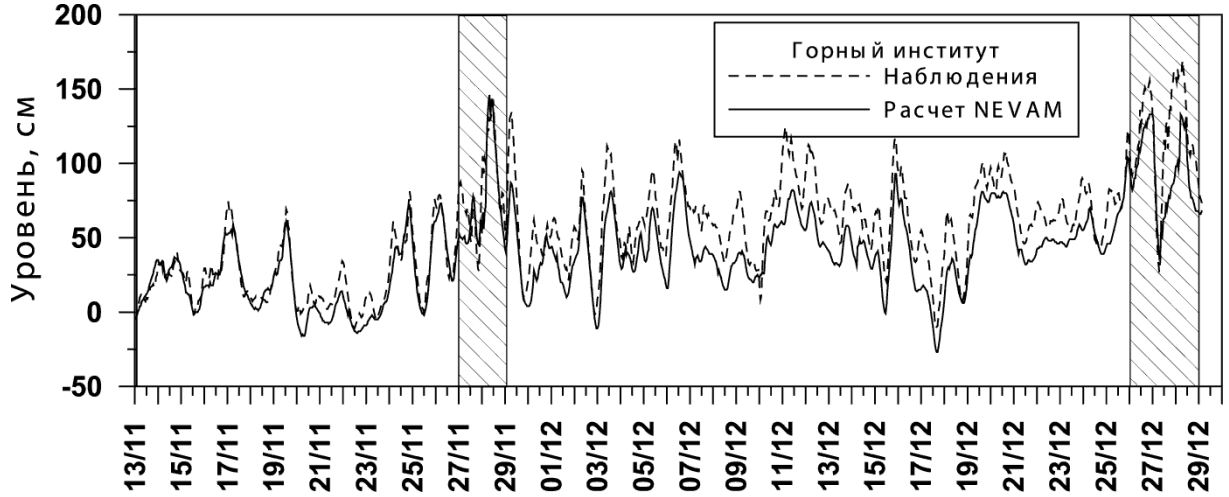
Max $\zeta \approx 170$ cm at ” Mining Inst.” at 07h 29 Dec

The 309th flood in St. Petersburg could not prevent (the accepted mark of flood is water level of 160 cm in BS).

Model runs with NEVAM against observations for Nov – Dec 2011

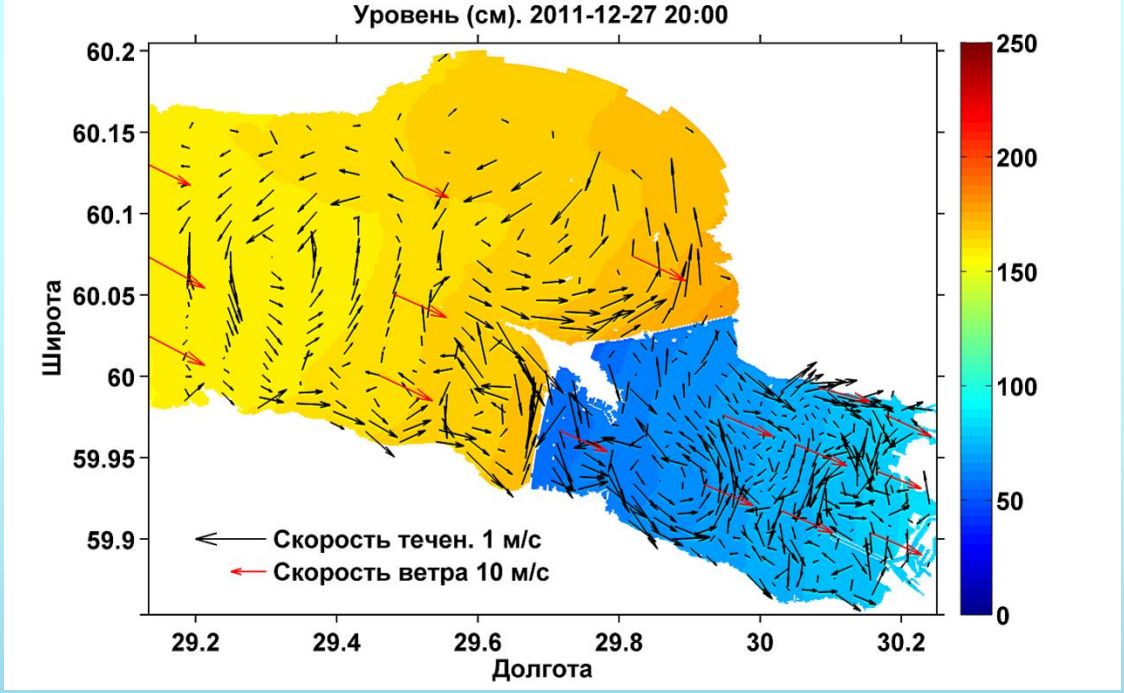


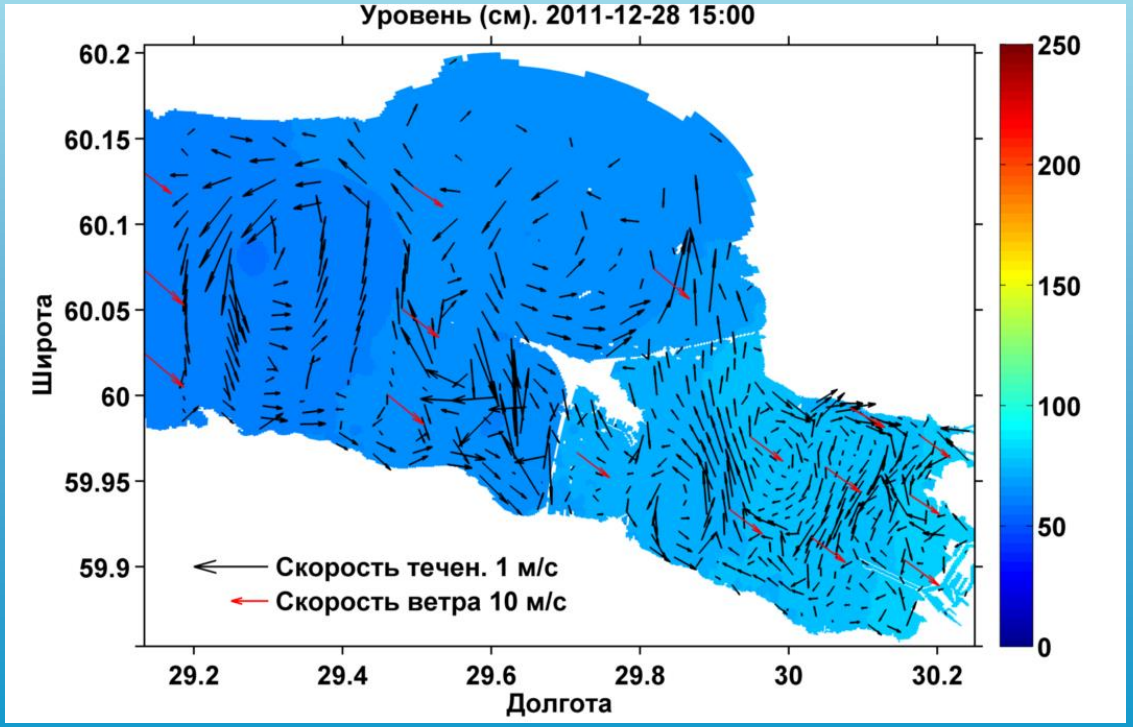
Observed and calculated values of the level in Kronstadt (near the dam) from November 13 to December 28 2011.



Observed and calculated values of the level in Mining Institute (the Neva mouth) from 13 November to 28 December 2011.

Periods of floods are shaded





Case of a storm surge, December 2011

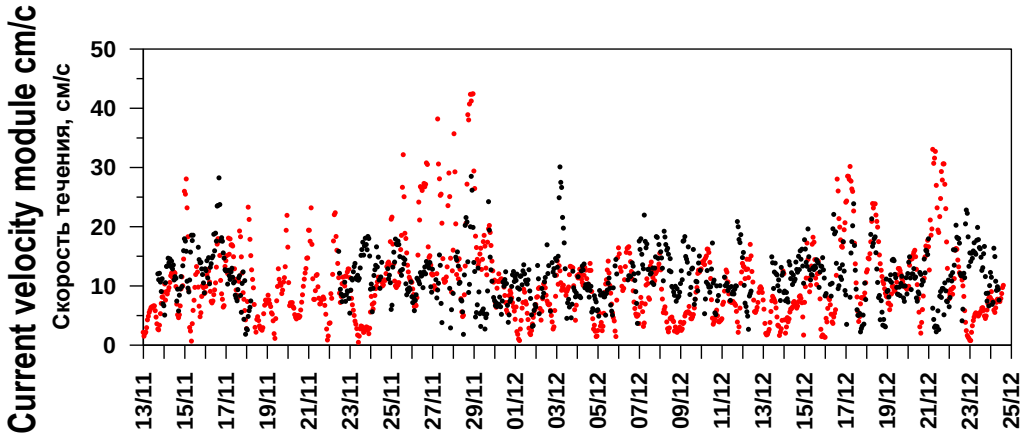
The calculated level and surface current velocity in east part of the GoF at closed and open gates of Flood Protection Barrier (FPB) 27.12.2011 at 20:00 and 28.12.2011 at 15:00 (Moscow time), respectively.

There is an internal surge
from "dam" to the Neva delta
Max ($\Delta\zeta$) ≈ 40 cm

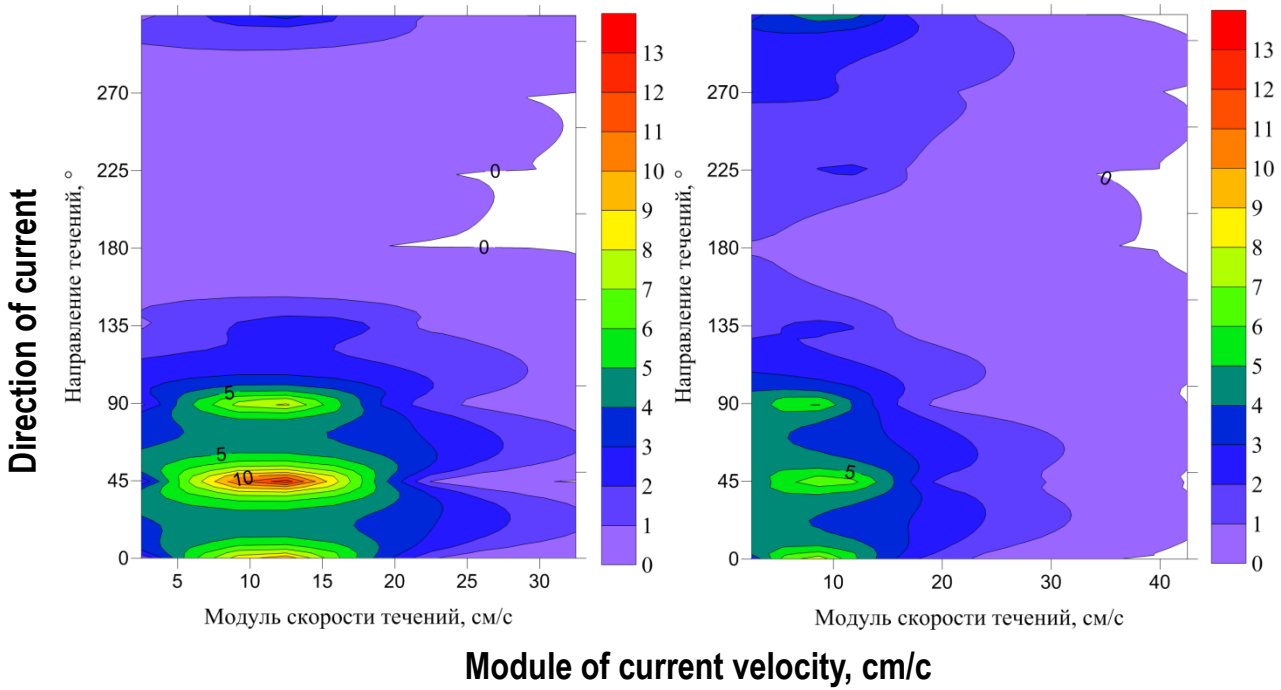
Statistical characteristics of the water level in the observation points Kronstadt and Mining Institute

	Water level, см	
	Mining Institute	Kronstadt
$(\zeta_{forecast} - \zeta_{obs})_{\max}$	-74.6	-53.4
$(\zeta_{forecast} - \zeta_{obs})_{\min}$	19.2	49.0
arithmetic mean (systematic) error, $\hat{\delta}$	-15.3	-6.4
the mean square error, σ	20.6	15.6
correlation coefficient, R	0.93	0.91
sample size, N	1026	1058

Comparison of measured and calculated values of current velocities at station "Kronstadt".



	Mean values				Max |V|
	V_1 cm/s	V_2 cm/s	|V|, cm/s	φ°	cm/s
Model	3,58	1,10	3,8	17	**42,4**
Data	**5,32**	**5,29**	**7,5**	**45**	**31,1**



Density distribution (in%) of current velocity according to measurements at station"Kronstadt" (left) and model (right).

Concluding remarks

1. According to runs with CARDINAL, in the case of passage of extreme cyclones over the Baltic Sea, the *additional* level rise in the GoF west of the FPB at the closing of all gates does not exceed 20-30cm. The total level rise can be up to 480 cm near Sestroretsk (north-eastern coast).

2. In Neva Bay in the case of closed FPB gates there is an accumulation of water because of Neva runoff. Within the Neva Bay a significant slope of level can be created. Near the FPB level rise is relatively low, but in the delta of Neva in St. Petersburg it can reach 1.5m. This conclusion is confirmed by observations during the floods of 2011 and 2013 and model runs with CARDINAL and NEVAM. Keeping in mind the overall level rise in the Neva Bay during flood, this additional rise due to Neva runoff can be dangerous and must be taken into account in operational activities with gates.

Publications

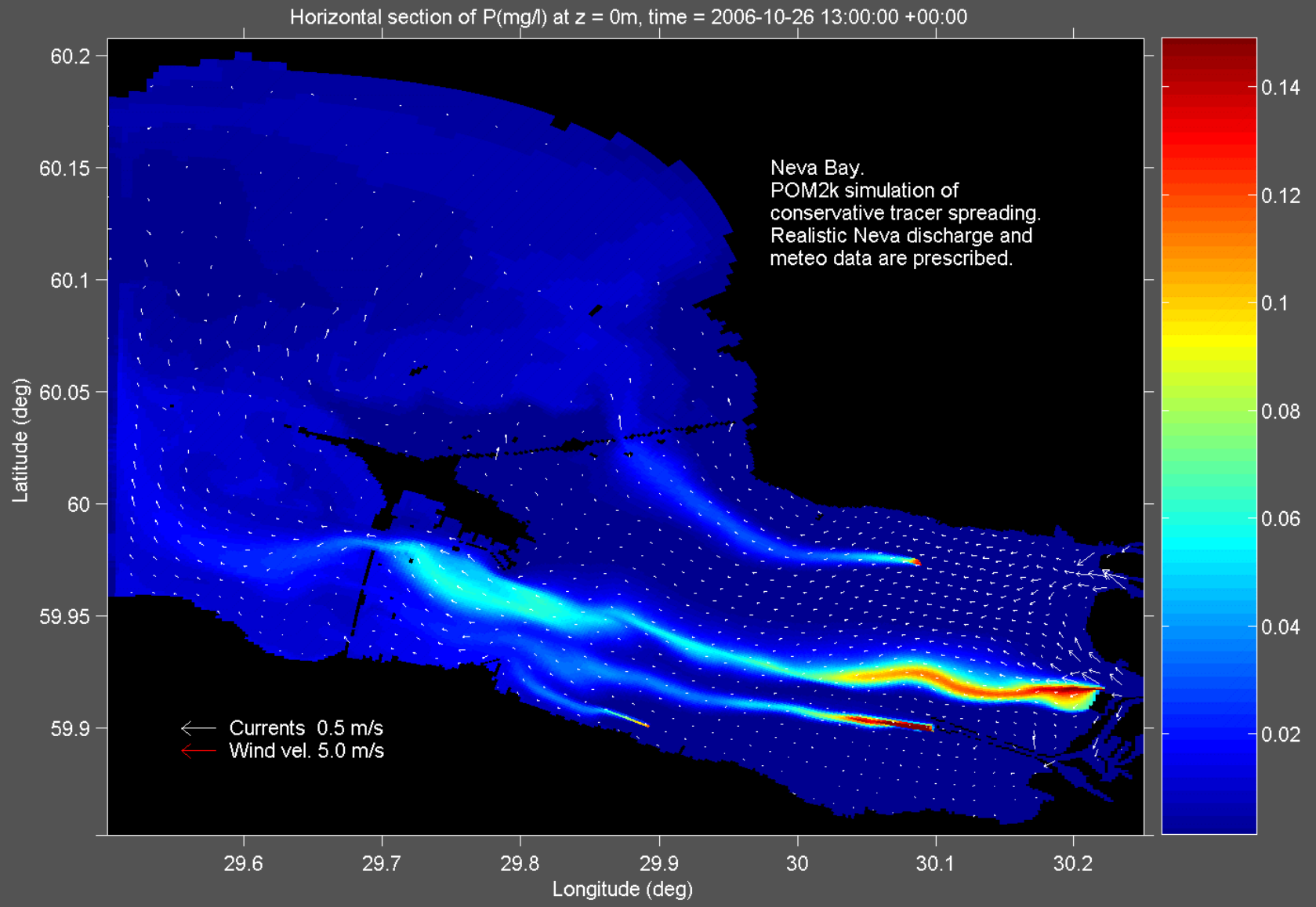
Averkiev A.S., Klevannyy K.A. A case study of the impact of cyclonic trajectories on sea-level extremes in the Gulf of Finland. 2010. *Continental Shelf Research*, v. 30, No. 6, 707-714.

Klevannyy K.A., Averkiev A.S. Simulation of extreme events in the level the Gulf of Finland allowance for the influence of Flood Protection Barrier of St. Petersburg. 2011. *In:* Basic concepts of the modern use of the coast. V. 3, 10-24 (in Russian).

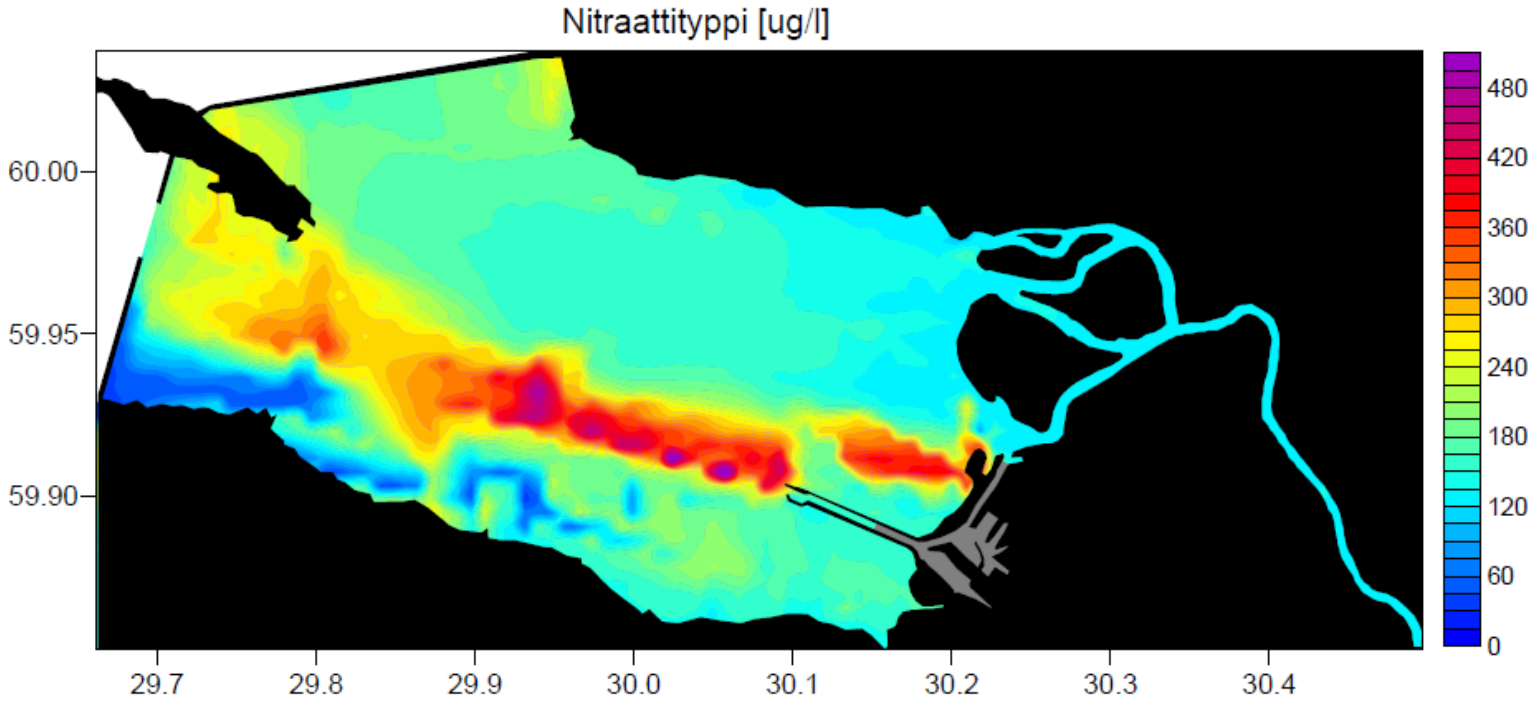
Ryabchenko V., Dvornikov A., Haapala J., Myrberg K. Modelling ice conditions in the easternmost Gulf of Finland in the Baltic Sea. *Continental Shelf Research*. 2010, v.30, 1458–1471.

Andreev P., Dvornikov A., Ryabchenko V., Smirnov K., Tsepelev V. Simulation of Storm Surges in the Neva Bay on the Basis of a Three-Dimensional Model of Circulation in the Conditions of Maneuvering by Gates of the Flood Protection Barrier. 2013. *Fundamental and Applied Hydrophysics*, v.6, No. 4, 23-31 (in Russian).

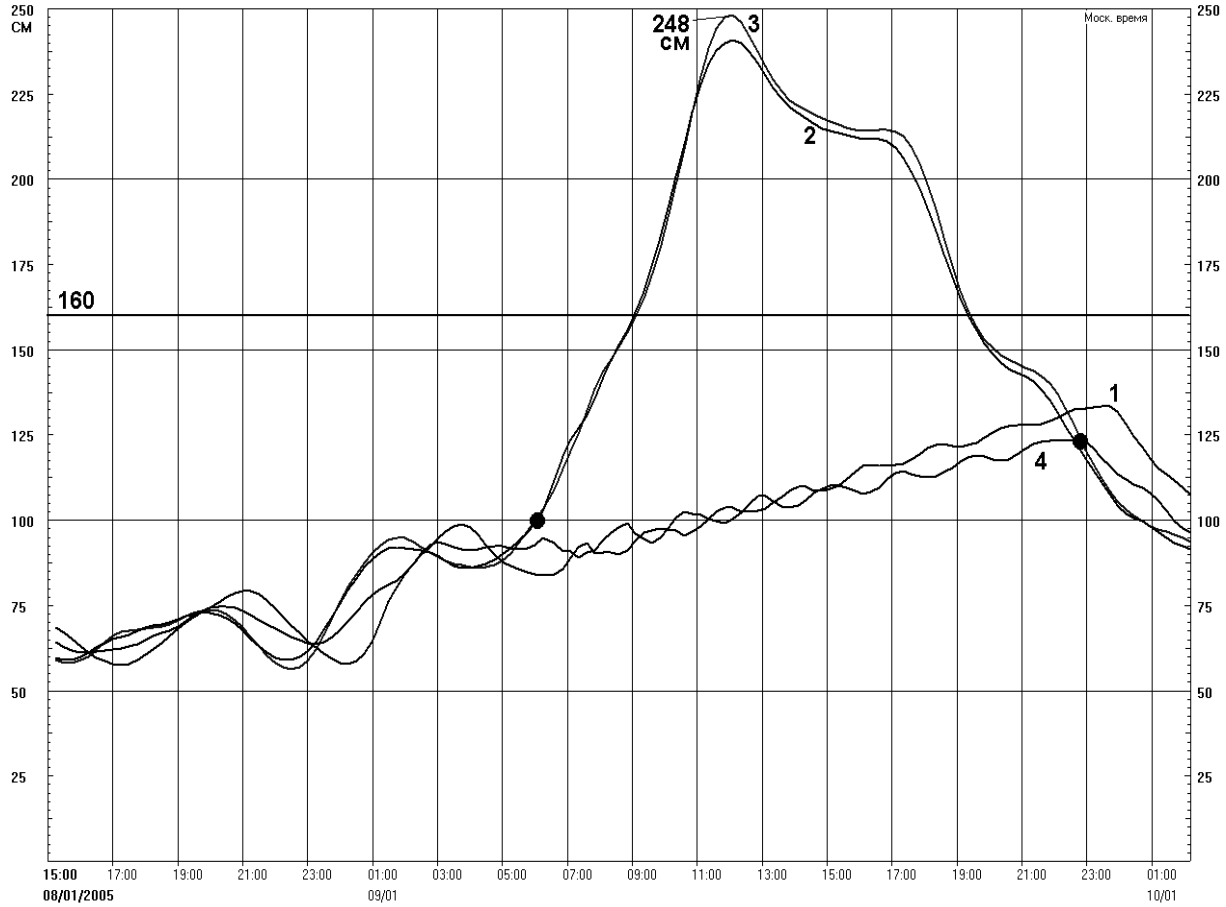
Spreading of wastewater from Wastewaters Treatment Plants (Central, Northern, South-West and of Petrodvoretz), October 2006



Example of Luode High-resolutions maps, generated from fast moving boats



Waste water spreading St. Petersburg 2005



Calculated time course of the level on the station “Mining Institute”(curve 1), near the opening C-1 on the part of Gulf of Finland (2), in Sestroretsk (3) and near the opening C-1 from the Neva Bay (4) in a flood similar to the case of January 9, 2005; GLC project status and closes the period of flooding. The dark points show opening and closing moments of the FPB.

Knowledge gaps

1. Influence of the FPB on the hydrodynamics and transport of substances in the eastern part of the GoF