Calculation of extreme water level rises along the western part of the Gulf of Finland

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- Results
- Future plans

Background

Studies made during the first and the second project phases:

The most dangerous cyclone trajectories and extreme possible water level rises were studied with the CARDINAL modeling system for the points in the Eastern Gulf of Finland:

- St.Petersburg,
- Kronshtadt
- Leningrad Nuclear Power Station (LNPS).

Simulations were done for an idealized round cyclone with extreme parameters:

- pressure in the cyclone center is 960 hPa,

- maximum wind is 30-35 m/s in 200 km from the center and behind the cold front.

Model improvements

Time dependence of cyclone deep was taken into account with the following expression

$$\Delta P = \Delta P_o \exp\left(-\frac{|t - T_o|}{\Delta T}\right)$$

To take into account the existence of the cold front we have introduced the next correction in the pressure field

$$P_a(x,y,t) = P_a^{'}\left[1 - \gamma_1 \exp\left(-\frac{|\vec{r} - r_T|}{r_T}\right)\exp\left(-\gamma_2 \frac{|\alpha - \alpha_0|}{\alpha_2 - \alpha_1}\right)\right]$$

The main aim of the present studies was to make similar calculations for points located in the Western Gulf of Finland (Hanko, Helsinki, Nuclear Power Station in Loviisa, Kotka) and also for Parnu in the Gulf of Riga. Parameters of the cyclone were chosen the same as earlier.

The second aim was to compare calculated maximums with the observed ones and with the results obtained with extrapolation of statistical data

Historical maximum values along the Baltic Sea coast were collected (except the Polish and the German stations). Data were presented by our colleagues and the project participants.

Data are shown in the next Figure and in the Table.

- Data are presented as they were sent. For the Russian and the Baltic States they are given in the Baltic System (mean observed water level in Kronshtadt in 1825-1835). Sweden has no general water level ‘zero’ due to rapid uplifting of its lands with different velocities. Values here are given relative to mean water levels for each station.

Observed historical maximums of water levels in the Baltic Sea

Historical maximums of water level along the Lithuanian and Latvian Baltic Sea coast

STATION	Max (cm)	Date	Min (cm)	Date	Period of observations	Comment
KLAIPEDA	186	18.10.1967	-91	1984	1840-1940, 1949-2002	
JOUDKRANTE	149		-70		1901-1915, 1925-1938, 1955-2002	
NIDA	154	28.4.1958	-70		1925-1938, 1948-2002	
VENTE (lagoon)	164	4.5.1958	-72		1925-1942, 1955-2002	
UOSTADVARIS (lagoon)	146		-49		1901-1915, 1925,1932, 1961-1965, 1973-1985, 1977-2002	
SVENTOJI	143				1926-1931, 1945-1958	
PALANDA	85				1922-1925	
RIGA	214	1969				213 cm 09.01.2005
VENTSPILS	148	18.10.1967	-90	31.12.1978	187-1913,1920-1944,1946-	134 cm 09.01.2005 Min data till 1980
LIEPAJA	174	18.10.1967	-92	1.2.1937	1884-1894,1901-1913,1925-1944,1946-	Min data till 1980
KOLKA (IRBES STRAIT)	134	18.10.1967	-100	30.1.1937	At least since 1959	Min data till 1980

Historical maximums of water level along the Finnish Baltic Sea coast

STATION	Max (cm)	Date	Min (cm)	Date	Period of observations	Comments
KEMI	201	22.9.1982	-125	21.11.1923	Since 1922	
OULU	183	14.1.1984	-131	14.1.1929	Since 1922	
RAAHE	162	14.1.1984	-129	4.10.1936	Since 1922	
PIETARSAARI	139	14.1.1984	-113	4.10.1936	Since 1922	
VAASA	144	14.1.1984	-100	14.1.1929	Since 1922	
KASKINEN	148	14.1.1984	-91	31.1.1998	Since 1926	
MÄNTYLUOTO	132	14.1.1984	-80	10.4.1934	Since 1925	
TURKU	130	9.1.2005	-74	10.4.1934	Since 1922	
HANKO	132	9.1.2005	-78	10.4.1934	Since 1887	
HELSINKI	151	9.1.2005	-92	22.3.1916	Since 1904	
HAMINA	197	9.1.2005	-110	20.11.1975	Since 1928	

Historical maximums of water level along the Russian and Estonian Baltic Sea coast

STATION	Max (cm)	Date	Min (cm)	Date	Period of observations	Comments
KRONSHTADT	367	19.11.1824	-172	21.9.1883	1703	
GORNII (ST.PETERSB)	421	19.11.1824	-122	10.11.1951	1703	
VYBORG	207	9.1.2005	-117	5.2.1922	1889-1938, 1948-present	Min data till 1980
GOGLAND	132(160)	23.9.1924	-115	10.3.1972	1920-	160 – correlation Min data- till 1980
KALININGRAD	200	4.12.1999	-128	25.12.1904		Min data till 1980
DIRHAMI	150	1967				
ROHUKULA	160	18.10.1967	-101	9.12.1959	1938-1941, 1950-	Min data till 1980
RISTNA	209	9.1.2005	-79	28.3.1980	Since 1950	Min data till 1980
SUURPEA	169	9.1.2005	-89	24.12.1938	1924-1940,1950-1957, 1961-	Min data till 1980
VIRTSU	152	18.10.1967	-112	9.12.1959	1899-1912, 1948-	Min data till 1980
TOILA	166	9.1.2005				
TALLINN	155	9.1.2005	-90	9.3.1972	1899-1917,1923-1940, 1947-	Min data till 1980
PARNU	275	9.1.2005	-122	14.10.1976	1923-	Min data till 1980
KUNDA	160	6.1.1975	-110	10.3.1972	Since 1949	Min data till 1980
NARVA-JESUU	194	9.1.2005	-113	2.11.1910	1899-1915, 1923-	Min data till 1980

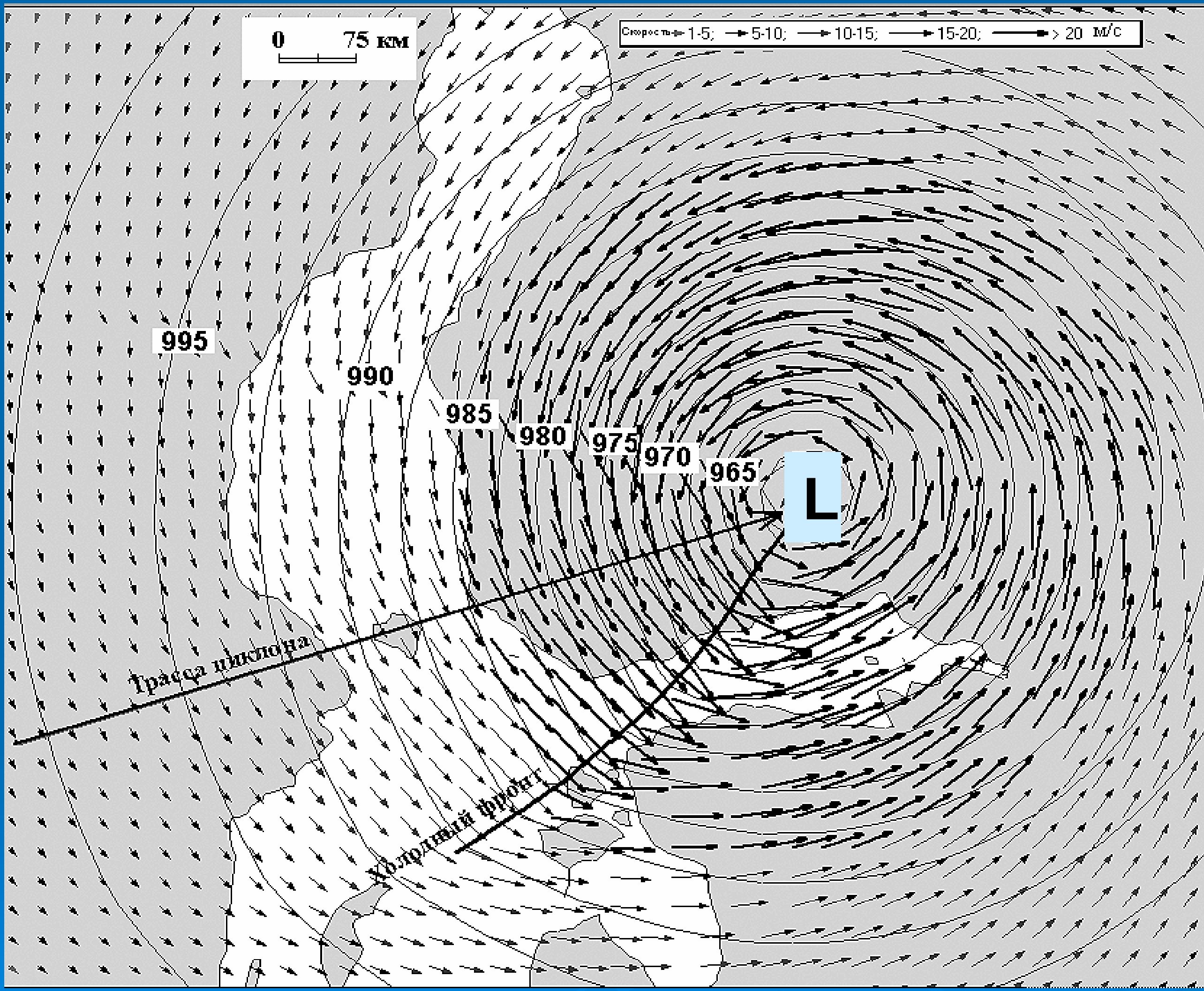
Historical maximums of water level along the Sweden Baltic Sea coast

STATION	Max (cm)	Date	Min (cm)	Date	Period of observations	Comments
KALIX	177	14.01.1984			1974 - 2007	Only more then 150 sm, exclusive STOCKHOLM
FURUÖGRUND	150	14.1.1984			1916 - 2007	
STOCKHOLM	117	18.1.1983			1889 - 2007	
VIKEN	166	1985			1976 – 2007	
RINGHALS	165	8.1.2005			1887 – 2007	Med stöd av Varberg
GÖTEBORG-TORSHAMNEN	169	4.12.1914			1887 – 2007	Med stöd av Gbg-Klippan
GÖTEBORG-KLIPPAN (closed)	169	4.12.1914			1887 – 1968	Med stöd av Gbg-Ringön
STENUNGSUND	156	27.2.1990			1990 – 2007	
SMÖGEN	150	16.11.1920			1910 – 2007	
KUNGSVIK	148	16.10.1987			1973 – 2007	

Two times more refined model of the Baltic Sea BSM6 was used in parallel to the previous version BSM5. In general, significant increase of extreme levels was obtained with BSM6.

The view of the model cyclone with the cold front is presented in the next figure.

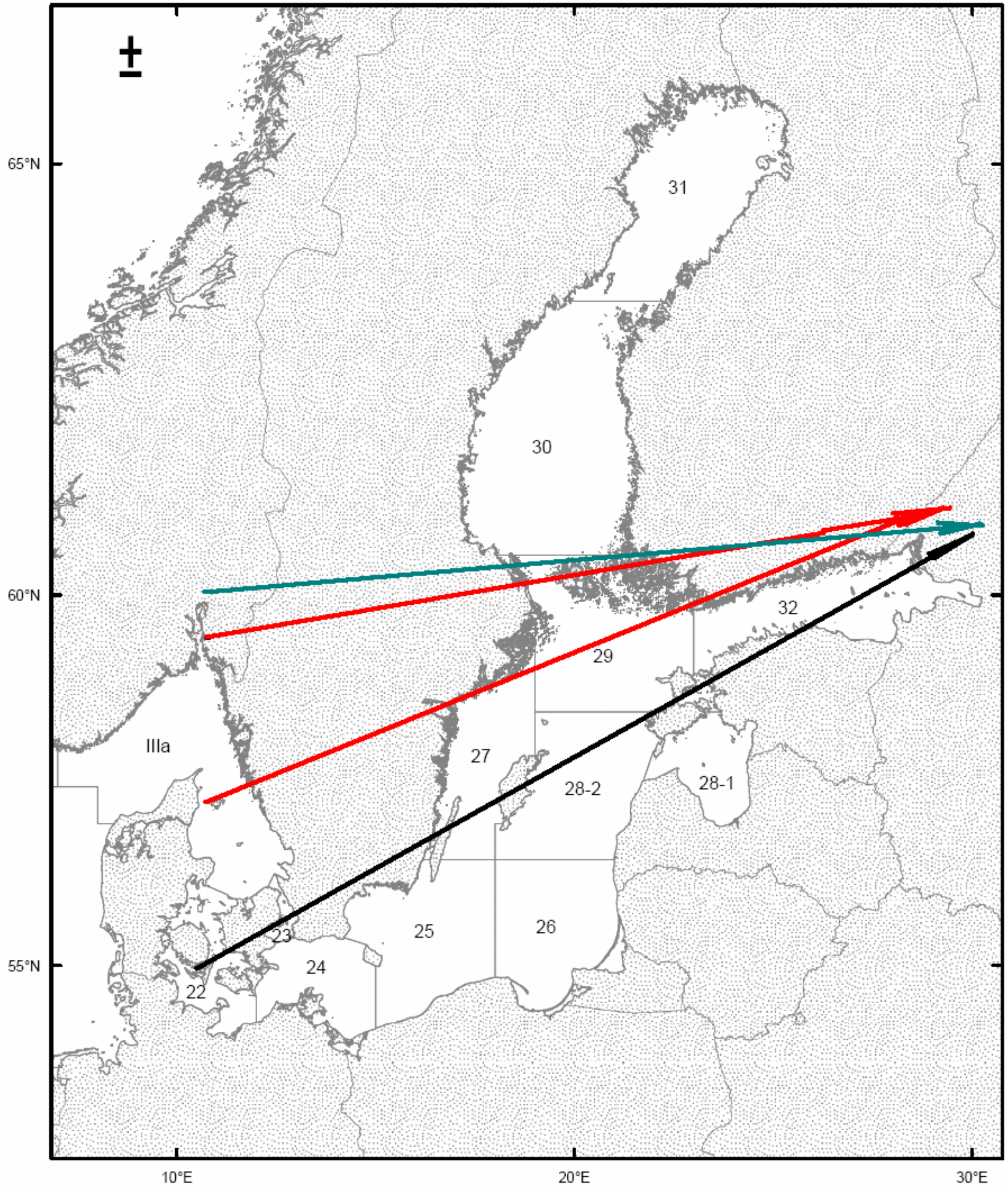
An idealized cyclone with the cold front



The numerical experiments revealed that maximum wind velocity in 50 m/s on the cold front at the moment $T=T_0$ is obtained if the pressure in the cyclone center P_0= 960 hPa and r_0=200 km (ΔP_0 = 50 hPa and P_∞=1010 hPa).

Extreme water levels in different points were obtained with cyclone paths, which have considerable differences among themselves.

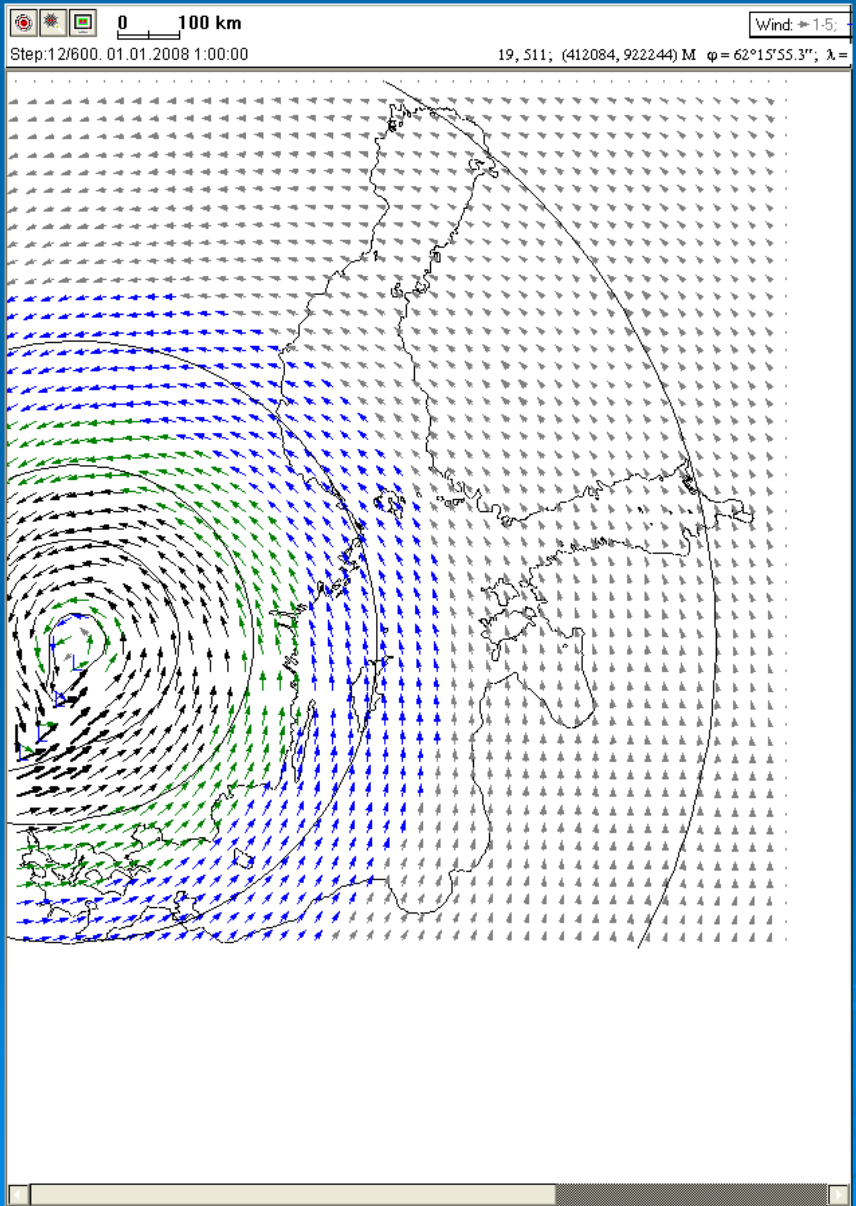
The most dangerous cyclone paths for extreme water levels are shown in next figure.

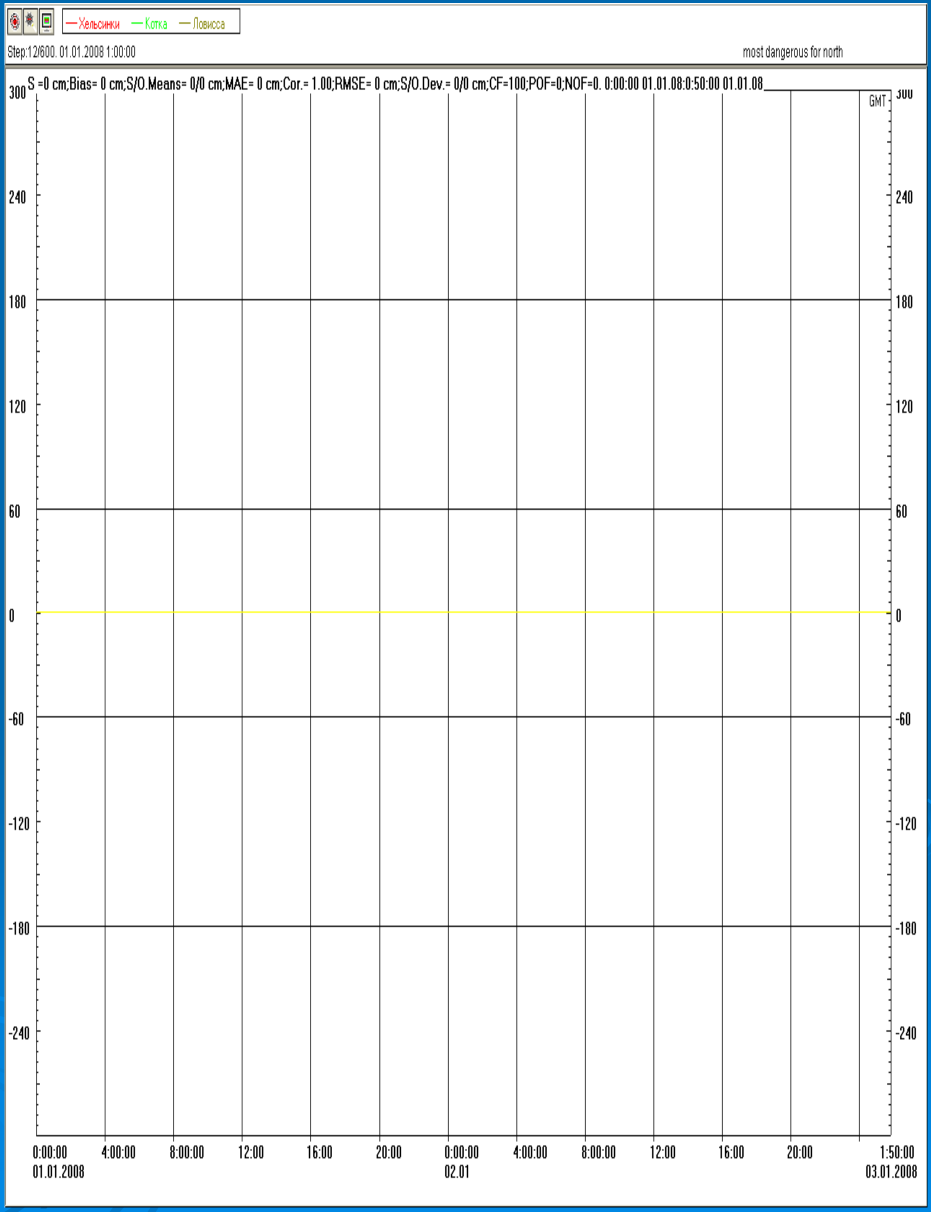


The most dangerous cyclone paths for extreme water levels.

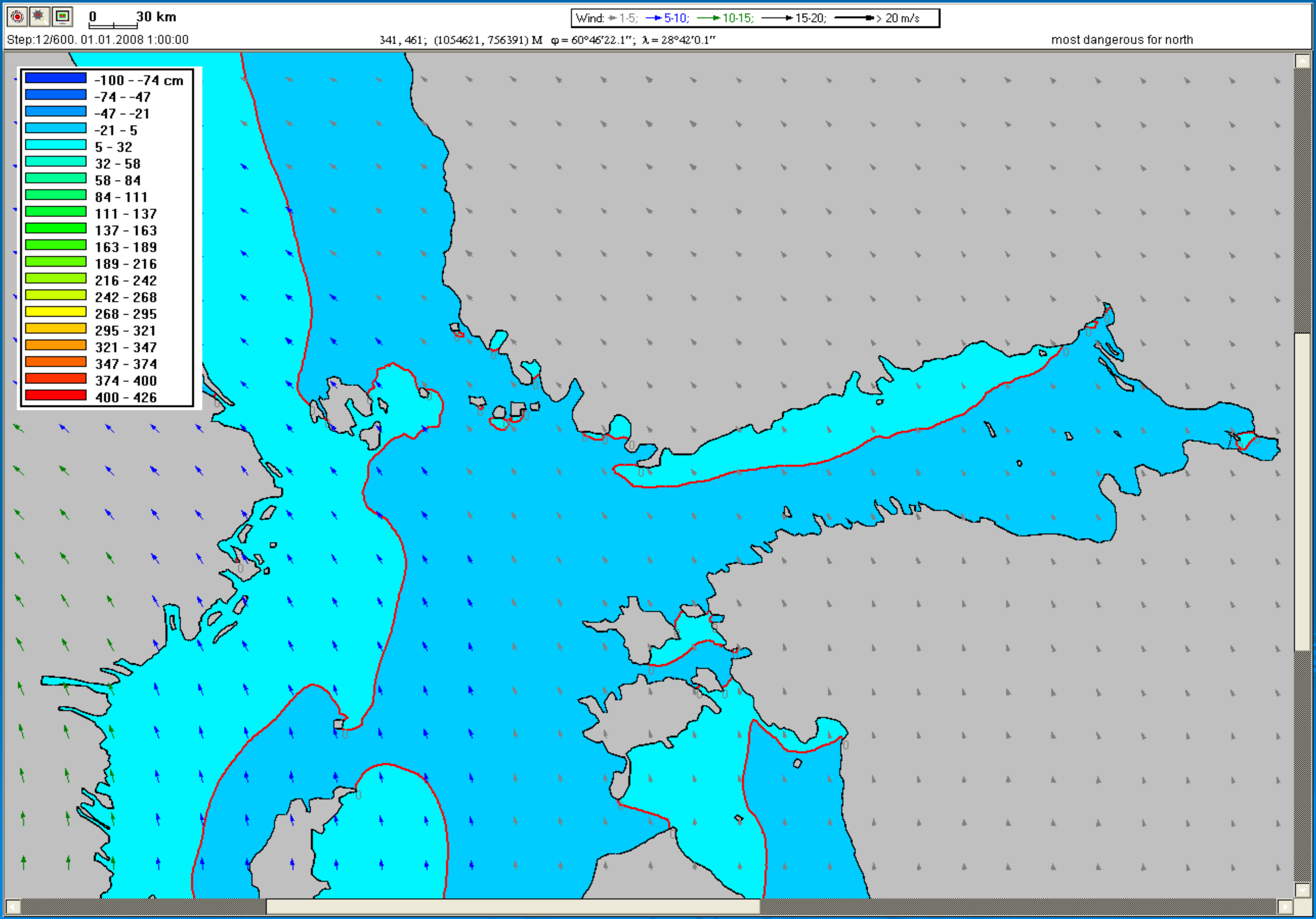
Sector among the red lines are for the northern coast of the Gulf of Finland, the blue line is for the Eastern Gulf of Finland and the black line is for the Gulf of Riga.

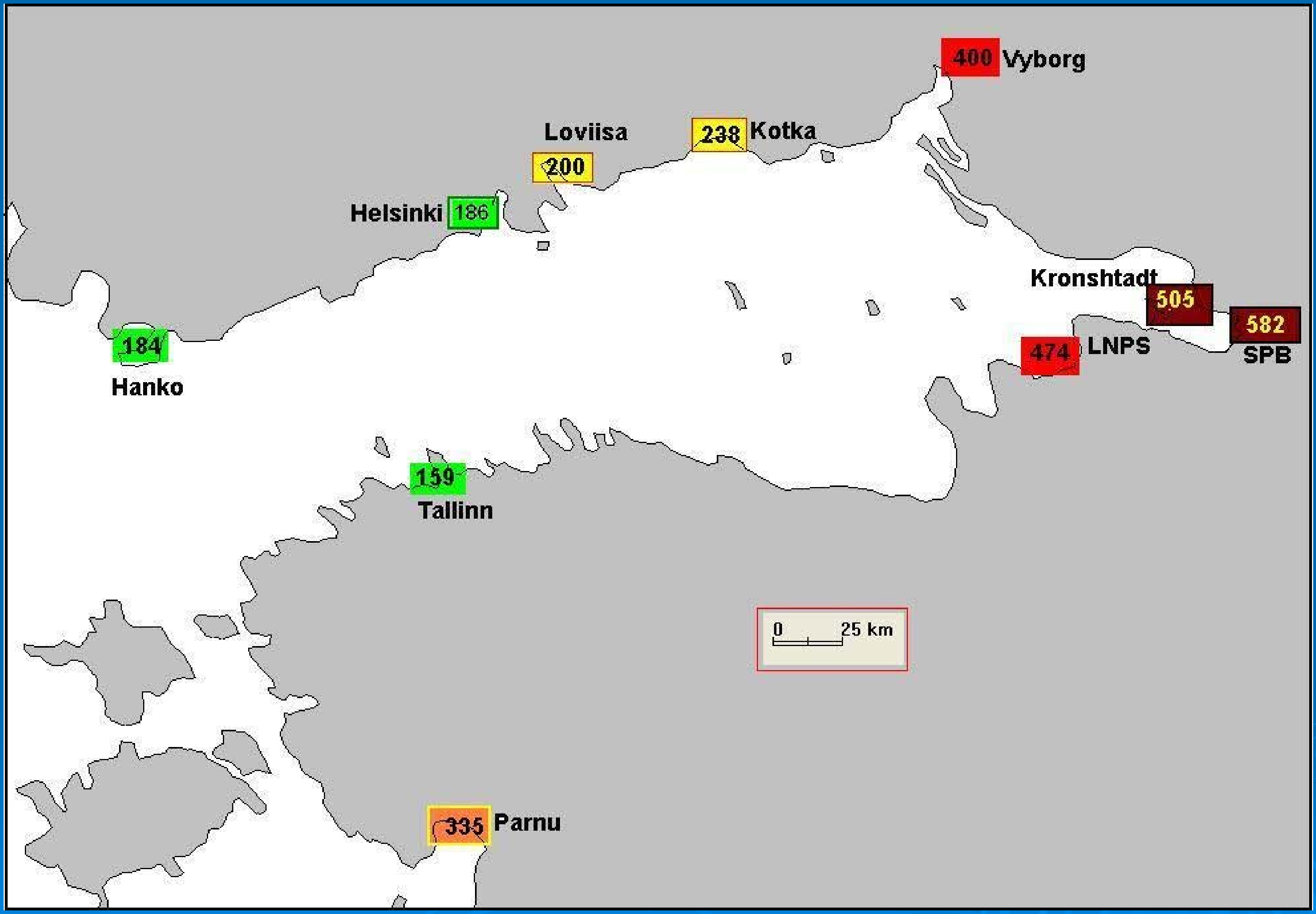
Propagation of the most dangerous for the N-W Gulf of Finland cyclone and corresponding water level time histories in Helsinki (red), Kotka (green) and Nuclear Power Station in Loviisa (brown)





Water level izolines in the Baltic Proper and in the Gulf of Finland under the action of the most dangerous for the N-W Gulf of Finland cyclone





Calculated extreme water levels (cm) in the Gulf of Finland and in Parnu

Observed (blue filling cells) and estimated maximum water levels in different points in the Gulf of Finland and in the Gulf of Riga (values in the previous figure are in green filling cells)

Point	Observed maximums	Estimations made with BSM5	Estimations made with BSM6	Estimations made with extrapolations of observed rows
St.Petersburg (Gornii Institute)	421	558	582	540[1]
Kronshtadt	367	474	505	465[1]
LNPS in Sosnovyy Bor		416	474	470[2]
Hamina	197	209	238	265[3]
Loviisa (NPS)	175	195	200	
Helsinki	151	183	186	230[3]
Hanko	132		184	204[3]
Tallinn	155	127	159	
Parnu	275	189	335	

1 Once in 10 000 years 1. Nezhikhovskii R.A. Problems in Hydrology of Neva Bay and the Neva River. Leningrad. Gidrometeoizdat. 1988, 224 p., 2. Bessan G.N., Technical Report, 2006

2 Once in 10 000 years. Apukhtin A.A., Technical Report, 2007

3 Once in 200 years. http:/www.gtk.fi/projects/seareg/Tallinn/Helsinki.ppt

It was shown that the obtained simulated maximums:

- are always higher than the observed ones,
- are close to the extrapolated ones

The cyclone parameters, which were used in this study are close to the real ones (cyclones Edwin, 2005, Kirill 2007).

Therefore it may be concluded that obtained simulated maximums may really occur if trajectory of a deep cyclone will coincide with the most dangerous one for the given point.

Future plans

- Study of extreme minimum water levels, which at present are of increased importance due to construction of new ports and increased tonnage of ships. Significant negative values were already obtained in some points in our numerical experiments.

- It was found that shapes of water rises may be different. In some cases there is one peak and in other cases they are two peaks. Study of this is important for the management of St.Petersburg Flood Protection Barrier.

Thank you for attention!