Wave interpretation of major Baltic inflows

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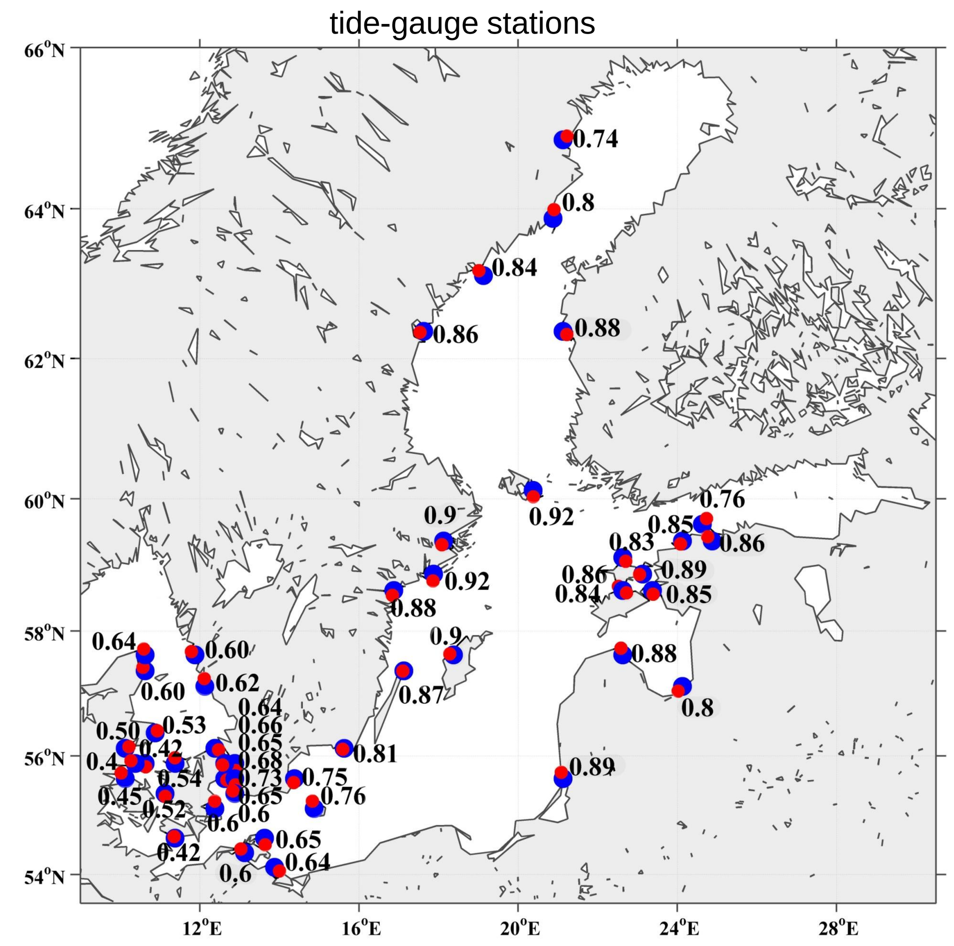
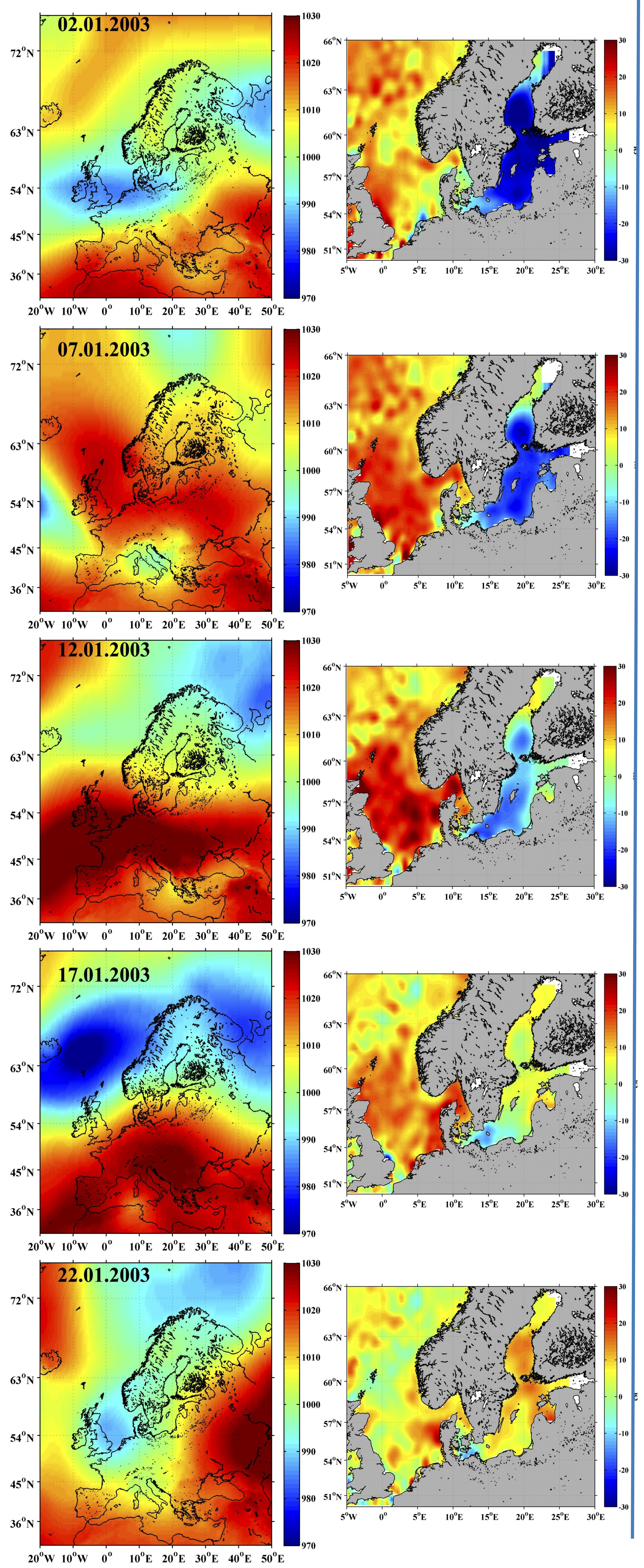
Verification of satellite altimetry in the Baltic Sea

Correlation coefficients of the sea level between altimeter data and coastal tide-gauge stations

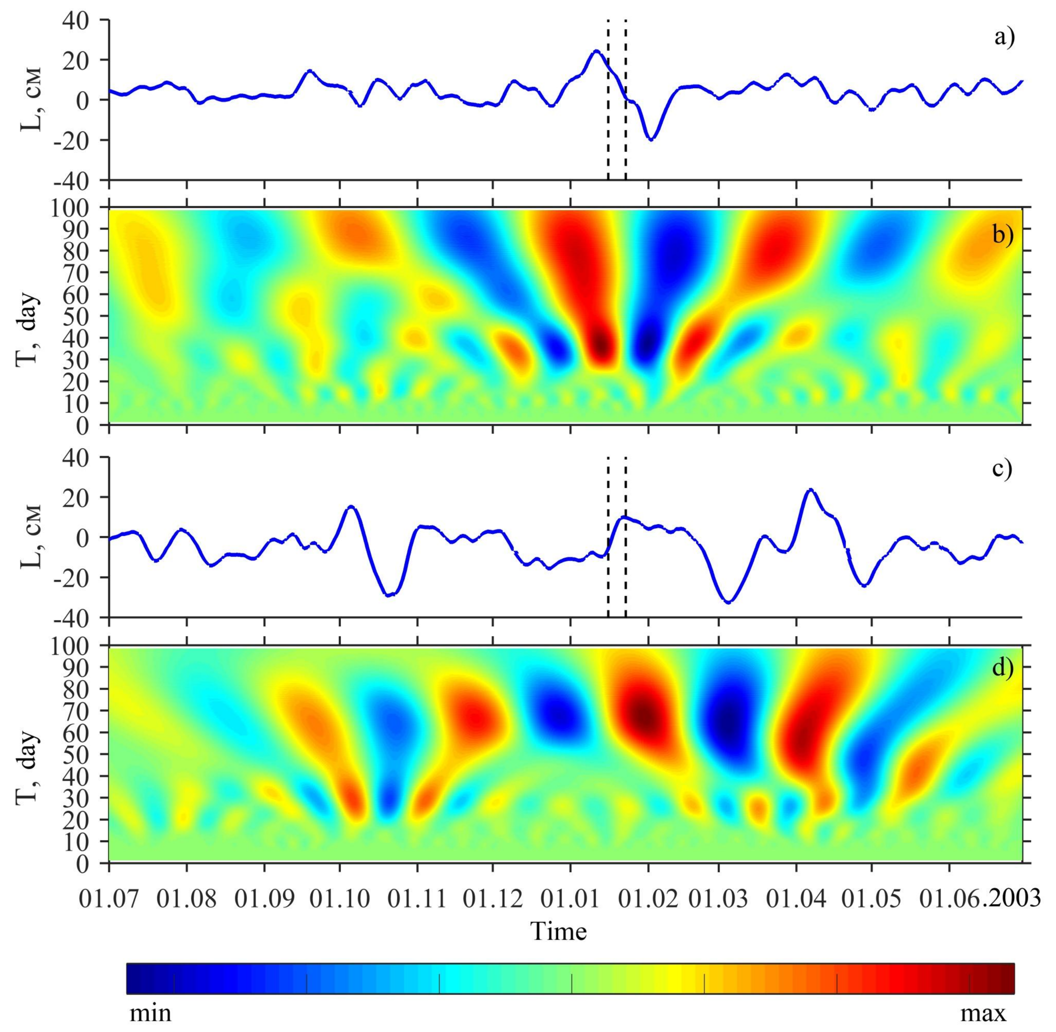


Maps of distribution of sea level and atmospheric pressure for the North and Baltic Seas and analyzed in advance at the beginning of the period a Major Baltic Inflow, which occurred on 16-22 January 2003, see. [11]. It was established that in early January under the influence of passing cyclones observed surge levels in the North Sea, which proceeds until 12 January. Then, due to changes in weather conditions and under the influence of an anticyclone located to the south of the North Sea, and also due to the cyclone, formed north of the Baltic Sea, there is inflow of North Sea water into the Baltic Sea. The difference in level between the Baltic and the North Sea on January 12, 2003 was 60 cm, and on January 22 level has leveled off. Inflow in 1993 took place on a similar scenario: in January 12 under the influence of a cyclone occurs surge of water to the eastern shore of the North Sea and North Sea waters begin to penetrate into the Baltic Sea (until January 28), and the pumping of water to the eastern shores of the North Sea continues until January 17. Level difference between the North and Baltic Seas to the beginning of inflow and his end was about 50 cm.

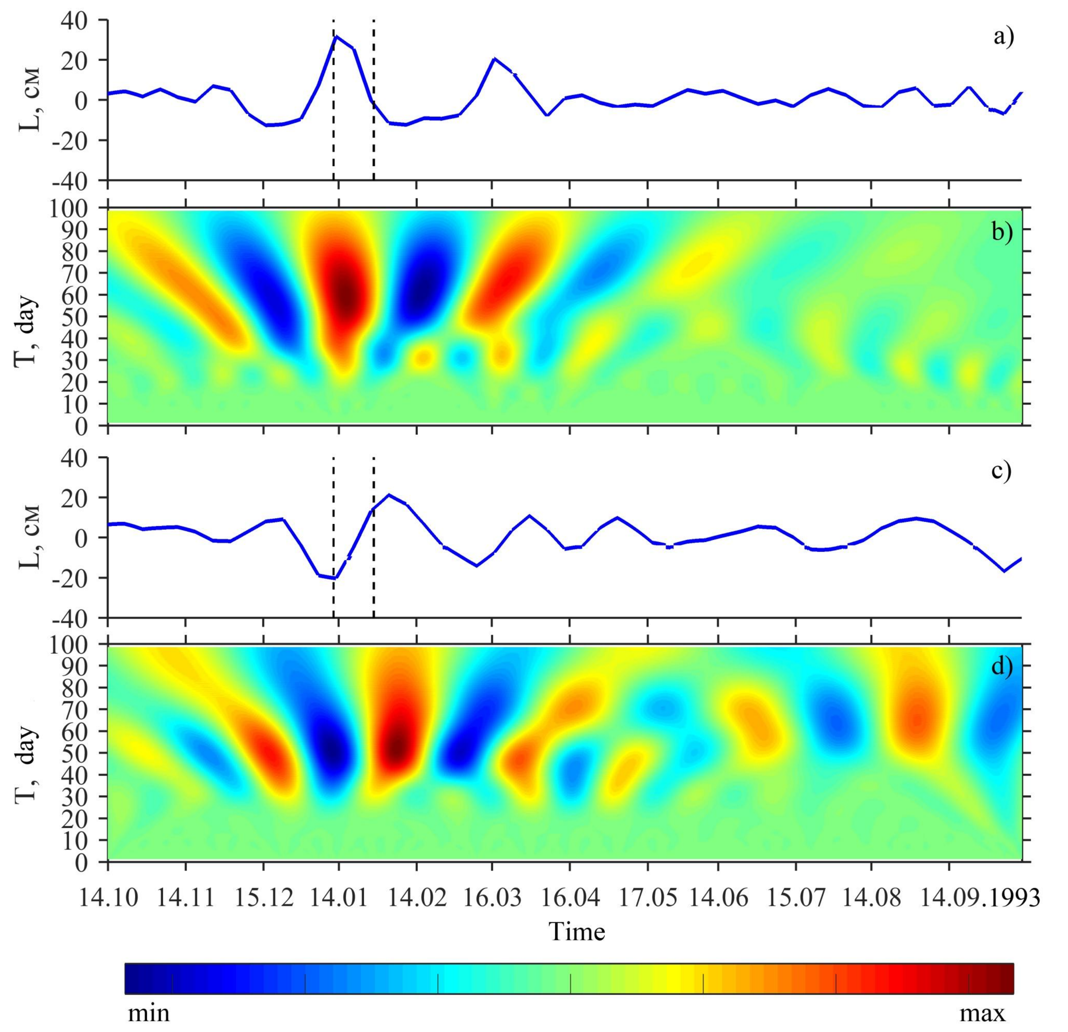


Water dynamics in the straits between the North and Baltic Seas during two major Baltic inflows occurred in January 1993 and 2003, based on satellite altimetry data, are investigated. It was noted that before the Baltic inflow occurs surge of water mass to the east coast of the North Sea, and the level difference between the two seas, is about 60 cm. The main research is on the low-frequency fluctuations of sea level, its wave characteristics, by wavelet - and frequency-directional spectral analysis reveals the wave nature of the mechanisms leading to the major Baltic inflow. A comparison of the empirical characteristic of the obtained low-frequency waves with the theoretical dispersion relations for the gradient-vorticity waves showed that in a period of Major Baltic Inflow in the Danish Straits fluctuations are identified as baroclinic Rossby waves. The analysis of cyclonic activity in the northern hemisphere showed that during Inflow observed persisted cyclones, which prove the possibility of resonance mechanism of occurrence of major Baltic inflow.

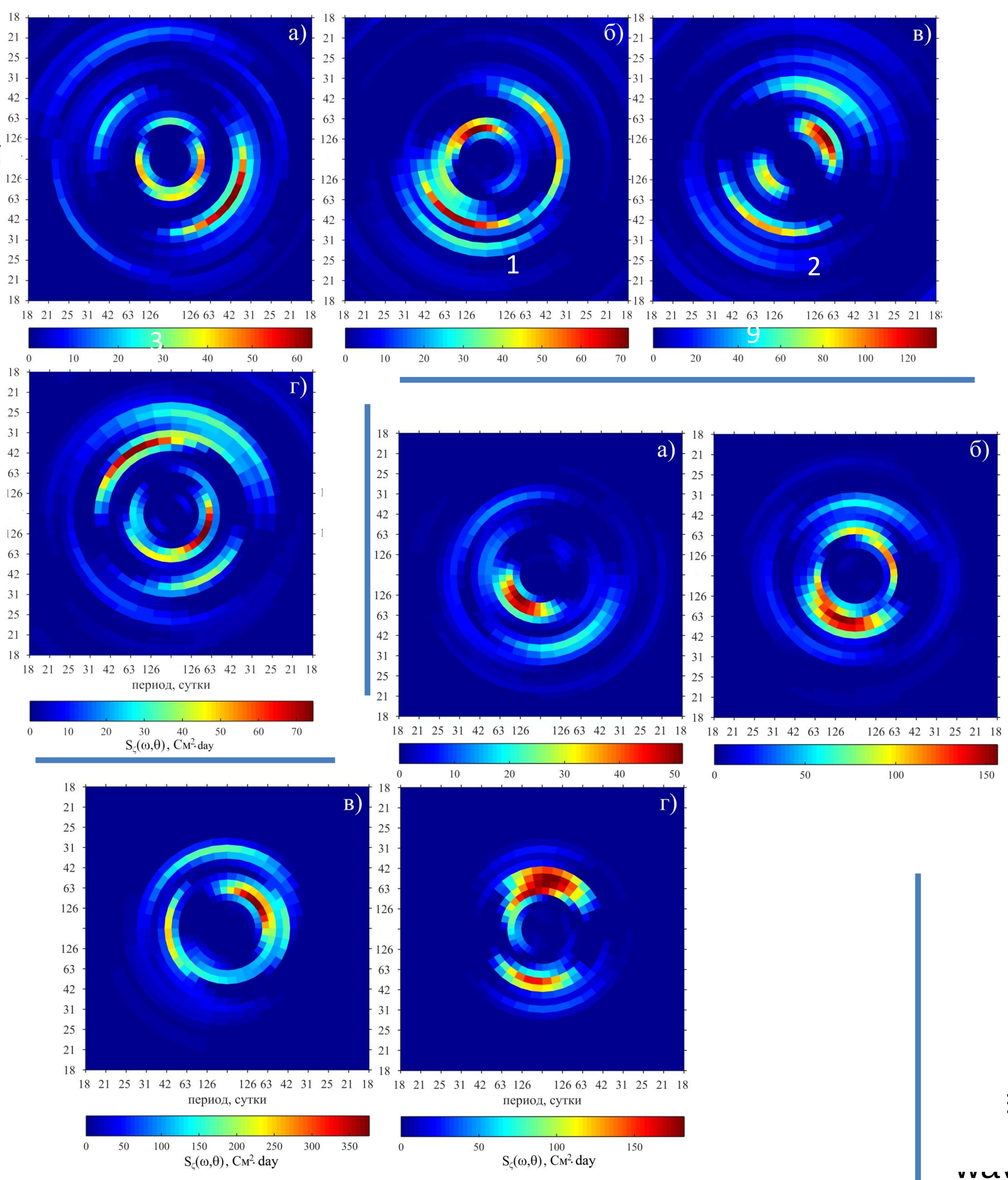
The sea-level (a,c) and sea-level wavelet analysis (b,d) for Major Baltic Inflow 2003
a, b - at the point 2; c, d – at the point 5; dashes marked period of inflow



The sea-level (a,c) and sea-level wavelet analysis (b, d) for Major Baltic Inflow 1993
a, b - at the point 2; c, d – at the point 5; dashes marked period of inflow



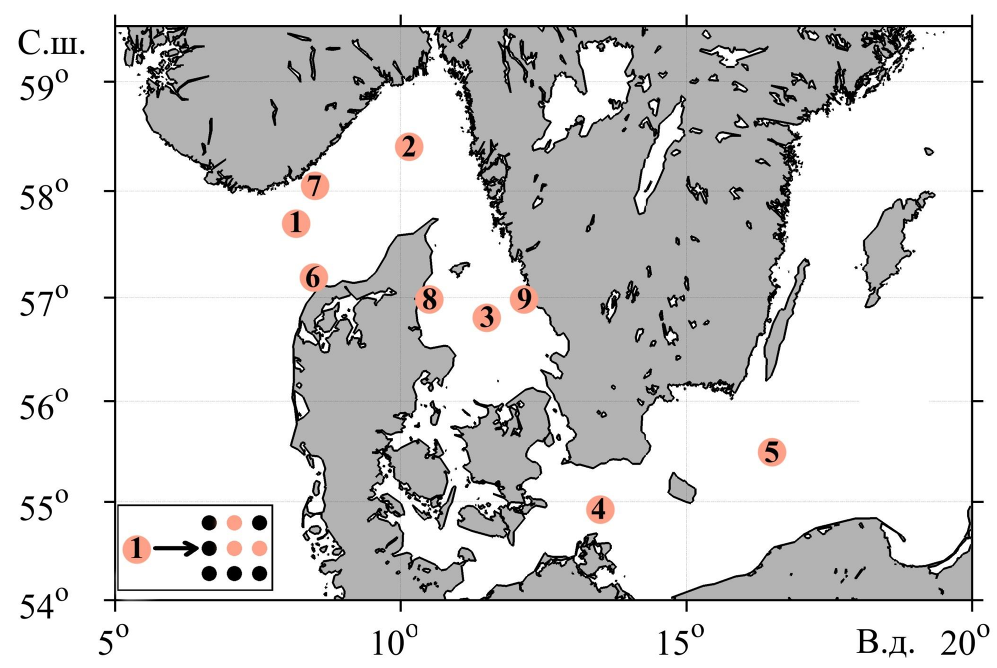
Directional spectral analysis at (top) for the Major Baltic Inflow 2003 and at (down) for the Major Baltic Inflow 1993



Characteristics of low frequency waves in period of the Major Baltic Inflow in 2003 and 1993, frequency obtained by spectral analysis

Point number	Period, days	Wave length, km	Direction	Wave speed, cm/s
2003 y.				
1	36	456	135	14,5
2		878	220	27,92
3		760	220	24,17
6		449	315	14,29
7		351	135	11,12
8		275	350	8,71
9		863	315	24,42
1993 y.				
1	73 33	295 501	120 349	4,67 17,50
2	73 33	317 411	210 160	5,04 14,38
3	73 61	848 740	60 190	13,46 14,12
4	73 52	993 1601	40 260	15,54 35,62
5	61 52	1145 1207	190 0	21,83 26,88
6	61	767	3260	14,63
7	73 52	365 375	160 330	5,79 8,33
8	73 33	367 516	0 40	5,83 18,04
9	61	213	190	4,04

Map of selected districts from altimetry for research.



Comparison the empirical characteristics of level fluctuations with the theoretical dispersion relation for topographic waves. Used formula derived analytically by V.R. Foux

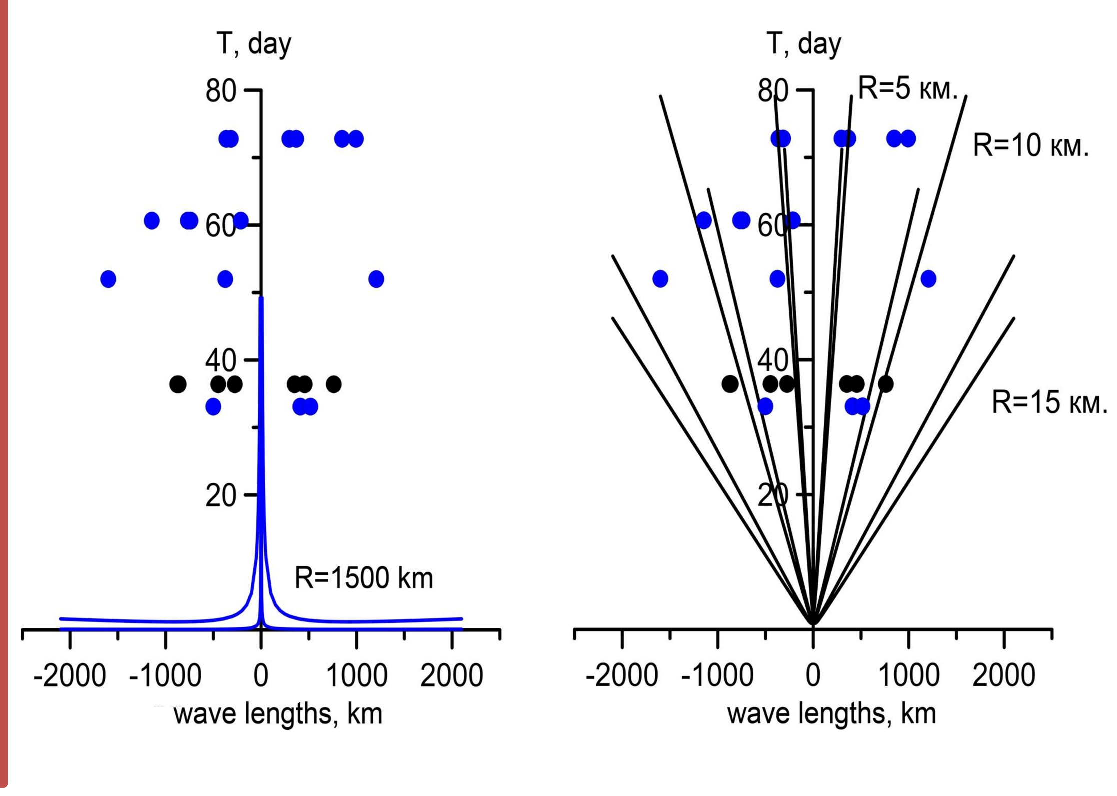
$$\sigma = -\frac{-kf\frac{\partial \ln H}{\partial y} + nf\frac{\partial \ln H}{\partial x}}{\left(\frac{m\pi}{l_x}\right)^2 + \left(\frac{p\pi}{l_y}\right)^2 + k^2 + n^2 + \left(\frac{2\pi}{R}\right)^2},$$

where: σ - wave frequency, $k=\frac{2\pi}{\lambda_x}$, $n=\frac{2\pi}{\lambda_y}$ – components of the wave numbers, λ_x, λ_y – wavelengths along the axes x and y; H – the depth of the sea, R – Rossby radius of deformation.

If $R = R_0 = \frac{\sqrt{gH}}{f}$ – barotropic (external) Rossby deformation radius. For the average depth of the Gulf of Finland, equal to 29 m, R_0 = 1405 m. if $R = R_i = \frac{NH}{f}$ - baroclinic (internal) Rossby radius of deformation, where $N=\sqrt{\frac{g\Delta\rho}{\rho\Delta z}}$ – Brunt-Vaisala frequency, g-acceleration of gravity, ρ - density of water. $\frac{\partial \ln H}{\partial y} = \frac{1}{H}\frac{\partial H}{\partial y}$, $\frac{\partial \ln H}{\partial x} = \frac{1}{H}\frac{\partial H}{\partial x}$ – the slopes of the bottom along the x and y axes, f - the Coriolis parameter, l_x, l_y – pool dimensions along the axes x and y; m, p – mode number of the standing wave.

Comparison of the theoretical and empirical dispersion relations of Rossby topographic waves

The theoretical dispersion curves for barotropic (barotropic Rossby radius was assumed to be 1,500 km), a) and baroclinic waves (b); black and blue dots - allocated wave in the sea level in 2003 and in 1993 respectively; the number of curves for each of the Rossby radius corresponds to the number of slopes to the bottom (in the Skagerrak and Kattegat).



Results

- By using wavelet analysis wave level fluctuations were found during two Major Baltic Inflow
- Identified wave oscillations with periods of 36 to 72 days, and wavelengths from 200 to 1600 km were identified as topographic baroclinic waves
- Baroclinic topographic waves associated with inflows of North Sea water is generated at the entrance to the Skagerrak and may spread to the southern part of the open Baltic Sea.
- Analysis of weather conditions showed the presence of stationary cyclones. Not excluded resonance mechanism generation dedicated low frequency waves passing between cyclones and water mass, formed in the east of the North Sea at the beginning of inflow.