Investigating the influence of sea level oscillations in the Danish Straits on the Baltic Sea dynamics

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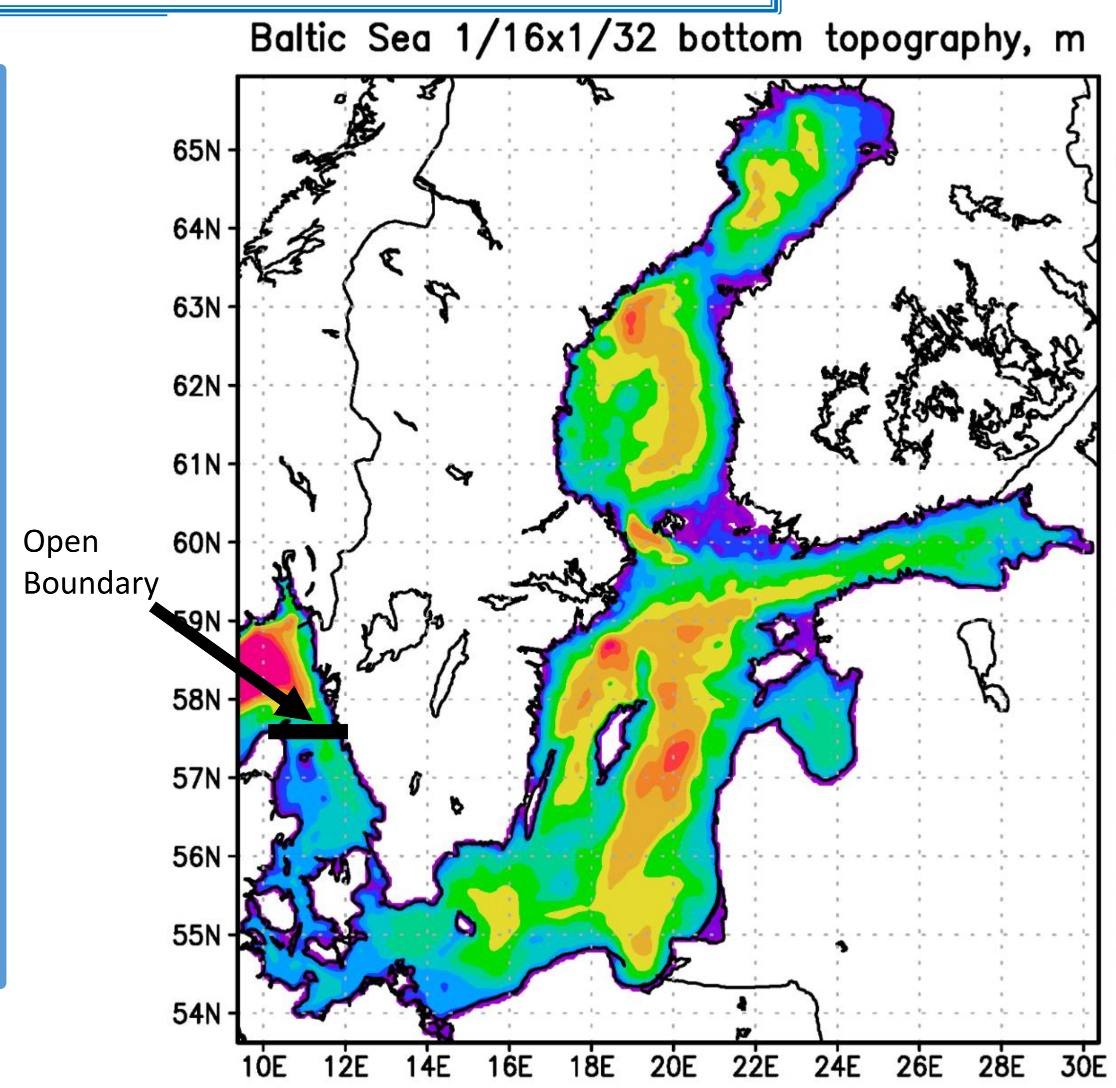
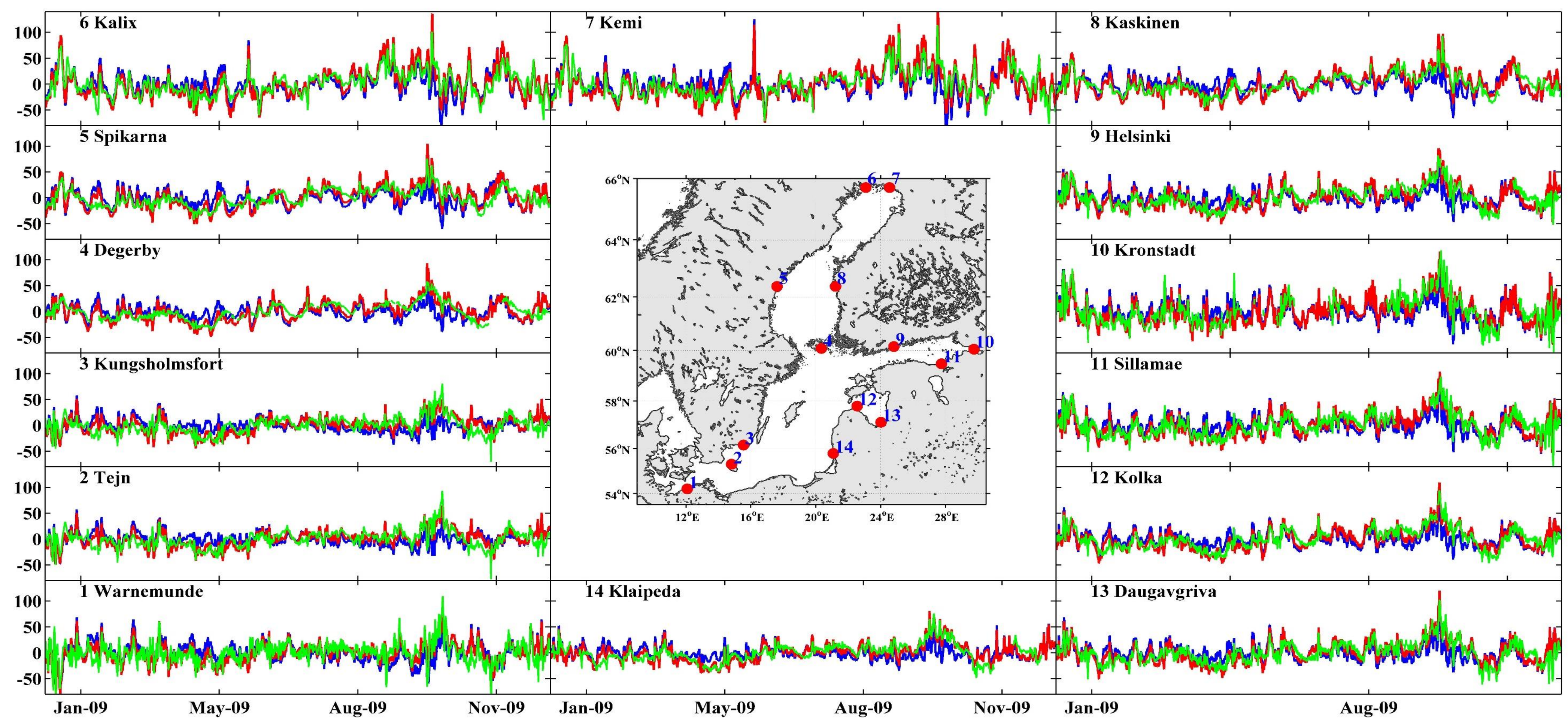
In this research, we study the influence of dynamic processes in the Danish Straits on the sea surface height (SSH) oscillations in the Baltic Sea. For this purpose, we use the model of marine and oceanic circulation INMOM (Institute of Numerical Mathematics Ocean Model).

- Vertical coordinate - σ (isobathic).
- Spatial resolution: 1/15°×1/30° (311×359 nodes) in the horizontal plane, and 25 non-uniform σ-levels.
- Time step - 5 minutes, period - 2009-2010
- Initial conditions - temperature and salinity from http://www.myocean.eu, rest state and ice nil.
- Atmospheric forcing - CFSR (NOAA), 0.5° resolution:
  - 2 m air temperature and humidity,
  - Sea level pressure
  - 10 m wind speed
  - downward short-and long-wave radiation
  - Precipitation
- Sum of the water discharges was considered as a runoff, the climatic monthly mean data of 29 rivers of the Baltic Sea were used.
- Sea ice dynamics and thermodynamics is included
- Open boundary at 57.74°N



The 1st series of runs

1st run: T and S are set at the open boundary, 2nd run: T, S and SSH are set at the open boundary



SSH evolution. Green – observed, red – 1st run, blue – 2nd run. Red points are observation stations

Correlation between simulations and observations

Station	1st run	2nd run
Bothnic Gulf		
Kalix	0.70	0.90
Kemi	0.73	0.89
Spikarna	0.46	0.87
Kaskinen	0.52	0.88
Gulf of Finland		
Kronstadt	0.57	0.81
Helsinki	0.57	0.87
Sillamae	0.61	0.89
Gulf of Riga		
Daugavgriva	0.61	0.90
Kolka	0.54	0.90
North open part of the sea		
Degerby	0.34	0.85
South open part of the sea		
Warnemunde	0.46	0.82
Kungsholmsfort	0.21	0.81
Klaipeda	0.36	0.87
Tejn	0.30	0.83

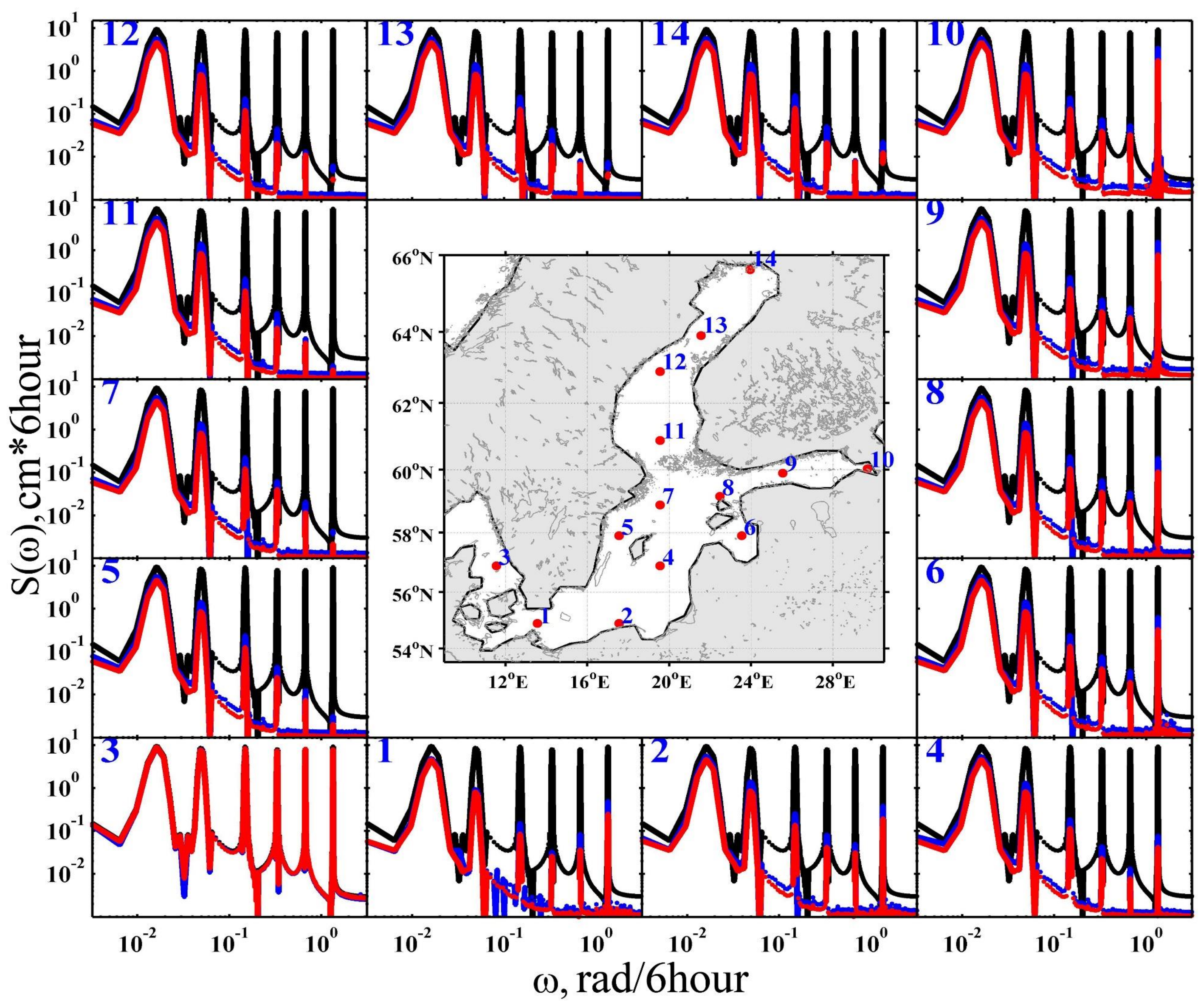
The results of the 1st simulation series showed us that setting SSH observed data at the open boundary significantly increases the SSH simulation quality in all areas of the sea, where the comparison was made. In particular, the correlation coefficients between the simulated and measured SSH data increased from 0.21-0.73 to 0.81-0.90

The 2st series of runs

1st run: 3d barotropic run, constant density, no wind stress and pressure gradient
2nd run: 3d baroclinic run, space variable density, no wind stress and atmospheric pressure gradient

Open boundary data: observed T,S and synthetic SSH (sum of 6 harmonics)

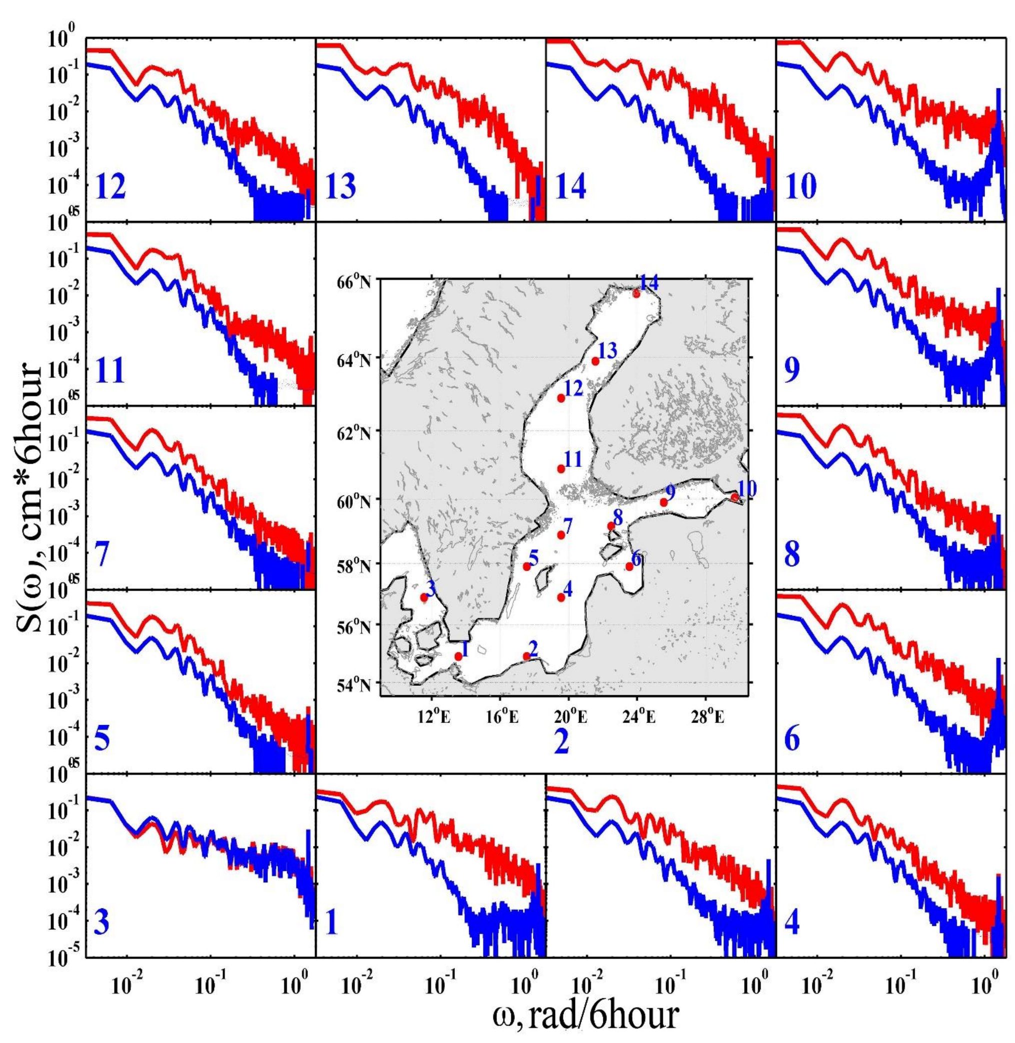
Harmonic number	Period (days)	Initial phase(degree)	Amplitude (cm)
1	1.5	0	50
2	3.0	45	50
3	6.0	90	50
4	13.5	135	50
5	40.5	180	50
6	121.5	235	50



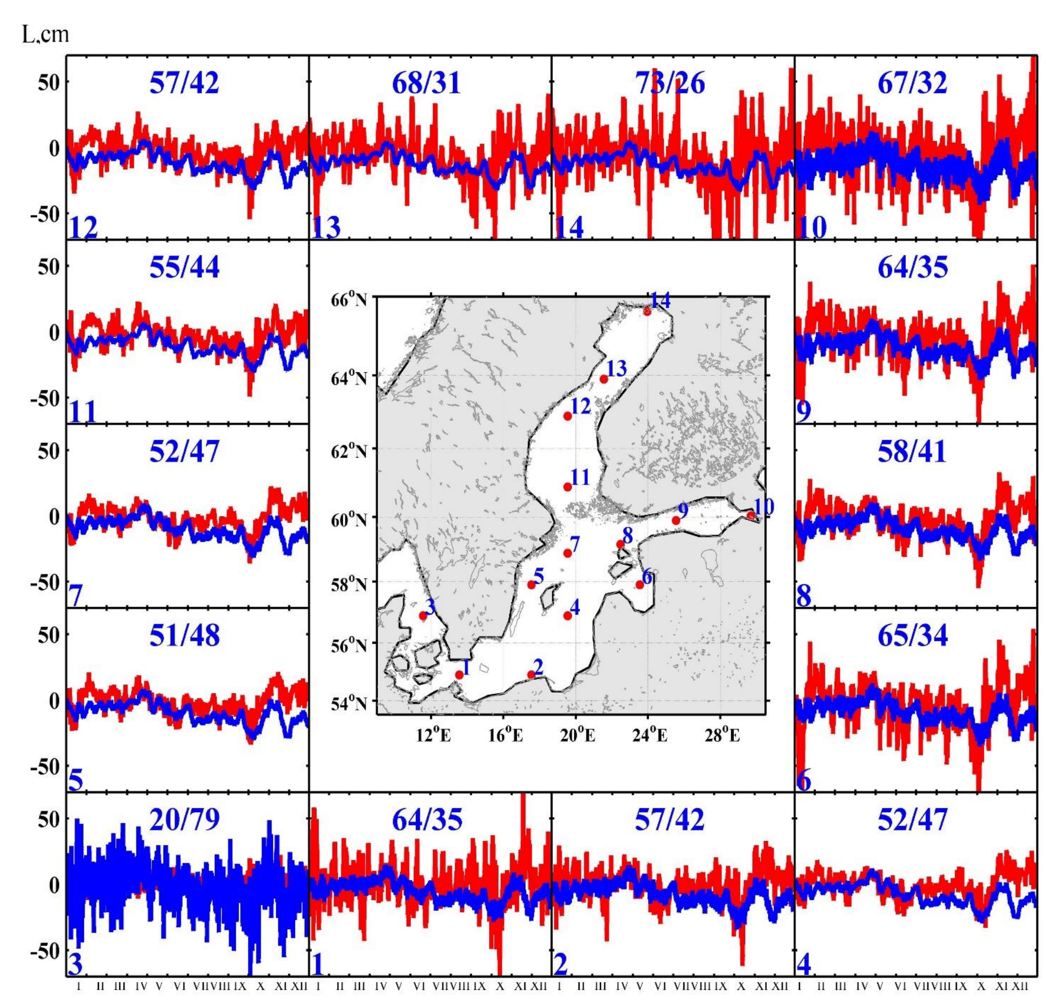
Spectral analysis.
Black - synthetic boundary SSH, red – SSH of 1st run, Blue – SSH of 2nd run

3rd run: 3d baroclinic run, variable density, heat, water fluxes, wind stress and atmospheric pressure gradient
4th run: 3d baroclinic run, variable density, heat, water fluxes, no wind stress, no atmospheric pressure gradient

Open boundary data: observed T,S and observed SSH



Spectral analysis.
Black - observed boundary SSH,
red – SSH of 3rd run,
Blue – SSH of 4th run



SSH evolution for 2009 yr
Blue – 2nd run (no wind and pressure forcing)
Red – difference between 3rd and 4th runs
Ratio is relation between RMSs of red and blue lines

Conclusions

1. Setting SSH observed data at the open boundary significantly increases the SSH simulation quality in all areas of the sea
2. Danish straits do not filter the oscillations of synthetic harmonics. The oscillation with frequencies of these harmonics can be found in the open part of the sea, as well as in its main gulfs. The amplitude changes are highly variable: harmonics of 40min – 2dy keep their amplitude almost unchanged, while ones of 3-15dy significantly reduce their amplitudes.
3. The significant contribution to the net SSH RMS is made by the oscillation propagated from the North Sea to the Baltic Sea, and not just SSH perturbations due to anemobaric forcing.