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Ocean Science Discussions

Interactive comment on "Spatio-temporal structure of Baltic free sea level oscillations in barotropic and baroclinic conditions from hydrodynamic modelling" *by* Eugeny A. Zakharchuk et al.

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We appreciate the Referee valuable remarks, recommendations and his profound corrections and carefully addressed them in the new version of the manuscript. . Our answers on the major comments can be found in the text bellow and full answers are given in the Supplement materials.

On behalf of all authors,

Elena Zakharova

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Referee 2 major comment.

The oscillations studied in this paper occurred in a model where some parameters were adjusted to unrealistic values in order to reduce damping (l. 182-183). It would be interesting to see some discussion on how the results obtained relate to the sea level behaviour in the real Baltic Sea. How much are such oscillations expected to contribute to the real sea level variability? Is there a possibility that the parameter adjustments affect the oscillation frequencies?

Reply: 1.The parameters of adjustments affect the dissipation speed and do not affect the frequencies. If we do not reduce these parameters we can't catch the oscillations of seasonal scale. We edited corresponding phrase in the text for clarification. 2. A comparison of tide gauge and numerical simulation spectra is shown on figure XX . The real sea level fluctuation is the superposition of forced and free oscillations of different origin. The tide gauge spectrum contains very big amount of peaks those amplitudes are significantly higher. In contrast, the spectrum of simulated free oscillations is characterised by a small number of peaks of lower amplitudes which are masked by forced oscillations. So, we decided to exclude comparison of real and simulated spectra from the discussion.

How fast would they be damped?

Reply: The answer for this question is given in the Section 2.3. "Under natural conditions, the free sea level oscillations attenuate rapidly due to the dissipative effects of vertical and horizontal viscosity, near-bottom friction, non-linear effects, and Earth's rotation (Proshutinsky 1993, Zakharchuk et al., 2004). According to a theoretical concept and previous numerical experiments (Proudman, 1953; Wübber and Kraus, 1979; Zakharchuk et al., 2004; Leppäranta and Myrberg, 2009), the relaxation of the Baltic large-scale free sea level oscillations takes several days."

Fig. 8: Why is there so much white space in these maps? The areas around the oscillation nodes are apparently excluded due to low amplitude. But why are e.g. phase

speeds for the eastern Gulf of Finland missing in Fig. 8b, even if the amplitude of the oscillation should be high (Fig. 7b)?

Reply: We introduced additional phrase to the caption of corresponding figures and following phrase into the body text. "In areas where ΔFx and ΔFy equal to zero (white areas on fig 8), the standing wave component prevails."

In a seasonal scale in the baroclinic simulation, after all the external forcing ceases, I would assume that something happens to the temperature and salinity distribution also. Were such processes considered, and how would they affect the surface height?

Reply. Yes, we would also expect some changes in T,S fields and their potential effect on free sea level oscillations of seasonal scale. Indeed, considering that these oscillations occur only in baroclinic conditions, they can be related to spatial variability of the T and S (e.g. water density). However, an investigation of this interesting problem was out of scope of presented manuscript and will be studied in future.

l. 499-502. Most of the interannual variability in the seasonal sea level fluctuations likely originates directly from the interannual variability in the atmospheric forcing. E.g. the role of the air pressure conditions, the NAO index, etc., have been shown to explain a significant portion of the interannual variability. Thus, I suppose the contribution from the baroclinic free oscillations is minor. (Which might be mentioned.) L. 499-502.

Reply: We agree that the interannual variability in the seasonal sea level fluctuations is apparently related to interannual variability of seasonal fluctuations of the wind and atmospheric pressure. This fact was supported by many researches (Ekman and Stigebrandt, 1990; Ekman , 1998; Plag and Tsimplis, 1999; Stramska et al, 2013; Barbosa and Donner, 2016; Cheng et al, 2018). This is also true that our estimated amplitudes of free baroclinic oscillations of seasonal scale are low (2,5 – 5,5 cm). Nevertheless, these amplitudes are of the same order as the amplitudes of annual Baltic Sea level variability (4 - 13 cm) estimated using stationary approximation from the tide gauge observations for 60 year period (Ekman, 1996). Corresponding phrase

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was added to the Discussion section. Indeed, for non-stationary process observed annual amplitudes are higher and can reach 30-40 cm (Ekman and Stigebrandt, 1990; Medvedev, 2014). In our Discussion section we put forward the idea that the role of found in our study baroclinic free oscillations under combination of specific conditions (resonance, favorable stratification), of cause, occurring not each year, might be non-negligible. And this question requires more clarification in future studies.

Please also note the supplement to this comment:
https://os.copernicus.org/preprints/os-2020-110/os-2020-110-AC2-supplement.pdf

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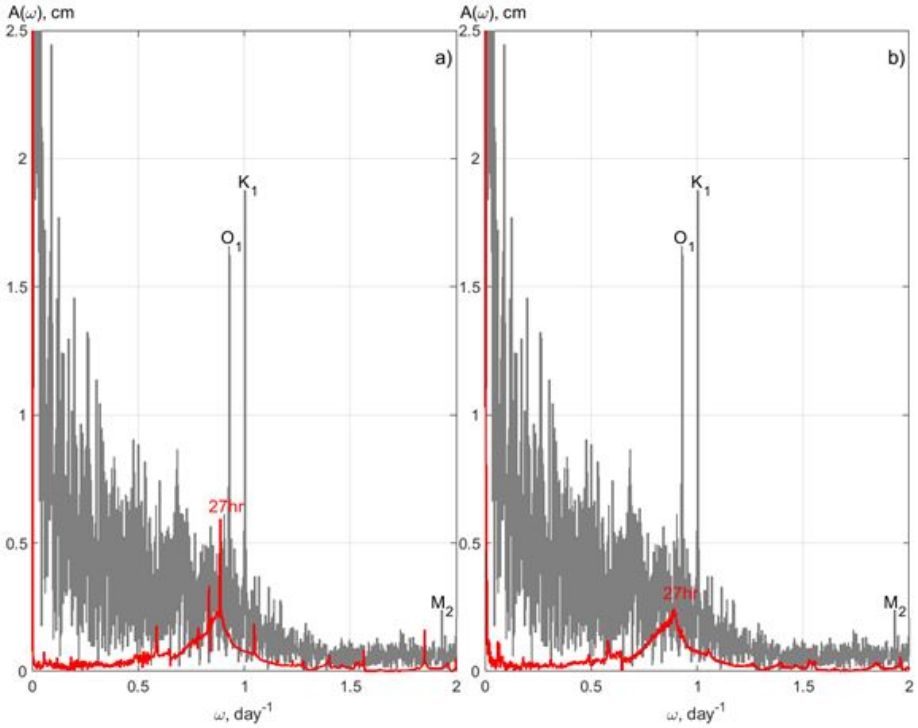

Figure XX. Amplitude spectra A(ω) of tide gauges at Helsinki station for 2009-2010 (grey line) and of simulated free oscillations in barotropic (a) and baroclinic (b) conditions (red line).

Fig. 1. Figure XX

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