Ocean Sci. Discuss., 10, C233–C241, 2013
www.ocean-sci-discuss.net/10/C233/2013/

Ocean Science
Discussions
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Interactive comment on "Investigation of saline water intrusions into the Curonian Lagoon (Lithuania) and two-layer flow in the Klaipėda Strait using finite element hydrodynamic model" *by* P. Zemlys et al.

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Received and published: 22 May 2013

Comment: Conclusions are reached but would be of wider interest if there were a more systematic consideration of a fuller set of non-dimensional quantities (see detailed comments); this could help application (or testing of conclusions) in other locations. The present results are strictly for a simulation of the Curonian Lagoon and Klaipeda Strait, and in my opinion too focused on that location. Most potential readers will be more interested in somewhere else.

Response: We thank the reviewer for the helpful comments, which helped us to improve the manuscript. A fuller set of non-dimensional parameters, consisting in the Kelvin number, the Ekman number, the Wedderburn number and the ratio of the buoyancy layer to water depth, have been computed and will be considered in the revised manuscript. See response to detailed comment for p. 334 line 20.

Comment: This is strictly a model simulation. Although the model has been used in several contexts as cited, not much evidence is given of how good it is here. The agreement with (only) four pairs (top and bottom) of salinity measurements at different times is good - how selective are these four times? The correlation between modeled and observed surface salinity time series at one location is fair (only). All the observations in these comparisons are about half way between S1 and S2, i.e. relatively close to the wider Baltic; no model test is shown for areas further towards or in the lagoon. The manuscript would be more convincing if the model were better validated for this context.

Response The model was tested also in other locations (three inside the lagoon and one in the Baltic Sea, 25 km north of Klaipeda) not only in KlaipÄŮda strait. Just because the study is concentrated on the strait testing results were plotted only for this area. Unfortunately, there are no more salinity profiles in this area and model results were compared mostly with surface observations. Model performance on the surface water salinity, surface water temperature and water level are summarized in Table 1, that is given as supplement to this response and will be included in the revised manuscript. Moreover, statistics will be reported and commented in the revised version of the manuscript. The model reproduces the seasonal fluctuations in water level observed in lagoon and describes well the seasonal cycle of the surface water temperature. RMSE is on average 1.2 ËŽC for the sea surface temperature and 4.4 cm for the water level. The correlation coefficient between model results and observations is on average 0.95 for the water level and 0.99 for SST. The statistical results for the surface salinity show that RMSE is 2.3 ‰ in KlaipÄŮda and varies between 1.6 and 0.1

‰ inside the lagoon. Correlation between observed and modelled surface salinity is 0.74 in KlaipÄŮda and decreases going southward into the lagoon due to the episodic behavior of the salt water intrusion.

Comment: Page 322 line 7. “one year” – 2009 might be mentioned.

Response: “one year (2009)” will be inserted in the final version.

Comment: Page 323 lines 7-8. This is one reason to study lagoons and their connection with wider seas. There are others!

Response: The following text will be included on page 323 line 8 after “1973).” : “Lagoons are an invaluable component of the nature and ecosystem of the shores and they also give comfortable possibilities for the surrounding inhabitants to develop fishery, tourism and other activities. They are the most productive areas of the coastal environment.”

Comment: Page 323 lines 16-22. These are other reasons to study lagoons in general. I suggest that much of this (modified) material be moved to the previous paragraph; it would add to the motivation in the first paragraph. Then the remainder of the second paragraph can be merged with the third and really be about the Curonian Lagoon.

Response: The following rearranging of paragraphs will be done in final version: The part of the first sentence “The Curonian Lagoon, situated in the south-eastern part of the Baltic Sea, is a shallow (the average water depth is 3.8 m) and large transboundary estuarine lagoon” will be joined to the beginning of the next paragraph. Modified last part of the paragraph “Estuarine lagoons with complex interactions between biotic and abiotic components depend on the water exchange between themselves an sea. The eïňĂective management of such a complex systems cannot be limited to the results based on observations and measurements. It requires also more sophisticated tools such as mathematical models that provide scientists and decision makers with a more holistic view of the physical, chemical and biological processes. “ will be moved to the

end of previous paragraph.

Comment: Page 327 line 23. “without solving a linear system.” This is very vague: the reader might guess what this is about, but in that case they would probably understand the sentence without this phrase. Please either omit or say what is really meant.

Response: Phrase will be omitted in the final version.

Comment: Page 327 line 27. “. .partially modified from the classic formulation. This approach . .” Nothing here is defined. Page 328 line 3. “With respect to the original formulation”. I guess this refers to page 327 line 27 but as that is not defined it is no help. Perhaps something needs to be cited.

Response: This piece of text will be rewritten in final version of the manuscript in following way to make it clearer: The spatial discretization of the unknowns has been carried out with the finite element method, partially modified from the classic formulation (Galerkin method). This modification was necessary to avoid high numerical damping and mass conservation problems, due to the combination of the semi-implicit method with the finite element scheme. With respect to the classic formulation, here the water level and the velocities (transports) are described by using form functions of different order, being the standard linear form function for the water level, but stepwise constant form function for the transports.

Comment: Page 328 lines 28-29. Much of this can be omitted because all is said starting with “the standard linear form . .”

Response: We think the comment refers to lines 8-9 of the same page. The sentence “This results in a grid that resembles more a staggered grid often used in finite difference discretization” will be omitted in the final version of manuscript.

Comment: Page 329 line 25. “As mentioned in the text” Where? This is the text!

Response: Will be changed to “As mentioned above” in final version.

Comment: Page 331 lines 15-16, 17. It would help if there were explanation of why southward winds cause set-up over the open shelf and the opposite in the lagoon; especially the former is not obvious - does it relate to the bend in the Baltic and the Baltic's limited depth and extent further west? Does "modulation" mean "lowering"?

Response: This sentence was not clear and therefore it has been reformulated as follows: "Water level in the shelf sea is usually higher than in the northern part of the lagoon during southward winds (red band). This is due to the water level setup in the Baltic Sea and the wind induced modulation of water level inside the shallow Curonian Lagoon, with higher values in the southern part of the lagoon and lower ones in the north".

Comment: Page 333 lines 7, 8. I think that "velocities around 0.3 m/s" and "this area" both refer to the area seaward of S3. Anyway, please clarify.

Response: The sentence "energetic saltier water (velocities around 0.3 m s$-$1 comparable with surface outïňĆow speed)" will be changed to "energetic saltier water (velocities around 0.3 m s$-$1 comparable with surface outïňĆow speed) coming from the sea" in the final version.

Comment: Page 334 line 20. In principle there are more than these two governing dimensionless parameters. Another would be (ghΔrho/rho)**1/2 /(fb) where b is the width of Klaipeda Strait. Others might relate to the size of the lagoon (which surely controls the relative extent of intrusion into the lagoon proper) and the rate of freshwater input; however, conceivably these influences might be represented in the Strait by the "a posteriori" Δrho.

Response: Following the reviewer suggestion we computed more dimensionless parameters to hydrodynamically characterize the Klaipeda Strait and highlight the driving processes. In order to estimate the degree of lateral structure of the exchange flow we computed the Kelvin number (Ke), which compares the estuary width (B) to the internal Rossby radius (Ri), and the Ekman number (Ek), which compares frictional to Corio-

lis effects (Valle-Levinson, 2008). The Kelvin number for the considered narrow strait (about 500 m wide and 12 m depth) is always lower then 1 (the average value is 0.25). Therefore, Earth's rotation effects on density-induced or wind-induced water exchange are not appreciable and the buoyant outflow flows across the entire width of the strait. The estimated Ekman number has an average value of 0.03. Such low value of the Ekman number indicates that the Klaipeda Strait is characterized by moderate frictional conditions. According to Valle-Levinson (2008) these values of Ke and Ek suggest that the Klaipeda Strait displays preferentially vertically sheared flow and lateral shear is negligible. The a posteriori water density difference along the strait, which accounts for the characteristics of the lagoon and fresh water input, is considered in the parameters discussed in the manuscript. In the revised version of the manuscript we will include and discuss the full set of non-dimensional parameters.

Comment: Page 335 line 26. W is also a measure of stratification.

Response: We modified the sentence according to the suggestions as follows: "...strongly reduce stratification (mean hb/H <0.2, W » 1) ..."

Comment: Page 337 lines 19-20. I think the intended meaning is ". .with a decrease to the South." As written the trend varies with location.

Response: ". .with a decrease to the South" will be written in the final version.

Comment: Figure 1 caption. Is the "surface salinity continuous monitoring station" Klaipeda harbour as referred to in the text?

Response: "surface salinity continuous monitoring station in Klaipeda harbour" will be written in Figure 1 caption.

Comment: Figure 5 caption. Please say which time series are observed and which are modelled. Please be more precise about "northern part of the lagoon" (twice).

Response: There is no observed time series on this picture. All time series are explained in the figure caption. "Modelled time series..." will be written instead of "Time

series..” in the Figure caption in the final manuscript version.

Comment: Several figures, notably 1, 4, 6 (arrows), 10 (wind rose): electronic versions can be magnified but in print various annotation is presently too small relative to figure size.

Response: The figures will be corrected in final version.

Comment: Abstract line 21, page 333 line 27 and page 338 line 15. “85-100” does not quite agree with Figure 8 where the S4 value is about 70.

Response: It will be written“One-directional inflow duration is almost the same for all sections ïňĆuctuating in the range 70–100 days yr−1” in final version.

Comment: Page 325 line 14. “z” not “zeta”?

Response: This phrase will be reformulated to phrase “z-grid was used in this study for vertical coordinate system” in final version.

Comment: Page 330 lines 7, 8; page 337 line 20; figure 4 caption (x3); figure 5 caption and possibly elsewhere. I think this should be “vertically-averaged” not “vertically integrated”. The units seem to be parts per thousand (without multiplication by depth as would be implied by integration).

Response: “Vertically integrated” will be changed to “vertically-averaged” everywhere.

Comment: Page 338 line 16. Better “. .cross-sections two-directional flow has longest duration, while . .”

Response: The proposed change will be introduced in final version.

Comment: Page 338 line 22. Better “The analysis of (i) ratio . . . and (ii) the Wedderburn number . .”

Response: “of” will be inserted after “analysis”in final version.

Comment: Figure 10 caption. Add “from” before “NN” to clarify the convention for wind

direction.

Response: The proposed change will be introduced in final version.

Please also note the supplement to this comment:
http://www.ocean-sci-discuss.net/10/C233/2013/osd-10-C233-2013-supplement.pdf

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Interactive comment on Ocean Sci. Discuss., 10, 321, 2013.

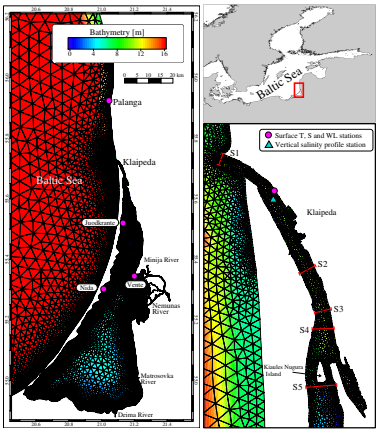

Figure 1: Computational finite element grid of the Curonian Lagoon and coastal area of the Baltic Sea with a zoom on the Klaipėda Strait. Red continuous lines mark the location of cross-sections (S1-S5) and the black dashed line marks the along-strait section. The magenta circle marks the location of the surface salinity continuous monitoring stations (Klaipėda harbour station is shown on the magnified part on the right) and the cyan triangle marks the location of the vertical salinity profile station.

Fig. 1. Revised figure 1