Ocean Science Discussions

Ocean Sci. Discuss., referee comment RC1
https://doi.org/10.5194/os-2021-56-RC1, 2021

Comment on os-2021-56

Anonymous Referee #1

Referee comment on "Refined estimates of water transport through the Åland Sea in the Baltic Sea" by Antti Westerlund et al., Ocean Sci. Discuss., https://doi.org/10.5194/os-2021-56-RC1, 2021

Review of submission os-2021-56

Title:
Refined estimates of water transport through the Aland Sea, Baltic Sea

Authors:
A. Westerlund, E. Miettunen, L. Tuomi, P. Alenius

General:
The study by Westerlund et al. investigates main pathways of water transport through the Aland Sea by means of a high-resolution regional model application. Previous observational and model approaches provided limited understanding of the transport and circulation structure in that area because of the strong seasonality of the regional atmospheric forcing as well as the complex bottom topography which requires high-resolution data coverage both in space and time to adequately capture the main transport characteristics. The aim of the study, as I understand it, is to gain insight into exchange dynamics between the Baltic Proper and the Bothnian Sea at interannual and seasonal scales of the recent past. To this end, the authors constructed a bathymetric representation of the Aland Sea with an unprecedented resolution of 500m horizontally and 200 vertical layers. The applied hindcast simulation with NEMO provided hourly to daily model output for the period 2013-2017.

While the model setup has been evaluated against available station data and seems to perform sufficiently well, my main concern is related to the rather limited use of the comprehensive model output. Substantial parts of the ms are dedicated to the discussion of the model biases and their possible origins. The transport dynamics as being the main focus of the study, by contrast, are presented in a rather descriptive way whithout analyzing and discussing any driving mechanisms or broader context that would finally

gain our process understanding of the Aland Sea circulation. Apart from the shown figures, the transport rates are not even quanitfied. In this way, the only new finding of the study seems to be that about 25% of the transport entering the Aland Sea from the south does not follow the main strait at 20.5°E but rather happens through a topographic depression at 19.6°E. Of course, it is valuable to reflect on the model biases. But if the focus on the analysis and discussion of the model results is underrepresented, it conveys a rather defensive and repetitive flavor.

Nevertheless, I do see great potential to use the performed simulation for further analysis that, in my opinion, would substantially increase the depth, relevance and impact of this study. For instance, questions that naturally arise while reading the present version of the ms and could well be addressed, are: What drives the occasional northward turn of the surface flow? Is it exceptional wind conditions? Does the northward surface flow lead to SSH and pressure anomalies in the Aland and Bothnian Sea? Do these anomalies temporally weaken the more steady sub-halocline northward flow? What drives the sub-halocline gyre in the Aland Sea Proper? Why is the surface circulation strongest in summer? Is this related to melt water discharge from land? What are the transport budgets of the individual basins of the Aland Sea? Is the sub-halocline northward transport a continuous steady flow or is part of the inflow returned and exported southward horizontally or temporally or via mixing with the surface flow? Are there regionalized future projections for wind and freshwater discharge available that could be utilized to hypothesize on potential climate change impacts (e.g. those used by Meier et al. 2021, https://doi.org/10.1038/s43247-021-00115-9)? Could one also hypothesize/extrapolate from your results on the water mass exchange to the nutrient supply into the Bothnian Sea?

The conclusions could then follow a more explanatory line, if supported by the model results, such as: Continuous northward transport into the Bothnian Sea is dominated almost entirely by sub-halocline water masses. Northward flow potentially occurs in any area where the bathymetry exceeds the local depth of the halocline. If these areas are wide enough (with respect to the deformation radius?) the Coriolis force aligns the northward flow to the eastern side of the passages, which leads to a shoaling of the halocline at the eastern side and a deepening at the western side. Wind conditions can drive the predominantly southward surface flow of the estuarine-type general circulation towards the north on monthly to seasonal scales, causing significant anomalies in SSH and halocline structure. Further conclusions could be drawn from addressing some of the questions given above.

I therefore would like to encourage the authors to dive deeper into the subject, provide more detailed analysis of the simulation already available, and from this derive more comprehensive and thoughtful conclusions.

Some minor specific comments:
L21: What are these changes in the eutrophication status? Would be helpful information to better understand the context of the study.

Fig.1: Would be helpful to have an additional (small) inlet that shows the entire Baltic Sea and marks the location of the Aland Sea.

L24-35: This paragraph would be better structured if it was split between the Aland Sea and the Archipelago Sea.

L40: Maybe extend the last sentence by: " ... as the Archipelago Sea is too shallow to establish significant sub-halocline fluxes."

L46/47: It is stated that there are 'no clearly defined water masses' in the Aland Sea but in the next sentence, 'the existence of a deep water type' is mentioned. Isn´t this contradictory?

L55: The unit [g kg-1] is used to refer to a change in salintiy. The cited study by Palosuo, however, dates back to the year 1964, where probably [psu] was used.

L62-66: This paragraph can be condensed to: "... More recently, numerical modelling allows us to investigate intra- and inter-annual variability with much richer detail than we could with observations alone."

L82: "... in this topographically complex and irregular area."

L83: "... information about the bottom topography and related dynamics of different exchange pathways."

L88: "... represents realistic bathymetric features in the investigated area."

L89/90: The aim of the study is not well outlined. I assume, the aim is at least to provide a detailled understanding of the present-day water mass exchange dynamics in the Aland Sea. And maybe some more such as to draw conclusions on the nutrient fluxes in the area or generally to provide information for the development of a science-based marine management strategy?

L96: You may refer to the flushing times of the Aland Sea to justify the comparatively short spinup time of 6-7 months.

L110: Why does the use of a sea ice model with thermodynamic formulation reduce computational demands?

L110-114: Would you expect that the water mass exchange is different during years/winters with large ice cover?

L116-119: The calculation of volume transports does not have to be explained. These sentences could be condensed to: "We analyze volume transports across several transects to investigate the pathways of water exchange more closely."

L128-133: Suggest to condense this paragraph to: "To mitigate artificial interpolation issues we checked and edited ... to ensure that it accurately represents the coastline and depth variations in the 0.25 NM resolution model domain."

L134-140: Suggest to delte this paragraph as it does not contain important information.

L141: Why is it advantagous or necessary to smooth the steepest bathymetry gradients?

L182: What are these processes? Would be helpful to name a few examples: "... other processes such as ..."

Fig.3: Have you compared the station data also with the ocean reanalysis product you use to drive the model? As you are mentioning in L457, might be that the S biases are related to the boundary conditions.

L209ff: Suggest to delete the first sentence and start with "We evaluate modelled current magnitudes and ...". Also suggest to delete L211-213 (While time ... ADCP was located.)

L261: Why can the stronger surface flow at the western side be expected? Would be interesting to elaborate more on the dynamics.

L264: Why is the persistency of surface currents lower in autumn? Due to stronger or more frequent south-westerly wind conditions?

L267: What driving mechanism turned the surface flow northward during winter 2013/2014?

Fig.8: Why is the surface circulation strongest in summer? Due to melt water discharge and export?

L296: At least give correlation coefficients to support this statement.

L316: "... through the Northern Aland Sill."?

L326: What are 'the issues discoverd by Tuomi et al. and Miettunen et al.'?