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Ocean Science Discussions

Interactive comment on "On contribution of horizontal and intra-layer convection to the formation of the Baltic Sea cold intermediate layer" *by* I. P. Chubarenko and N. Y. Demchenko

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To Referee #3 (osd-5-S243.pdf)

1. Results should be focused, and comparison with other studies – moved to the discussion section.

Done: section “Conclusions” is written.

2. It would be interesting if some perspective on Baltic Sea modeling could be given. Present models seem to make reasonable simulations of the cold intermediate layer, although I am sure that no one made detailed comparison enough;

We did some general analysis in frames of PhD-work on the Baltic modelling: models (say, HIROMB) typically produce some CIL, but its features are different from what is really observed (especially concerning sub-layer with T<Tmd). MIKE3 for the whole Baltic also produces warmer and thicker CIL, even if to play with horizontal/vertical coefficients of turbulent exchange. Convection by itself is difficult to model, and even more difficult when over inclined bottom; so, when investigating the very physics – people write original models (in spherical co-ordinates). With real basins – it is a problem, and sigma-coordinate models work definitely not well (we have experience with POM). We now go the way with rectangular grid, many layers plus nesting.

3. Per definition, the thermal expansion coefficient is zero at temperature of maximum density (TMD). This implies that salinity variations are comparatively important near TMD. For example, reducing temperature from 2.4 to 1.4 (at 7.5 psu) gives a comparable decrease in density as changing S from 7.5 to 7.49. Of coarse results like the T-S diagram is still valid, but I think that effects from varying buoyancy fluxes due to freshwater transports should be discussed more.

Yes, freshwater influence is important for sure. In fact, exactly this theoretical expectation was the reason why we decided to put in the paper so much on our field measurements. (Measurements were far from the Tmd, but we also caught a freshened plume.) General physical conclusion: all the mixing mechanisms work at the same time, i.e. both vertical mixing, and wind drift, and horizontal gradient flows (due to both salinity and temperature differences) – all are present, every one slightly changed by the presence of others. For the particular case of horizontal thermally-induced exchange in the presence of salinity variations, this “slight change” is the shift of compensating flow from surface to intermediate layers (see Figs. 6,7,8), what (i) supplies the coastal zone with saltier water and (ii) makes this exchange less dependent on possible freshened plumes near coast or wind-induced currents. There may be various such “slight changes”, the main thing for the paper is – the exchange works anyway.

Specific comments

4. The reference HH92 is probably an excellent and relevant general reference to the Baltic Sea, but being in Russian it is not readily accessable to the international audience. There has been a number of reviews of the physical oceanography in the Baltic Sea in the past decade. I suggest that you use one or some of these instead or complementary were possible.

Yes, thank you, we put an additional reference:

State and Evolution of the Baltic Sea, 1952-2005. A Detailed 50-Year Survey of Meteorology and Climate, Physics, Chemistry, Biology, and Marine Environment (2008) Eds: Feistel R, Naush G, Wastmund N. J Wiley & Sons

To Referee #1 (osd-5-S264.pdf)

1. After reading the paper 3 times I still have not completely understood how the processes of CIL formation should work. The authors sometimes speak about warming, sometimes about cooling. However, they forget to explain once and for all the exact mechanism of CIL formation.

We tried to explain more where possible. Heating or cooling are used only to characterize spring or fall conditions; for the very physical process (cascading) not the heat but the buoyancy flux is important. See also the answer to your comment 8.

2. It is also unclear to me why Tdm exists. As I understand, this Tdm is possible only for water cooler than 4 degrees in lakes, and even lower temperatures in the Baltic. But the authors talk about water masses with a temperature of 20 degrees, and still mention the Tdm. Is it because of the salt content? I have no idea.

Yes, the Tmd depends on salinity and pressure (depth). One always can say that water has a temperature above or below the Tmd, so we did as well.

3. Unfortunately, instead of clarifying some aspects that have to do with deep water formation and cascading, the authors tend to confuse as much as they can. There is a lot of material in the paper, and sometimes I think that presenting one point well of the

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many points they treat would be much better than scoping over all the processes they do actually treat.

Yes, true… thank you!

4. It is also not clear what the contribution of the authors are. It seems to me a good (but confusing) review, but I cannot find a clear statement where the authors have introduced original new concepts, data, modeling. I think it is important that the authors should say exactly what are the new, original contributions in this paper on the subject.

New solid things are: (i) reporting of field observation of cascading in the Baltic Sea environment; (ii) idea of spring cascading; (ii) attribution of the coldest CIL water to spring cascading; (iii) demonstration of presence of the conditions favorable for intralayer convection within the Baltic CIL. This is described now in Abstract, at the end of Introduction and in Conclusions.

5. I have to say that I am not an expert on the subject. But I expected at least. after finishing this paper, to know more on the subject. I am afraid this did not happen. I am much more confused than before. Therefore I would ask the authors to be much more clear when they explain the Tdm formation, and maybe give also some examples.

We added some introductory and general sentences. Literature on mixing processes around the Tmd in lakes is quite abundant, we wanted to focus in the paper more on specific features of the Baltic CIL.

Specific comments:

6. Abstract: After reading the abstract it is not clear to me what is the subject of the paper. In the abstract they mention spring heating, but soon after, in the Introduction they talk about winter convection, i.e, cooling.

Abstract is re-written.

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7. p 583, 21-24: how is it possible. Surface water is cooler than bottom water, which is above Tdm, so the bottom water is warmer than 4 degrees? How can then exists cooler water above this warmer water? You must explain better. You should explain better the mechanism of CIL formation and the Tdm mechanism.

Cooler water can lie above warmer water because there is salinity stratification as well (see fig. 8, fig. 10 for examples of measured T, S, density profiles).

8. p 585, 10-15: again not clear. Can you make an example (with temperatures etc.) so one can understand better what is going on?

Due to non-linearity of the equation of state, water becomes denser in both cases: (i) when it has T>Tmd and is cooled (“autumnal” situation) and (ii) has T<Tmd and is heated (“spring” situation). If the process goes in a basin with inclined bottom, then – in both cases – down-slope cascading of denser water is formed. See (Chubarenko, Demchenko, 2008) for details of physical mechanism, which is driven by surface buoyancy fluxes and horizontal pressure gradients. We put this reference in the text of the paper here, however have refrained from wider explanation of physics in Introduction.

9. p 587, 5-15: Is this important for the paper?

We find this general information quite important for understanding the process, but have made the text shorter.

10. p 585, 17: What is F?

“F” is surface heat flux, see Table 1. Mistake was 3 lines above, where it was denoted as “H”. Now corrected, thank you.

11. p 591, 5-15: not clear. Now the intermediate water is warmer?

Exactly. The same mirror-like logic: in autumn, denser waters, cascading from shelves, will form in stratified environment WARM intermediate layer, while in spring –

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COLD one.

12. p 592, 19-30: Not clear: if we have a down slope current, then there will be a return flow in the surface layer, right?

Above the down slope current – yes, of course, but not necessarily in the very surface layer: the velocity maximum typically is at some intermediate depth. It is not much surprising in field situation particularly because: (i) off-shore wind may cause off-shore drift in surface layer, while cooling causes down slope cascading near bottom – and the both are supplied by compensating flow at intermediate depth; (ii) we discuss in this paper a cross-shelf (i.e. – 2D) exchange only, but really its structure is kind of Ekman 3D-spiral, with most intense cross-shelf flows again at intermediate depths.

13. p 595, 10: You have a new section 3 here. But should be compared to winter cooling and cascading. But this is section 2.1. So I feel the organization is not good. You could call section 2 directly Winter cooling, then it would make more sense to me.

Thank you, we have adjusted this – a bit changed the structure.

14. p 595, 20-25: give a temperature example.

Done.

15. p 597, 2-9: Does this mean that the masses are heated from below 2 degrees, say? Doesn’t this process of complete mixing happen in autumn?

Yes to both questions. In fresh-water lakes, these correspond to “fall” and “spring” overturns.

16. p 598, 10: negative buoyancy flux... I thought you were heating??? It is really not clear if you simulate heating or cooling. Sorry for not understanding.

We simulated heating. The buoyancy flux into the surface layer is negative for both combinations (in autumn) and (in spring), see p.596 (1-15). So, while heating of the

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basin with T<Tmd, we first have negative surface buoyancy flux, and then (upon reaching the Tmd) – positive one.

17. p 603, 20 to 605, 19 is repeated in the manuscript -> delete Fig 4: several hours later... of what? Fig 5: units on the x axis. Fig 6: measured when?

Corrected, thank you very much.

Interactive comment on Ocean Sci. Discuss., 5, 581, 2008.

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