How do eddies mix coastal water offshore?

Investigating the role of mesoscale eddies for the coast-to-basin exchange in the Baltic Sea

M. Meier, H. Radtke, G. Väli*, Institut für Ostseeforschung, Universität Rostock*

In Short

- Exchange between shallow and deep waters is restricted
- Mesoscale and submesoscale eddies contribute to turbulent mixing
- Our project investigates what controls this mixing intensity in the Baltic Sea

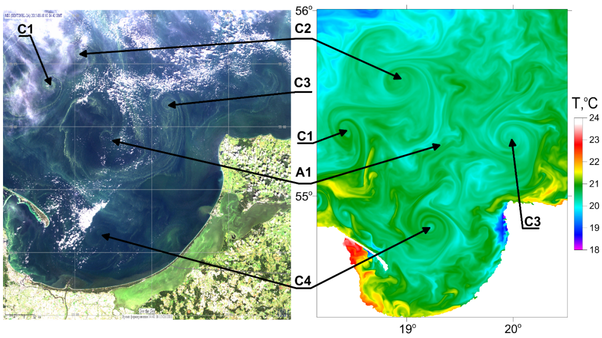

Figure 1: *High resolution satellite image over the limited area in Gulf of Gdansk (southern Baltic Sea) along with the high resolution model result for sea surface temperature at the same date.*

Exchange of water masses between coastal and open-ocean regions is inhibited by a dynamical barrier. Mean currents are typically directed alongshore, parallel to the lines of constant depth. So only intermittent features like upwelling filaments and mesoscale eddies are typically responsible for the across-shelf mixing.

From an ecosystem perspective, this mixing is of high relevance: The coastal waters are typically rich in nutrients, since these enter the sea with river discharge. The cross-shelf mixing also transports them into the open sea. It is therefore a key process since it strongly influences primary production in the deep central basins.

To understand the functioning of marine ecosystems like the Baltic Sea, marine ecosystem models can be used, these represent the real ocean by a large number of grid cells. The models simulate both physical processes, like currents transporting the water, and the most important biogeochemical processes, like algal blooms. Typical regional ocean models with a resolution around 1 nautical mile are, however, not able to resolve the coast-to-basin transport processes, even if they permit some mesoscale eddies to be formed. Therefore, the effect of the horizontal exchange by smaller structures needs to be included by a "sub-grid-scale parametrisation", e.g. a Smagorinsky scheme, which describes the effect of turbulent structures which are smaller than the grid resolution.

The problem is that choosing a specific parametrisation does not account for possible variations in the mixing intensity. The question how the exchange between coast and open sea can change between seasons, years or decades with different climate might strongly affect the ecosystem response of the open sea to these changes. Our study therefore aims at estimating the influence of external drivers, like changes in upwelling frequency, river runoff or storminess onto the intensity of the coast-to-basin coupling. We apply a very-high-resolution model of the Baltic Sea physics (200 m grid size) in which the small eddies can evolve from the hydrodynamic equations solved by the model. We can then compare statistical properties of the turbulence created by the model to high-resolution satellite images to check if these processes are realistically represented.

Finally we want to use our model to estimate how strong the exchange between coast and open ocean really is, and how it is affected by different external drivers. For this purpose, we mark the water coming from the rivers (entering the coast) and see how long it takes until it is transported offshore. We use two techniques for this: The first can be thought of as a virtual ink which is put into the coastal zone, and the model calculates its transport and how the concentration of it changes over time. In the model, we can then not only see the changes in the concentration, i.e. how it is mixed offshore, but the model also tells us the amount of transported ink in every time step, so we can see when and where these transports are specifically strong. The second method is introducing virtual particles which are passively transported with the model currents. These allow us to track when and where as specific water parcel was in our model during the course of the simulation.

The knowledge we gain will help us to correctly represent the coast-to-offshore mixing in ecosystem models and improve our understanding of the functioning of the Baltic Sea ecosystem.

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https://www.io-warnemuende.de/markus-meier-en.html

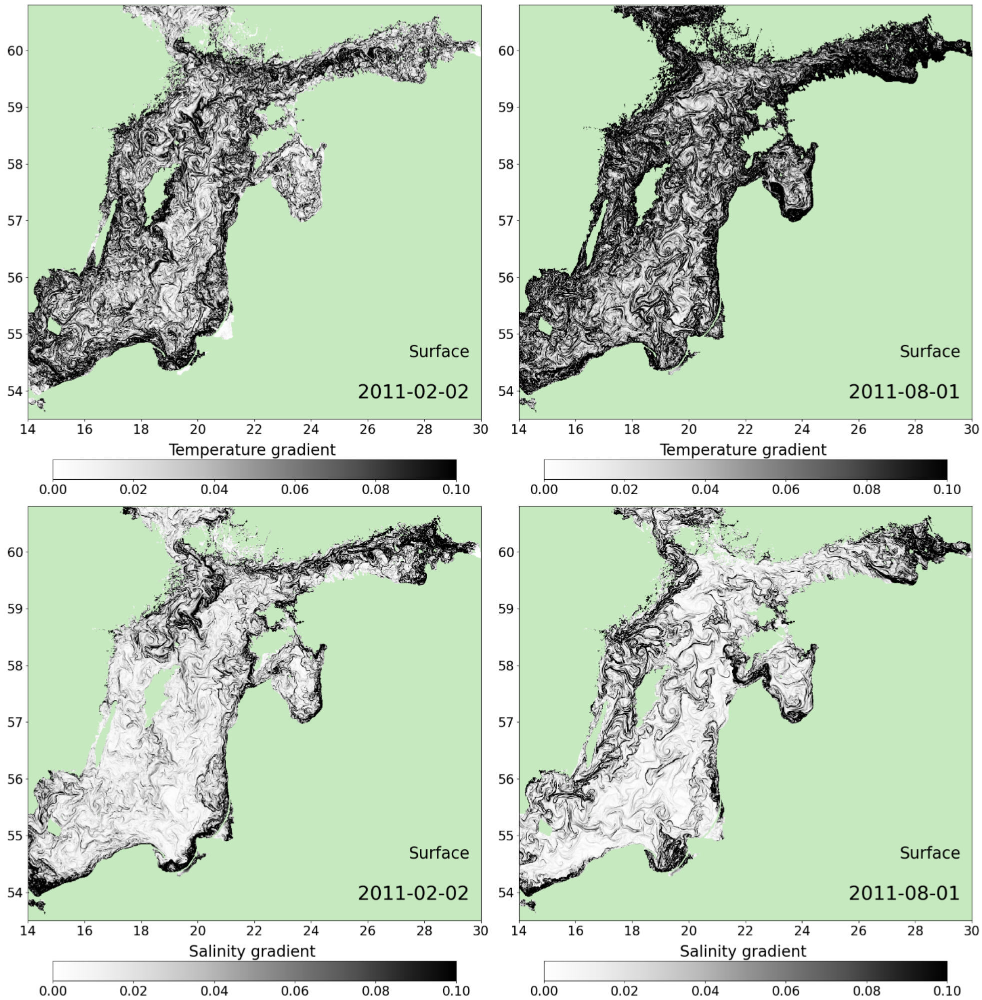

Figure 2: *Gradients of temperature and salinity as simulated by the model, during winter.*

More Information

[1] G. Väli, V. Zhurbas, U. Lips, J. Laanemets, *J. Mar. Syst.* **171**, 31-42 (2017). doi: 10.1016/j.jmarsys.2016.06.010

[2] G. Väli, V. Zhurbas, J. Laanemets, U. Lips, *Fundamentalnaya i Prikladnaya Gidrofizika* **11**, 21-35 (2018). doi:10.7868/S2073667318020028

[3] V. Zhurbas, G. Väli, M. Golenko, V. Paka, *J. Mar. Syst.* **184**, 50-58 (2018). doi: 10.1016/j.jmarsys.2018.04.008

Project Partners

Leibniz Institute for Baltic Sea Research Warnemünde, Tallinn University of Technology